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LATE QUATERNARY ENVIRONMENTS IN THE CHALBI BASIN, KENYA

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LATE QUATERNARY ENVIRONMENTS IN THE CHALBI BASIN, KENYA:

SEDIMENTARY AND GEOMORPHOLOGICAL EVIDENCE

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REPORT OF A PROJECT CARRIED OUT FOR THE

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1. INTRODUCTION

This report presents the results of research done in and around the Chalbi basin, Marsabit district, Kenya, from 1982-1984. The broad objective of this research was to trace evidence of past environmental conditions, and in particular to establish whether a fresh-water 'Lake Chalbi' existed in what is now the Chalbi playa, during the Upper Pleistocene to Holocene. Fieldwork was carried out on four occasions: July-August 1982, January-February 1983, August 1983 and December 1983-January 1984. A number of specimens of volcanic and sedimentary rocks were collected, as well as fossil bone, shell, fossil wood, pottery and stone tools. Some analysis of this material has been done, and is referred to where appropriate later in the report.

The research was funded by the United Nations Environment Programme (Global Environment Monitoring System) and by Kenyatta University College. I am extremely grateful to both these institutions for their support. Research clearance for the project was issued by the Government of Kenya, under Permit No. RDST.13/001/C856/33, dated 15th June 1982.

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Some of the rock analysis was carried out while I was on sabbatical leave at the School of Geography, University of Oxford. I am extremely grateful to Professor Andrew Goudie for making it possible for me to spend a term as Visiting Scholar at the School, and to the Nuffield Foundation for providing the financial support that made my visit possible. Help and advice on the analysis of the rocks I took to Britain was given by:

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3. REGIONAL SETTING

The Chalbi basin is an inland drainage basin in Marsabit District of northern Kenya (figure 1). In its centre lies the "Chalbi desert", a surface of mud and salt subject to occasional flooding; a 'playa' according to the criteria of Mabbutt (1977 p. 184). The long axis of the Chalbi basin (and of the playa) runs approximately northwest to southeast; in this direction the playa is about 110 kilometres long. The width of the playa varies from 10 to 20 kilometres. The surface of the Chalbi playa is slightly under 1500 square kilometres in area, and it lies at an elevation of approximately 370 metres above sea level.

Rainfall records for this area are few, but at North Horr the records taken over 24 years give a mean annual rainfall of 153 mm, and at Maikona 10 years of records yield a mean annual rainfall of 206 mm. The average figures are almost meaningless; the North Horr annual totals range from 7.2 mm in 1973 to 362 mm in 1977. At times rainfall on the Chalbi catchment area brings water to the playa, via a number of intermittent drainage lines (lagas), as shown in figure 2. Some years, the amount of water brought into the playa is enough to create a 'Lake Chalbi', a sheet of water some tens of centimetres deep; in 1978, parts of the playa were flooded for several months.

The Chalbi playa is largely surrounded by volcanic terrain; the basaltic lavas of Kulal, Chari Ache, the Huri Hills and Marsabit. For tens of kilometres the lava forms the top of prominent cliffs that rise 20 to 30 metres above the playa. Elsewhere, a belt of sedimentary rock of gently rolling relief separates the lava and the playa. Figure 3 shows the broad topographic and geologic divisions of the study area.

4. RESEARCH OBJECTIVES AND METHODOLOGY

The primary research objective was to describe past environmental conditions in the Chalbi basin, largely through the interpretation of landforms and sediments. In particular, the aim was to find out whether there had ever existed a permanent fresh-water 'Lake Chalbi' in this basin, and if so, over what period it had existed. Evidence for the existence of this lake might include the following:

Topographic features: shoreline cliffs (concave wave-cut notches), sand and gravel beach ridges, sand spits.

Sediments: fine-grained, horizontally bedded sediments (lake silts and clays), regularly bedded sands (deltaic or littoral deposits).

Faunal and floral evidence: fossil or sub-fossil remains of plants and animals that lived in the lake or on its shore.

Landforms and sediments may also provide evidence of environmental conditions different from those of today, apart from the existence of a former lake. Fossil sand dunes indicate past greater aridity; drainage networks may have formed during periods of higher runoff than the present. During the fieldwork in the Chalbi basin, a search was made for such features.

The methods used to search for the above evidence included the following:

Inspection of satellite imagery, air photographs and topographic maps. A number of topographic and geologic features could be recognized on the remotely sensed imagery, including the alignments of the lava margins, structures within the lava, and pale-coloured patches of possible lake sediments. In this way sites of possible interest were identified, most of which could be visited later on. Certain general statements about the area were made on the basis of its appearance on the remotely sensed imagery, in particular in terms of major geological structures.

Field transects, in a vehicle or on foot. Much time was spent crossing the study area on the ground, carrying out a detailed search for evidence of a former lake. The area was not covered on a basis of randomly sampled sites, or by regularly distributed transects; time and transport facilities did not permit this. Sites visited were those which, from field and remotely sensed observation, appeared likely to have evidence relevant to the problem. In particular, the possible margins of a former Lake Chalbi were visited wherever possible. Problems of accessibility limited the area coverage, in particular on the southern and southwestern margins of the Chalbi playa . The time spent in the field was broadly occupied as follows:

July and August 1982 (about 24 days) - Maikona (short visit), Balesa El Dere (short visit), Kalacha Goda (detailed study of sediments and of the lava front, mapping of sediment exposures that contain freshwater gastropods), area north of Kalacha Goda, including lower course of Laga Kubi Badana (detailed study of sediments and of lava front). January and February 1983 (about 12 days) - Olturot (detailed study of sediments which contain gastropods and fossil bone), Kargi, Maikona, Kalacha Goda, North Horr (short visits). August 1983 (about 12 days) - North Horr, Chari Ache, Malabot (detailed study of sediments and lava front), Maikona, Ramatrobi, Karole, Algas (inspection of lava/sediment contact), Koroli mesas (brief visit). December 1983 and January 1984 (about 22 days) - topographic surveying to determine altitudes of important features between Maikona and North Horr. Study of Koroli mesas and underlying sediments.

From the above research the following data was obtained:

Descriptions, sketchmaps and sketch profiles of geomorphological features. (See figures 3 and 6).

Descriptions and measured sections of rocks, both sedimentary and volcanic. (See figures 4, 5 and 7).

Rock specimens, selected from those sedimentary and volcanic rocks that appeared likely to provide information about the environmental history of the basin. The results of the analysis of some of these rocks are referred to later in this report.

Fossil gastropods, bone and plants. Information on the analysis of this material is given in Section 7 and Appendix A.

Collections of archaelogical material (stone tools and pottery), which have been analysed at the National Museum in Nairobi (see Section 8).

Height data obtained by barometric levelling (altimetry); see Appendix B.

5. EVOLUTION OF THE CHALBI BASIN

Fuchs (1939) presents a geological map which shows the Chalbi basin (though not by name) as an area of 'undifferentiated alluvial deposits' between Miocene and Pleistocene lavas. Dixey (1948) describes the 'Chelbi' basin and postulates the existence of a lake there during part of the Lower Pleistocene. The Chalbi basin is not included in the mapping by the Geological Survey of Kenya at the scale of 1:125,000, but relevant information can be found in reports and maps on other parts of northern Kenya, for example Baker (1963), Dodson (1963 and 1971), Dodson and Matheson (1969), Joubert (1966), Walsh and Dodson (1969) and Randel (1970). Reconnaissance mapping at the scale of 1:250,000 is currently being carried out in this area as part of the Samburu - Marsabit Geological Mapping and Mineral Exploration Project of the British Geological Survey and the Department of Mines and Geology, Ministry of Environment and Natural Resources, Kenya.

Research into aspects of the physical environment of this area has been carried out by IPAL (Integrated Project in Arid Lands; UNESCO/UNEP Man and Biosphere Project 3). Reports have been written on geomorphology (Sinda 1981, Bake 1982), vegetation (Herlocker 1979), climatology (Edwards _et al_. 1979, Bake 1983) and hydrology (Ongweny _et al_. 1983, Bake, 1985).

Understanding of the evolution of the Chalbi basin benefits from the detailed work done in the East Lake Turkana (Koobi Fora) area to the west, among which the following sources may be mentioned: Bowen (1974), Vondra and Bowen (1978), Owen _et al_. (1982) and Watkins (1982). Important information on the sequence and geochronology of the volcanic rocks of north-central Kenya is presented by Brotzu _et al_. (1984).

The oldest rocks of this part of northern Kenya are Precambrian metamorphics which outcrop to the north, south and west of the Chalbi basin, for example in the Nyiru range and the Ndoto mountains (Dodson 1963, Baker 1963). In the area of the Chalbi basin these rocks are overlain by an undetermined thickness of younger sediments and volcanics, but structures within the Precambrian rocks may have influenced the alignment of the Chalbi basin margins. The Precambrian rocks underwent a long period of erosion, warping and possible faulting, resulting in a surface of rather low relief on which the younger sediments and volcanics accumulated. Some of these sediments have been grouped together in the literature (e.g. Joubert 1966, Walsh and Dodson 1969) under the broad heading 'Turkana Grits' which are said to range from the Cretaceous to the Pleistocene in age. Sediments on the eastern and southern margins of the Chalbi basin may be correlated with some of the Turkana Grits. There is an exposure of sediments covering several tens of square kilometres in the Ramatrobi area east and south-east of Maikona (see Figure 3). The surface of Ramatrobi is covered by drifts of orange sand and patches of smooth rounded quartz pebbles, and it is surrounded by lava to its north, east and south. The western margin of Ramatrobi slopes towards the Chalbi playa. Over a distance of approximately 2 kilometres (in an east-west direction) there is a terrain in which cliffs (up to 5 metres high) of red and purple sandstone and grit rise from debris slopes covered with rounded quartz pebbles, mostly in the size range 2-6 centimetres. For over 5 kilometres lava is absent from the Chalbi playa margin, which here runs broadly northnorthwest - southsoutheast. It seems that lava has never overlain Ramatrobi; there is no evidence of even a thin lava cover removed by later erosion. This surface may thus represent part of a pre-volcanic landscape. Air photographs and satellite imagery indicate that northwest-southeast trending structures within the rocks of Ramatrobi may have influenced the alignment of the basin margin here. To the north of Ramatrobi, exposures in the walls of Laga Dambito (see Figure 3) show sandstone overlain by basalt. The indication from these exposures (Figures 4A -C) is that the sandstone had undergone considerable dissection before the lava flowed across it. Figures 5A and 5B show other sections from the eastern margins of the Chalbi basin. The red sandstones appear to dip southwards and are lost from the base of the section close to Mayidahad. At Koronli and Karole pale grey and cream coloured clays and silts are visible; no fossils were found at the localities visited. Further south, fossil bone and fossil wood are washing out of sub-volcanic sediments at Algas and at Falama respectively. The fossil bone, discussed in a later section (see also Table 2) is of particular interest in that it indicates the presence of a large body of deep water in this area at the time some of these sediments were laid down. The sub-volcanic sediments may span a considerable age range; R. Key (pers. comm.) considers that the Ramatrobi sandstones may be as old as Jurassic. On the evidence of the fossil wood (see below) it has been suggested that the Falama sediments may be Mio-Pliocene, while the Algas sediments underlie basalt dated at 2.5 Ma (see Appendix A).

It is likely that the volcanic rocks in this part of northern Kenya also cover a considerable age range. According to Watkins (1982) vulcanism began in the late Oligocene to the north-west of the Chalbi basin; basalts of the Suregei-Asille district have an age of 28.2 Ma. Dates quoted by Brotzu _et al._ (1984) suggest that the north-western and northern margins of the Chalbi basin may have been defined as early as the Miocene. Lavas to the north of North Horr give dates of 6.1 and 4.5 Ma, and on the Huri Hills 'plateau basalts' date from 7.3 and 5.4 Ma. On the Huri Hills the foundation of older rocks is overlain by younger 'multi-centre' volcanics which date between 2.3 and 1.4 Ma.

Brotzu _et al._ have no dated rock older than 0.6 Ma from Marsabit; the rest of their samples had ^{40}Ar below the limit of detection and it is assumed that these rocks are probably less than 1 Ma. (Brotzu _et al._ p. 78). However, a basalt from Algas, near Kargi on the western margin of the Marsabit lava, has been dated to 2.5 ± 0.3 Ma. (Sample R-6920; see Appendix A for details of the analytical work). Thus the eastern margin of the Chalbi basin may not have come into existence until the Pleistocene.

The southwestern and western margins of the basin are formed by the dissected volcanic ridge Kulal and its northwards extension, Chari Ache. Earlier authors (e.g. Fuchs 1939) placed Kulal in the Miocene, but it also includes younger rock. Dodson (1963) shows Pleistocene basalts covering a low plateau on the southern slopes of Kulal, while Brown (pers. comm.) has dates of 2.0 and 2.4 Ma, also for the southern slopes.

On the southern margin of the Chalbi basin lie the Koroli plateaux. There are about ten of them; they are mesas whose approximately horizontal tops stand about 100 to 150 metres above the surrounding surface. Exposures in the mesa slopes show a maximum of about 10 metres of basalt overlying sediments (see Figure 5C). The mesas probably originated as a continuous sheet of lava, which has been considerably reduced by erosion. No radiometric dates are yet available for these lavas, but the degree of dissection which has taken place (some of the plateaux are separated by over 4 kilometres from their nearest neighbours) suggests that they may be among the older volcanic rocks of this area.

The Chalbi basin appears to be a feature of compound origin. In part it exists as a result of the building of lava mountains to the north, east and west, leaving the Chalbi as an interior lowland between them. However there are indications of tectonic influences on the landscape. The western margin of the Chalbi basin lies less than 60 kilometres from the rift system, which in this latitude runs from the southern section of Lake Turkana through the Kinu Sogo fault belt, with an alignment slightly to the east of north. Landsat images show similar alignments in the Precambrian terrain to the south (Mara, Nyiru and the Ndoto ranges), as well as along the western margin of the Marsabit lavas, the southwestern edge of the Huri Hills, and the eastern edge of Chari Ache.

The eastern margin of the Chalbi basin does not owe its existence purely to the accumulation of lavas to form Mount Marsabit. Along much of this margin, lava only forms the top 2-3 metres of the slope, over 5-10 metres of sediment. In the Ramatrobi area, lava is missing from the basin margin for a distance of more than 5 kilometres. The western margin of Ramatrobi may represent the margin of a depression that existed before the formation of Marsabit and the Huri Hills. Alternatively it is possible that the eastern margin of the Chalbi basin has been formed by downfaulting to the west after the eruption of the Marsabit lavas. In this context it is of interest to note that close to Karole water-hole there is lava exposed in the Chalbi playa floor; dark grey vesicular basalt occupies an area of several hundred square metres between the waterholes and the base of the marginal slope.

Along the eastern edge of Chari Ache there is evidence of relatively recent faulting. Air photographs show a clear lineation that runs for more than 10 kilometres with an alignment varying between north-south and about 10^{o} east of north. Where it is crossed by the ephemeral drainage lines that run broadly west to east off Chari Ache it has caused several of them to be deflected in a north-south direction for some hundreds of metres. In the field the fault is in one place marked by an open crack, 50 centimetres to 1 metre wide, extending for several metres down through the basalt boulders that form the surface of this part of Chari Ache.

The Rift System, marked in this latitude by the Kinu Sogo fault belt, lies less than 60 kilometres west of the Chalbi basin, and continued seismicity may be expected in this area. Swain (pers. comm.) reports that in the course of gravity surveys across the Chalbi basin in the 1960s and 1970s, he found the area to be seismically active. Loupekine (1971) mentions an earthquake felt at Allia Bay on the east shore of Lake Turkana in 1896, and a strong one (estimated intensity VII on the Modified Mercalli scale) in the Suguta valley south of Lake Turkana in 1924.

The Chalbi basin may be, at least in part, a structural basin formed by downfaulting, and owing its shape to alignments in much older rocks.

6. GEOMORPHOLOGY OF THE CHALBI BASIN

The geomorphology of the study area is shown in Figure 3. During the course of the present study, particular attention was paid to the margins of the playa, as being the most likely areas to show evidence of the existence of former lakes in this basin. Cross-sections of the playa margins are given in Figure 6.

The Chalbi playa

Most of the playa surface is composed of brown mud which when dry forms a polygonal pattern of cracks, as shown in Plate I. In some places the surface is covered by a white crust of Halite (NaCl) and Thenardite (Na_2SO_4) (Pye, pers. comm.). This crust appears to occur where the groundwater is particularly close to the playa surface, for example near Karole and Korowe. In some other places the playa surface is loose and powdery, composed of pale grey and pale brown salty clay. No information about the thickness of sediment below the playa is at present available.

The playa margins

In places, as shown in Figure 3, the Chalbi playa abuts directly onto the margins of the lava shields. It is felt that these margins cannot strictly be termed 'lava fronts' since it is apparent from their topography that the lava has undergone a certain amount of dissection and retreat since it came to a halt on cooling. The lava-playa junction forms quite a spectacular feature, illustrated in Figure 6A. The angle of slope may be over 30^{o}, and the height of the slope 30 metres or more. On most of these slopes, a few metres of solid lava are visible at the top of the slope; the rest of the slope is heavily mantled with coarse, angular lava talus. Within this talus it is in places possible to distinguish fine-grained white to pale grey sediments which apparently underlie the lava. At the slope base there is a sudden transition (within less than 5 metres) between the talus-mantled slope and the brown mud of the playa. Scattered fragments of lava extend for only a few metres out onto the playa surface. At one locality close to Gamura lava boulders on the playa show a horizontal ring of different colours which appears to indicate a water-line about 30 centimetres above the playa surface; evidence of the occasional flooding of the playa. The material on the slope and at its base is all angular to sub-angular in shape. No well rounded material suggestive of shingle beach or river gravel was seen.

North of Kalacha the lava slope of the Huri Hills is separated from the playa by a belt of 'intermediate sediments' that in places is over 5 kilometres wide. Cross-sections through this terrain are shown in Figures 6B and 6C. A few kilometres to the south of Kalacha Goda village the lava of the Huri Hills appears to dip beneath horizontally bedded sediments; a section through these sediments is given in Figure 7. These sediments are visible in about ten little 'buttes'; flat-topped mounds that rise 2 to 4 metres above the surrounding terrain, with surface areas ranging from a few square metres to a few hundreds of square metres. These buttes are at present undergoing quite rapid erosion by running water, wind and the trampling of livestock. The fine grain size and horizontal bedding of these sediments indicates deposition in a low-energy environment, probably a lake or pond. This is also indicated by the gastropods found within some of the strata; Melanoides tuberculata is strongly dominant analysis. Diatoms are present in some of the sediments and the anlaysis of them (currently in progress) should provide further indications of the conditions of deposition. These sediments appear to be overlain by sands that occur in a narrow belt along the playa margins, and are presumably also overlain by the modern playa muds. A core through the playa mud could be of great interest in establishing whether these lake sediments extend below the modern playa.

North of Kalacha (Figure 6C) more outcrops of fossil gastropods occur in a few places (Figure 3) but the greater part of the 'intermediate terrain' is composed of ridges and mounds of carbonate rock, which form a rolling terrain of 5-10 metres relief. Despite this relief, no vertical sections were visible, except in the walls of Laga Kubi Badana, where a thickness of about 5 metres of white carbonate rock appears to overlie lava. This rock has been studied in thin section by Ken Pye and identified as a calcrete, formed by deep weathering of the underlying basalt. Other specimens of rock from the terrain north of Kalacha have proved difficult to identify, even following thin sectioning and x-ray diffraction analysis. According to Pye, some samples showed a rounded (pisoid) structure, which may indicate an algal origin, by deposition in a shallow lake or around a spring. Two samples from low mounds on the playa margins close to North Horr may be reworked calcareous lake sediments (marls). A search for diatoms within these sediments has proved almost entirely negative, although this might be due to conditions unfavourable to the post-depositional preservation of diatoms, rather than to their absence in an original water body. It seems probable that most of these carbonate sediments originated in an environment where there was more water present on the land surface than there is in this area today. However, it is unlikely that any of these sediments formed in a deep lake environment; according to Pye (pers. comm.) they are more likely to have formed in a series of shallow basin-margin pools of differing salinity. This is particularly likely to be true of the sediments at Olturot (see Figure 3), which lie at an elevation of about 540 metres on the south-west slopes of Kulal. Here fossil gastropods (again dominated by Melanoides tuberculata) occur in pale grey silts which form the top of a sedimentary sequence of about 2-3 metres, whose base is not visible. These sediments outcrop in two buttes whose dimensions are of the order of 1 kilometre by 0.5 kilometre; at present the buttes are being attacked on all sides by sub-aerial erosion. The eroded slope of one of the buttes is shown in Plate 2.

Comparable sediments occur at a number of other localities, as shown on Figure 3. North of North Horr there is a surface of low relief that rises very gently to the north; fossil gastropods were found within the sediments that underlie this surface, to a maximum elevation of about 409 metres. The surface continues northwards for some tens of kilometres with no sign of a former lake shoreline. To the north-west there is a terrain of low ridges mantled with lava gravel; solid lava is apparently present not far below the surface and is visible along some of the drainage lines. Buttes of horizontally bedded sediments occur near Laga Ilama, where fossil gastropods lie at an elevation of about 400 metres. Sandy terrain (such as around the village of North Horr) separates the old lacustrine sediments from the modern playa.

The same landscape components are visible along the eastern slope of Chari Ache (Figures 6D and 6E). Here the slope forming the edge of the lava shield seems to consist entirely of volcanic rock; 4 horizontally-lying flows were visible making up the approximately 30 metres thickness in one section. Lava appears to extend eastwards at no very great depth; in different places it can be seen underlying a gravel-capped pediment, low mounds of carbonate rock, and the playa mud. Sand is important along this slope, forming parts of several different features. Those shown in Figure 6E are ridges of cross bedded orange-brown fine sand and silt, in places over 10 metres high. Modern-day erosion is exposing small cliffs in the slopes of these ridges. At the same time, coarser, pale yellow to pale grey sand is being blown across this terrain and banked up against the lower slope of the Chari Ache lavas (Figure 6D). Other evidence of the work of the wind in this area includes two crescentic (barchan) dunes to the north of

North Horr (Plate 3), and an elongated (seif) dune about 7 kilometres long on the playa to the north-west of Maikona (Herlocker 1979 page 6). Evidence from all these features is of a dominant wind direction broadly from ESE to WNW.

Wide areas of sand are found on the southern margins of the Chalbi basin, in the areas known as Koroli and Hedad. Here the landscape consists of a gently sloping surface of orange sand crossed by shallow intermittent drainage lines which run broadly towards the north and the north-east. This surface is interrupted by the lava-capped mesas already described. Towards the playa margin the sandy surface breaks up into a landscape of low sand ridges separated by flat floored pans. The pans are tens to hundreds of metres long, bare of vegetation with a firm surface of pale grey sediments. The sand ridges are sparsely vegetated with thorn scrub and rise 5 or more metres above the level of the pan floor. The sand of which the ridges are composed is fine grained and yellow-orange in colour. Sand is also present along the playa margin at the foot of the Ramatrobi sandstone slope, where there are ridges between 2 to 3 metres high.

Other features of local importance on the basin margins are the alluvial fans of the major drainage lines, which fall into two classes; the gravel fans (e.g. of Laga Bulal and Laga Kubi Badana) and sand fans (e.g. of Laga Balesa). The gravel fans are recognizable in the field by their gently convex relief and surface of smooth, rounded lava pebbles. The Laga Bulal fan consists of a series of near-parallel ridges with pebble covered surfaces, separated by broad flat floored depressions containing fine-grained brown sediments. Within these depressions, some erosion and transportation of sediments by running water appears to take place, but the greater part of the fan (i.e. the gravel ridges) seems to be a fossil feature, no longer forming under present day conditions. It is possible that these fans developed during a past more humid period, during which greater amounts of runoff flowed into the Chalbi basin. Frostick and Reid describe a comparable feature from the north-eastern margins of the Lake Turkana basin, the Koobi Fora Plateau Gravel, as representing "the last significant deposit of overspill from Chew Bahir to the L. Turkana Basin" (1980 page 435).

Sequence of events:

Based on the features described above, one can outline a tentative sequence of events within the study areas as follows:

In the period (Pliocene and earlier) before the Chalbi basin in its present form came into existence there were basins of sedimentation in this area including some which contained deep water supporting a fresh-water aquatic fauna. The Chalbi basin probably came into existence in approximately its present form during the early part of the Pleistocene, by a combination of volcanic and tectonic events. These events included downwarping and downfaulting along an axis aligned approximately NW - SE and the emplacement of lava along the eastern and western basin margins.

During the terminal Pleistocene - early Holocene wet phase that is documented for most of Africa, the Chalbi basin contained a body or bodies of fresh water. A continuous body of fresh water may have extended to an elevation of slightly above 410 metres A.S.L., as indicated by the gastropods at Maikona, Kalacha, Laga Ilama and to the north of North Horr. The gastropods at Olturot lived in a separate, higher body of water ponded up for a time on the south-western slope of Kulal. 'Lake Chalbi' would have had shorelines along the lava slopes to the east and west, and extended some distance to the south across the Koroli sand plain. Its limits to the north and north-west are not recognizable. Sand beaches, bars and spits probably formed along parts of the lake shorelines; remains of these features may be recognizable along the southern and western margins of the playa.

Since the lake level fell during the last 9,000 years, the sediments have been subject to intensive erosion and have also been covered by alluvial gravels and the fine-grained material that is still being brought down to the modern playa.

7. FOSSIL FAUNA AND FLORA

Gastropods

Nine collections of fossil gastropods from sediments on the playa margins were identified by Martin Pickford. Two other collections (both from Olturot) were identified at the Department of Macropalaeontology, Netherlands Government Geological Service. In all these collections, Melanoides tuberculata was strongly dominant (see Plate 4), with Biomphalaria of secondary importance. Present in much smaller numbers were Lymnaea and some other genera. The indication from these gastropods is of shallow fresh-water conditions. Living Melanoides have not so far been recorded from this area. Two collections of modern gastropods were made from the lower slopes of Chari Ache. According to Pickford, Zootecus insularis was present in both of them; this is a desert terrestrial species, which reflects the locally extremely arid conditions on the sand ridges where it occurred. Bloyetia is adapted to semi-arid conditions, typical of much of the Chalbi basin. The third species, Bellamya unicolor, is a fresh-water gastropod. Its shells were found widely scattered over the brown mud of the playa, at the base of the north-western slope of Chari Ache. The snails presumably flourish and breed rapidly during the short periods when this area is flooded with fresh water. No Melanoides, either modern or fossil, were found in the area where the Bellamya occurred.

Shells of the Melanoides from Kalacha have been submitted to Paul Abell (University of Rhode Island) for oxygen isotope analysis. A preliminary comment on his results is that "The Oxygen isotope ratios, hovering near -2.5 to -3.0 suggest a fresh water, fairly cool environment, but that evaporation of the water body probably killed the gastropod as the oxygen isotope ratio climbed to -1.8" (Abell, pers. comm.).

Fossil bone:

Bone from two sites, Olturot and Algas (see Figure 3) was identified by Martin Pickford.

Olturot: Pale grey fossil bone is washing out from a slope of pale grey silt, less than 1 metre high. The fauna, listed in Table 2, indicates an environment basically similar to that of the area today. The modern vegetation around Olturot is described by Herlocker as annual grassland, with a strip of woodland (*Acacia tortilis* with *Duosperma/Indigofera*) along the course of Laga Balesa a few kilometres east of the site (Herlocker 1979, page 19 and map). No deductions about the age of this bone can be made, except to note that these are all modern species.

Algas: This may be the site described by Dixey (1948 page 12) as the Marsabit Road site, and said to contain sediments, namely "lacustrine limestones and clays yielding a rich mammalian fauna referred to the uppermost Lower Pleistocene". Bone collected in the 1940s has been identified; Table 2 summarizes the results of analysis of this bone and that collected in 1983. For the age of the fauna, Pickford suggested a date between 1.6 and 2.0 Ma, possibly closer to the older limit of this range (Pickford, pers. comm.). K-Ar dating of the lava overlying the bone bearing sediments yielded an age of 2.5 ± 0.3 Ma. (see Appendix A). The fauna from Algas/Marsabit Road comprises both lacustrine and terrestrial elements. Among the lacustrine elements are *Lates niloticus*, crocodile and hippopotamus. The large size of the *Lates* vertebrae (see Plate 5) suggests an extensive and deep body of water at or near the site. Terrestrial mammals include bovids and *Equus*, suggesting the presence nearby of open country. It is possible that different strata are yielding discrete aquatic and terrestrial faunas which are becoming mixed by present day erosional processes.

Evidence from just one site does not allow a palaeo-environmental reconstruction to be carried out, but the indication is that at the time of deposition of the Algas sediments (predating at least some of the Marsabit vulcanicity) there was a large, deep body of water in this area. However it is not possible to say what area this water covered, how long it existed, or what kind of climatic conditions allowed it to exist. The presence of *Lates niloticus* so far to the east is of interest, as it suggests faunal links with the Nile system to the west. By 2.5 Ma it would seem likely that Kulal and Chari Ache were already in existence, as well as the Chalbi - Turkana divide further north. Possibly the link with the Turkana basin was to the south of Mount Kulal.

Fossil wood

Fragments of fossil wood were collected from the slopes of Falama, one of the lava-capped mesas (see Figure 3 and Plate 6). Five pieces have been identified by Mark Crawley of the Fossil Plants Section, British Museum (Natural History). Four of them show similarity to the living genera *Afzelia*, *Dichrostachys*, *Macrolobium* and *Piptadenia*, and are assignable to the fossil form genera *Pahudioxylon*, *Dichrostachyoxylon*, *Berlinioxylon* and *Mimosoxylon* respectively. The fifth specimen shows similarities to *Copaifera* and *Guibourtia*, but also to *Chukrasia*, and is tentatively assigned to *Copaiferoxylon* form genus. The age of these specimens is estimated as Cenozoic, more precisely Mio-Pliocene. The fossils are broadly comparable with tropical forests/woodlands, but it is impossible to assign them specific habitats on just the evidence of the wood.

Although it is necessary to be cautious about drawing inferences from a few small pieces of fossil wood, it is interesting to note that Crawley assigns the wood to a significantly earlier date than has been obtained for the Algas fossil bone; Mio-Pliocene as opposed to terminal Pliocene. This tends to support the suggestion that the lavas capping Falama and the other mesas are older than those of Marsabit. The modern vegetation in the area around the mesas is described by Herlocker as shrubland (Herlocker 1979 page 20 and map), so a fossil assemblage of tropical forest/woodland might imply more humid conditions at the time these plants were living.

Pollen

Pollen from the Galana Boi beds is described by Owen et. al. (1982). Five samples were taken, the oldest of them from the base of a coquina dated at 9880+670 yrs. B.P. Concerning this sample, it is said that "It is characterized by abundant regional elements - montane forest and thicket taxa (36.8%), which do not occur in modern lake samples. The pollen grains were probably transported to the lake by rivers originating in the Ethiopian Highlands. They suggest both increased runoff and an extension of the highland forests. This, together with a high percentage of Pteridophytes (14.7%) suggests increased rainfall over the catchment". The four younger samples extend into the middle Holocene, and "are dominated exclusively by taxa that typically inhabit lake margins in sub-desert zones." The implication is that "by the middle Holocene, climatic conditions had become more comparable with those of the present".

Stiles (n.d.) describes pollen analysed from sediments collected from the Chalbi playa near North Horr. Compared to the modern (surface) pollen, pollen from sediments 120 cm. and 160 cm. below the surface showed:

A greater amount of highland forest pollen, in particular Podocarpus, which today does not occur on Marsabit, the Huri Hills, and probably not on Kulal.

Slightly more palm pollen.

Considerably less pollen identified as originating from sub-desertic scrub.

The pollen from the sediments 120-160 cm. deep indicates moister conditions than those of today. However no date is available for these sediments.

8. ARCHAEOLOGY AND PALAEOENVIRONMENTS

The study of human and pre-human remains can contribute much to the understanding of past environments. In Northern Kenya the most detailed work along these lines has been done in the East Lake Turkana area. Research here has outlined a picture of hominid and human activities in varying lake shore, deltaic and riverine environments over several million years. Tectonic and volcanic as well as climatic factors influenced the changing environments of East Lake Turkana, as they have done in the Chalbi basin.

Barthelme (1977) describes Holocene sites of the area north-east of Lake Turkana. He located over 35 sites, some close to the modern lake shore, others on volcanic terrain over 25 km. inland. From the study of the Holocene stratigraphy, it has been concluded that there may have been three Holocene transgressions of Lake Turkana; an early advance to a level 75-80 metres above the modern lake, a later advance to approximately 50-60 metres above the lake, and a final phase with a +35 to +40 m. lake level (Owen et al. 1982).

Barthelme found 13 bone harpoon sites, 7 of which are located on the 75 - 80 metre shoreline. As well as the bone harpoons, these sites contain microlithic stone tools (crescents and curved backed blades, mostly made of crypto-crystalline silicas and veined quartz) and (some of the sites) decorated and undecorated pottery. Dates of 8710 ± 130 years BP and 8395±270 years BP were obtained from two of the sites (Owen et al. 1982). A coquina composed of Melanoides shells from the base of one of the sites yielded dates of 9540±260 and 9260±235 years. BP (ibid.). Barthelme also found Pastoral Neolithic sites in this area, associated with the second phase of high lake levels. These sites contain the bones of domestic stock (ovicaprids and probably cattle), typical Later Stone Age microliths and several pottery types. A number of radiocarbon dates lie close to 4000 years BP. At these sites, fish bones indicate that fishing played an important subsistence role, but barbed bone harpoons are absent (Owen et al. 1982); the assumption is that "The early pastoralists had apparently devised an alternative, as yet unidentified fishing strategy".

Further south along the shore of Lake Turkana lies the Lowasera site, excavated by D.W. Phillipson (Phillipson 1977). The bedrock here is a small inlier of Basement system gneiss, over which lies a yellow brown tuff. Phillipson suggests that this tuff is of aeolian origin, deposited during the final Pleistocene, and eroded during a period of low levels of Lake Turkana, between about 35,000 and 8,000 years bc (i.e. 37,000 and 10,000 yrs. BP). At Lowasera the evidence for the high Lake Turkana is a beach at 73-82 metres above the lake level of September 1975, and lacustrine silts below the beach sand and shingle. Molluscs in these silts have been dated to 7470 bc±200 years (i.e. approximately 9420 years BP). Evidence of human occupation includes lava and obsidian tools, bone harpoons, pottery and ostrich egg shell beads; there were also very many fish bones and eight human burials were excavated. The occupants of this site depended very largely on fishing in the deep, relatively fresh Lake Turkana. According to Phillipson, the evidence at Lowasera shows that the lake remained high between the 8th and the 3rd millenia bc; that is it reached a high level between 9000 and 10000 years ago and it stayed at or near that level until sometime between 4000 and 5000 years ago.

To summarize the Holocene evidence from the east shore of Lake Turkana; it indicates a deep lake (reaching a maximum of about 80 metres above modern levels) along whose shoreline there were fishing communities who used bone harpoons as an important tool. These communities came into existence as early as 9500 years ago. About 4000 years ago pastoral communities continued to eat fish from what was still a high lake (50 - 60 metres above modern levels), but they no longer used bone harpoons. According to Owen et al., "The lake level fluctuations can be mostly attributed to variations in the water balance caused by climatic change", and thus any high stands of Lake Turkana should be reflected in the Chalbi basin. It might be expected that if a fresh water Lake Chalbi existed during the Holocene similar fishing communities would have been living around its shores.

Stiles and Munro-Hay (1981) excavated several burial cairns on the eastern margin of the Chalbi basin, at a site they call Kokurmatakore Hill, close to Kalacha Goda village. The material they found yielded very little information about people's economy. Goat bones were found within the mound stones of one cairn but no fish bones or bone harpoons were found. Based on the nature of the sediments uncovered below two of the cairns, Stiles and Munro-Hay suggest that there was a large lake in the Chalbi basin as recently as 1110 years BP. The sediments were described as follows:

Cairn 3: (at the top) 4. pebbles and cobbles, 10 cm.

3. soft brown sandy silt, 20 cm.

2. Dark brown fine silt with numerous dense lenses of calcified root casts, 40 cm.

1. Hard dark brown silt-clay, with numerous $CaCO_3$ pebble concretions, to base of section at approximately 160 cm.

Cairn 5: (at the top) 3. lava stones (10 cm.).

2. Unconsolidated, brown fine grained silts.

1. Compact whitish silt to clay, with $CaCO_3$ nodules, to base of section at 80 cm.

The authors interpret these sediments in terms of past more humid conditions in the Chalbi basin. Layer 2 in Cairn 3 is said to have been "laid down under conditions of shallow, standing water in which plants were growing" (Stiles and Munro-Hay 1981 p. 157). Of layer 1, below it, it is said that "This layer indicates that the Chalbi Lake at one time extended this far, a distance of approximately 5 km. from the present shoreline" (ibid.). Near the base of layer 2 in Cairn 3 a powdered wood branch was found <u>in situ</u> in the sediments, which yielded a radiocarbon date of 1110 ± 155 years BP. If the interpretation above is correct, then the 'Chalbi Lake' would have extended this far to the east about 1100 years ago; it would also have reached a surface level over 20 metres above the modern playa.

I was unable to examine the section described from Cairn 5, but Cairn 3 was re-excavated while I was in the area in August 1982, to show a section that I described as follows:

4. Brown silt with dark grey vesicular basalt fragments, angular to rounded in shape, up to 10 cm. long. Approximately 40 cm. thick, abrupt lower contact over:

3. Medium to dark brown clay, with a surface of small angular blocks. 60 cm.

2. Mixture of largely rounded basalt cobbles, many appear water-smoothed. A few up to 10 cm. long, most less than 4 cm. Circa 35 cm.

1. Mid to pale brown firm, rather gritty silt, lowest 30 cm. of section.

For a number of reasons it appears unlikely that any of these sediments are of lacustrine origin, as suggested by Stiles and Munro-Hay. In the first place their topographic situation does not seem favourable to lacustrine sedimentation; Kokurmatakore Hill is a spur of the lava slope that overlooks Kalacha Goda. Secondly, the sediments do not show the regular stratification and fine grain size that are typical of most lake sediments and are shown well in the sediments exposed at the foot of the lava slope, a few kilometres to the south (described in Section 6). Nor do they contain any of the freshwater gastropods that are abundant in sediments that occur both to the north and south of this locality. A sample from layer 1 at Kokurmatakore Hill was examined for diatoms, but none were found. A further point is that if the Kokurmatakore Hill sediments were laid down in a lake, the lake should also have flooded the areas to the north and south of Kalacha Goda where the gastropod-bearing sediments occur. The gastropods at Kalacha Goda were dated at 10,590 ± 255 years B.P. They lie in silts at the top of a sediment section, and there is no sign that these silts were ever overlain by younger waterlain sediments. Finally it should also be pointed out that there is no evidence from the nearly Lake Turkana basin of a high lake as recent as 1100 years ago, as postulated for the Chalbi basin by Stiles and Munro-Hay.

A more plausible interpretation of the Kokurmatakore Hill sediments from Cairn 3 is that the fine-grained strata (layers 1 and 3) may result from temporary local ponding up of water. To the north of the Kokurmatakore Hill spur the lava front recedes eastwards, and an alluvial fan has spread out from the mouth of a laga. The margins of this fan would have provided a suitable environment for small short-lived ponds of water to develop. The pebbles of layer 2 in Cairn 3 may have been laid down by surface runoff across the fan. The modern fan surface is covered by well-rounded lava gravels, though at present it appears to be a fossil surface like that of the Laga Bulal fan mentioned in Section 6.

Phillipson excavated two sites at North Horr, and these were re-excavated by Stiles. Their results are given in two so far unpublished reports, Phillipson (1980) and Stiles (n.d.). Phillipson described his sites as lakeside settlements, lying within the modern sand dunes of North Horr. At North Horr I, the site overlay "a calcareous deposit which apparently formed on the retreating margin of the old Chalbi lake". The material at the site included stone tools, decorated pottery, ostrich egg-shell beads, stone beads and some broken bone. Radiocarbon dates were obtained from the ostrich egg shell. At the base of the deposit, a date "in the middle of the 3rd millenium bc" was obtained; that is, approximately 4500 years BP. At the top of the deposit, a date "in the middle of the 2nd millenium bc" was obtained;

that is, approximately 3500 years BP. The second site, North Horr II, was at a lower elevation than North Horr I, and considerably later in date, covering the 5th to the 24th centuries a.d. Phillipson identified this site also as a lakeside settlement, its lower elevation indicating the extent to which the Chalbi lake had retreated since the occupation of North Horr I.

Stile reports that on re-excavating the two North Horr sites, and some other sites in the area, he found bones of cows, ovicaprids and a few wild ungulates, but no bones of fish or other aquatic life. At one of his new North Horr sites (GcJm 3) charcoal from a hearth at 95 cm. depth below the surface was dated to 1150 ± 110 years BP.

North Horr I appears to be a Pastoral Neolithic site comparable to those described by Owen et al. from the east shores of Lake Turkana. From the Lake Turkana evidence, it appears that conditions during this period (of the order of 4000 years ago) were significantly moister than they are today, to allow the lake to stand at 50-60 metres above its modern level. However the evidence from the Chalbi basin is not so clear. At North Horr there seems to be no firm evidence that the sites were actually located on a lake shoreline. The calcareous deposit to which Phillipson refers briefly need not indicate a permanent fresh-water lake, but could have formed in a number of other ways. There is no mention of diatomaceous silts, fresh water molluscs, beach sands, shingle, or other evidence of a large permanent body of fresh water. The absence of bone harpoons at North Horr would be consistent with the evidence from the Pastoral Neolithic sites at Lake Turkana, but fish bones and bones of other aquatic creatures are also absent at North Horr. The deduction must be that the people at North Horr did not include fish, crocodiles, hippopotamus, etc. in their diet. This does not by itself mean that a 'Lake Chalbi' was not in existence; it could have been too shallow or too saline to contain edible fish. However, on the basis of the data presented by Phillipson and Stiles from North Horr, it seems dangerous to assume that these sites definitely represent settlement on a former Lake Chalbi shoreline. There is permanent fresh groundwater at North Horr today, and people living there need not have been dependent on a hypothetical lake for their water supply.

It must be concluded therefore that the archaeological evidence so far published tells us very little about the possibility of there having been a Holocene Lake Chalbi. While there was a deep Lake Turkana with fishing communities along its eastern shore, we cannot as yet claim that there was a comparable body of water in the Chalbi basin.

During the course of my research in the Chalbi basin, I kept an eye open for archaeological material, and made some surface collections which were submitted to the National Museums of Kenya. Unfortunately, there is little of palaeo-environmental significance in what I found, but the results are summarized below:

Stone rings and cairns were observed at a number of places, including those recorded by Stiles and Munro-Hay. Almost always, the features were made of lava boulders, and they lay on the lower part of the lava slopes, or at its base. At Mayidahad, where the Chalbi basin margin is a slope of red sandstone, the cairns were of red sandstone too. At Olturot, one cairn made of slabs of the weathered lichen-stained limestone was found. South of Kokurmatakore Hill the cairns occur on the lower part of a lava slope where molluscs (Melanoides), root casts and fine-grained pale sediments are also present. The cairns show no sign of water having disturbed them or eroded the rocks of which they are composed. The assumption is that the cairns are of a substantially later date than the presence of water on this slope.

Two traditional Rendille sites were pointed out by one of my assistants, whose home is near Kargi. Both sites lie quite close to the Marsabit - Kargi road. Farren lies to the west of the road, in flat sandy terrain between the edge of the lava and the Chalbi playa. It consists of a ring of lava boulders, about 8 metres in diameter. The largest boulders are about 50 cm. long, and must have been brought to the site from the edge of the lava, which here is over 1 kilometre to the east. In the centre of the ring are two upright pieces of lava, each about 75 cm. high, with their tops stained with red ochre. When we visited the site, our informant took his shoes off and carried a branch of a shrub to add to a pile of branches around the central stones. This site is said to be the place where the ancestor of the Dubsahai manyatta of the Rendille originated. The second site is Algas, which lies to the east of the road, near the end of the lava spur that runs northwards (close to the bone site, see figure 3). This is also a stone circle; it has no central stones but has two slightly taller stones at one side which are stained with red ochre. Algas is said to be the place of origin of the Oruwen section of the Rendille. Fragments of pottery were found on the surface near Algas (besides the fossil bone described in section 7).

The largest surface collections were those made at Olturot, around the sites where gastropods and fossil bone were located. The stone artefacts have been described by Dr. Harry Merrick of the National Museums of Kenya, whose comments are summarized below:

Olturot SE 1: material collected from the surface in the same area as the fossil bone. The collections included 12 obsidian artefacts, of which two might be M.S.A. and at least 5 definitely L.S.A. Of 21 lava artefacts, at least 7 were attributed to the M.S.A. There were also some quartz and chert fragments of uncertain attribution. Dr. Merrick concludes that there are probably two archaeological components in this collection, an M.S.A. and an L.S.A. one. The fossilized bone might be associated with the M.S.A. artefacts.

Olturot H1: material from the top and lower slopes of the sediment mound from which were collected the molluscs which were dated to 10,430 years BP. Except for a small obsidian point and a lava flake, the material was definitely of L.S.A. character; a fragment of an ostrich egg shell bead also supports an L.S.A. attribution.

Olturot H2: material collected from the top and lower slopes of the second sediment mound at Olturot. Obsidian, lava and quartz artefacts were predominantly of L.S.A. date.

143 sherds of pottery collected from the different sites at Olturot were examined by Dr. Simiyu Wandibba of the National Museums of Kenya. Unfortunately the pottery was very fragmentary and only 7 of the sherds were decorated, so there was little that could be said about shape and decoration of the vessels. Dr. Wandibba classified the pottery according to its fabric, in which he distinguished three groups:

Group I: sub-rounded and rounded quartz grains
obsidian chips
some felspars and muscovites.

Group II: sub-rounded and rounded quartz grains
obsidian chips
some felspars
muscovites much less frequent than in Group I

Group III: finer fabric than the other two groups, characterized by many voids which are an indication of tempering by organic materials
quartz
felspars
iron ore
very sparse micas

The pottery from Group III is sufficiently different from that of Groups I and II to suggest a different manufacturing technique and probably a different production centre. From the sherds collected, it was not possible to make any comparisons of the Olturot pottery with the pottery that has been described from Lowasera, the East Lake Turkana sites or North Horr.

The archaeological evidence, sparse as it is, indicates that during much of the Holocene, people lived around the margins of the Chalbi basin. The impressive local concentrations of cairns and stone rings cannot be used as a basis for calculating population densities or for comparing past and present populations in this area. In the period after about 4000 years ago, Pastoral Neolithic peoples lived around the Chalbi playa, as well as to the east towards Lake Turkana. It remains uncertain whether there were Holocene fishing communities around the shores of a former Lake Chalbi, as on the shores of the high Lake Turkana.

9. PALAEOLAKE STUDIES AND CLIMATIC HISTORY

The enclosed basins of East Africa vary in their hydrological conditions. Some of them, for example the Naivasha and Baringo basins, contain fresh-water lakes. Others contain extremely saline lakes such as Lakes Magadi and Natron. Yet others contain no permanent body of water at all; such are the Chalbi and Olorgesailie basins. Since the modern conditions in these basins vary so much, it must be expected that conditions during the last tens of thousands of years must also have varied. However virtually all the lake basisn of East Africa contain evidence that at some time in the recent geological past they held lakes that were substantially larger and deeper than those of the present. Hamilton (1982 Chapter 4) presents a recent summary of the evidence for lake level fluctuations in East Africa. The evidence of some of these palaeolakes (in particular Lakes Nakuru and Naivasha) was used as the foundation for the 'Pluvial Hypothesis' which for many years dominated thinking on Quaternary environmental change in East Africa (Leakey 1931, Nilsson 1931 and 1940, Wayland 1934, and many other sources). High lake levels were held to indicate former high-precipitation 'pluvials' which were correlated with the Quaternary glaciations in mid and high latitudes. Since the 1950s the Pluvial Hypothesis has come under increasing attack (beginning with the work of Cooke, 1957 and Flint, 1959) and it has now almost disappeared from the scientific literature on Quaternary environments in Africa. However it is still accepted that East Africa, together with the rest of the world, underwent climatic change during the Quaternary, and that this climatic change influenced conditions in lake basins. The question here is how evidence from the lake basins may be used to arrive at estimates of past climatic conditions.

In some lake basins there is geomorphological evidence to indicate that water once stood at a higher level than it does today. This evidence includes concave notches marking former cliffed shorelines and spreads of rounded pebbles marking former shingle beaches. (Washbourn-Kamau 1971, 1975). Stromatolites (algal limestones) have also been described as evidence of former high water levels. (Tiercelin et al. 1981). Where such features are present it is possible to arrive at a close estimate of the shoreline level of a former lake. This will allow one to determine whether or not the lake shoreline is horizontal. If it is not, as in the case of some of Lake Victoria's high shorelines, the implication is that tilting due to tectonic processes has caused major changes within the lake basin. Interpretation of the lacustrine record purely in terms of climatic change is not possible in such a basin. Well-defined high lake shorelines will enable estimates of depth, surface area and volume of palaeolakes to be made. In many lake basins, evidence of actual high lake shorelines is hard to find. Well-marked shoreline features may never have existed, due to the local topographic and geological conditions of the lake basin. Alternatively, shoreline cliffs may have existed but have been destroyed by sub-aerial processes since the lake waters receded to a lower level. In such basins, there may be evidence of a former larger lake in the form of fine-grained sediments, possibly containing diatoms and fresh-water gastropods. The position of these sediment outcrops on the slopes of a basin will indicate a minimum level to which the lake waters rose but cannot provide a precise indication of lake surface level and area. Where such sediments contain fossil shell or bone that can be radio-carbon dated, they provide valuable evidence of the date of high lakes within a basin. Other aspects of these sediments can yield much information about conditions within the palaeolakes. Cerling (1979) studied lake sediments from the northeast side of the Lake Turkana basin and from analysis of (i) diatoms, molluscs, and fish, (ii) exchangeable cations of clay minerals and (iii) the presence or absence of certain minerals including gypsum, calcite, dolomite, montmorillonite and halite, arrived at estimates of alkalinity within Lake Turkana from the Pliocene (Kubi Algi Formation) to the present. According to Cerling's work, Lake Turkana was a fresh-water lake from the Pliocene until about 1.8 million years ago; since then it has fluctuated between a freshwater lake and a moderately alkaline lake. The reasons for these changes in the alkalinity of the lake are believed by Cerling to be climatic rather than tectonic; this assumption is based on isotopic studies of carbonates, e.g. from Olduvai Gorge, which indicate a climatic change taking place at about 1.8 ma. Cerling's work shows how detailed studies of aspects of basin sedimentology can be used to draw inferences about conditions over a much wider area.

Another approach to outlining the evolution of a lake basin is through the analysis of a core from the sediments in the basin floor, which may or may not lie below the waters of a modern lake. Such work has been done on cores from a number of East African lakes, among which one may name Lake Victoria (Kendall 1969 and Livingstone 1980), Lake Naivasha (Richardson 1966, Richardson and Richardson 1972), Lake Tanganyika and Lake Kivu (Hecky and Degens 1973). A discussion of plans for raising long cores from some of the oldest Rift Valley lakes is given by Livingstone et al. (1983). Analysis of the lake sediment cores usually focusses on mineralogy of the inorganic component and on diatoms, pollen and other microfossils; the organic material in the cores often provides radio-carbon dates for sections of the sedimentary record. The record from a core usually allows a curve to be plotted showing variations in the salinity of the lake water and thus, by inference, in the volume and depth of the lake. Episodes when a lake dried up completely at the core site, and eruption of volcanic tephra in a lake basin can also be recognized from a core.

Not all variations in lake level can be attributed to climatic change, especially in a region like East Africa, prone to tectonic and volcanic activity. The role of tilting in the creation of some of Lake Victoria's high shorelines has already been mentioned. Tectonic forces may disrupt a lake basin or its catchment area so that a lake goes out of existence; an example is the Olorgesailie basin of the Kenya Rift Valley (Owen and Renaut 1981). Volcanic activity may cause the building of a dam behind which a lake forms, as did Lake Kivu behind the Virunga volcanic range (Hamilton 1982 p. 51). A lake may lose or gain inflow through river capture or faulting within its catchment area. Downcutting at the outlet of a lake can bring about a progressive fall in lake level independent of climatic change, as may have taken place in the case of Lake Victoria. (Temple 1967). All such possibilities have to be eliminated before a change in level can be taken as a strong indication of climatic change.

If non-climatic influences on lake level can with some confidence be eliminated, then the question of which climatic elements caused changes in the lake volume and thus in its level has to be answered. An increase in mean annual rainfall over a lake catchment will cause the lake to rise in level, if other conditions remain unchanged. So will a fall in mean annual temperatures, causing a reduction in the rate of evaporation loss from the lake surface. Other changes can be envisaged; seasonality of precipitation, cloudiness, wind speed, and also a change in the vegetation conditions of the catchment area which would influence the percentage of the rainfall that reached the lake. Even if these other possibilities are ignored (since it is difficult to develop means by which they can be evaluated) the question of whether the lakes responded to a change in rainfall or in temperature (or both) remains. One possibility is to look beyond lake basins for indications of climatic change during the period of lake-level fluctuations. In East Africa, studies of highland pollen and of glacial fluctuations have allowed deductions of temperature changes during the Quaternary to be made

(Hamilton 1982, Chapters 3, 5 and 6). Assuming that temperature changes at lower altitudes were the same as those on the high mountains, it may be possible to arrive at estimates of temperature/rainfall conditions that allowed the existence of lakes at particular high levels. Research into this topic of 'Quaternary palaeohydrology' has been done in North America (Snyder and Langbein 1962, Reeves 1965); and in Africa (Street 1979, Kutzbach 1980). The present author made an attempt at calculating the precipitation-evaporation-runoff relationships which would have maintained a lake 180 metres deep in the Nakuru basin (Butzer et al. 1972, page 1074).

Little else on these lines has been done on the East African lakes, depsite the accumulation of an increasing amount of evidence about their high levels. Hamilton (1982 page 227) presents a very generalized picture of major environmental changes over the last 30,000 years. Temperatures in tropical Africa are shown as having been relatively low between 20,000 and 10,000 years ago, and markedly higher since then. The precipitation/evaporation ratio was also low between 20,000 and 10,000 years ago and rose substantially between 10,000 and about 4,000 years ago, after which it fell again. Thus there were cool and dry conditions in Africa between 20,000 and 10,000 years ago, approximately correlating with a glacial maximum in Europe. When the African lake levels rose, beginning around 12,000 years ago, temperatures were also increasing. The increase in precipitation must have been enough to compensate for higher evaporation rates and at the same time to provide increased inflow into the lake basins. It would be of great interest to test this general picture against some of the actual high lakes which existed during the last 30,000 years in this region; for example, to work out what kind of a 'warm and wet' climatic regime would have been necessary to maintain Lake Nakuru (to name only one lake) at its 180 metre level. This is one way in which palaeolake studies could contribute significantly to our understanding of Quaternary climates.

Having said this, it must be admitted that our present state of knowledge about the Chalbi basin does not permit us to use it as the basis of specific, rather than general, palaeoclimatic reconstructions. As has been indicated in the earlier part of this report, there is firm evidence of more humid conditions in the Chalbi basin during parts of the Quaternary period. From the radiocarbon dates for molluscs, it is clear that these conditions prevailed in the Chalbi at the same time as high lakes existed in many other East African lake basins. Unfortunately it has not been possible, on the basis of the field work carried out so far, to determine conclusively whether a large lake existed in the Chalbi basin, or to what level it may have risen. This makes it very difficult to carry out a palaeoclimatic reconstruction of the kind done for the Nakuru basin (Butzer et. al. 1972), in which an essential piece of data was the area of the former lake in the basin. The Nakuru basin reconstruction was based on a very simple water balance equation for existing and former lakes in the basin, namely:

$A_L.E = P_L.A_L + A_B.P_B.K$, in which

A_L area of lake surface

A_B area of rest of catchment

E evaporation from lake surface

P_L precipitation on lake surface

P_B precipitation on rest of catchment

K runoff constant, expressing the percentage of precipitation on the catchment that actually contributes to the recharge of the lake.

Such an equation could be applied to the Chalbi basin, despite the lack of evidence of a palaeolake level. One possibility would be to postulate the existence of a former lake just covering the Chalbi playa (an area of about 1,500 square kilometres according to my measurements) and to work out precipitation-evaporation-runoff conditions which would maintain such a lake in existence. An attempt was made to do this, using a figure of 1500 square kilometres for A_L. However problems arose with the estimation of other terms in the above equation; evaporation, basin precipitation and runoff among them. Parts of the Chalbi catchment area extend into southern Ethiopia, where data on rainfall and even altitude of the land is very hard to come by. It was felt that, given the available data, an attempt at calculating past climatic conditions in the Chalbi basin would be too speculative to be of much value. However if more information on existing conditions could be assembled, an attempt at reconstructing past conditions by use of the above equation or other similar equations could usefully be made.

10. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The Chalbi basin is an inland drainage basin in an arid region of Northern Kenya. In its centre lies the Chalbi playa, a bare surface of mud subject to occasional flooding by inflow of surface runoff from the surrounding uplands. The surface of the playa lies at an elevation of about 370 metres above sea level. The basin is surrounded by lava uplands that date from the Oligocene to the Pleistocene, and may owe its existence as a depression partly to the building of the uplands around it. Other factors that may have contributed to the creation of the Chalbi basin are downfaulting, downwarping and the removal of poorly consolidated sediments by erosion.

Along the eastern margins of the Chalbi basin, the lavas from the Huri Hills and Marsabit overlie sediments; pebble conglomerates, sandstones and silts. At Algas these sediments contain fossil bone originating from both terrestrial and aquatic species which indicate an age within the range 1.6 to 2.0 Ma. The aquatic species include Lates niloticus (large vertebrae), crocodile and hippopotamus, and suggest that there was an extensive and deep body of water at or near the site. It is not possible to define the limits of this body of water, or the period of time over which it existed. A potassium-argon date of 2.5±0.3 Ma has been obtained for basalt lava overlying the bone-bearing sediment at Algas.

Between the lava and the Chalbi playa there is a belt of younger sediment that includes sands and horizontally-bedded silts. Some of the sand occurs as curved ridges which rise to between 4 and 6 metres above the desert floor and may be beach ridges or sand spits from a former lake in the basin. There are also low rounded hills and ridges of white carbonate rock, which may be of varied origin, including algal deposits and reworked calcareous lake marls. The horizontally-bedded sediments were probably laid down in calm, fresh water. At several localities, they contain large numbers of fossil fresh-water gastropods, mainly Melanoides tuberculata. Radiocarbon dating of these gastropods has given dates ranging from 9,530 to 11,080 years before present. Barometric levelling has yielded heights ranging from 375 to 542 metres for the gastropod-bearing sediments. The gastropods at 542 metres are those at Olturot, some tens of kilometres to the southwest of the Chalbi playa, and can be attributed to a separate little body of water, not to a former lake Chalbi. The remaining gastropods lie at elevations between 375 and 409 metres, and may have originated within a Lake Chalbi with a surface level slightly above 410 metres. Alternatively, they could have existed in a number of separate ponds or swamps on the basin margins. The evidence of early Holocene humid conditions within the Chalbi basin agrees with that from the Lake Turkana basin and from other lake basins in Eastern Africa.

At present, a variety of agents are shaping the landforms of the Chalbi basin. Wind as an agent of transportation is active in winnowing away loose fine material from the lava and sediment surfaces. Wind does not appear to function strongly as an agent of abrasion on rock surfaces, and many of the sand surfaces appear relatively stable. Active sand dunes are restricted to a very few localities. Running water is restricted in time to the occasional heavy rains, but its role in erosion and transportation can be recognized over much of the area. On the edge of the desert floor, standing water is probably responsible for chemical (salt) weathering of lava boulders. These boulders move down the slope under the influence of gravity, no doubt most actively during the rainy seasons when the underlying sediments are moist.

From the above information it is clear that much still remains to be discovered about the Chalbi basin and its surroundings. Perhaps the most obvious gap lies in our knowledge of its geology, which should be narrowed when the work of the Samburu-Marsabit Project referred to earlier is complete.

Based on the results of the present project, the following suggestions for further research in the Chalbi basin are made, though not in any order of priority. The suggestions include both field and laboratory work, and would involve expertise in a number of different fields. Topographic mapping would be extremely valuable, both to provide more height information and to check the accuracy of the height measurements already made. Ideally, a large-scale contour map of the basin should be prepared, but this would be prohibitively expensive. Establishment of accurate heights of the majority of the sediments of possible lacustrine origin would be very useful. Study of the volcanic rocks of the basin should include the obtaining of some more potassium-argon dates, in particular from Chari Ache, the Koroli lava plateaux and Kulal. Detailed petrological analyses of the lavas would allow them to be compared to each other. Where lava outcrops at or close to the surface of the Chalbi playa (e.g. at Kalacha Goda and at Karole water hole) it should be compared with the lava from the top of the nearby slope. If the results of this analysis indicate that the same flow is present both above and below the basin margin, the suggestion of a down-faulted margin would be supported. Detailed field mapping should also allow faulting to be confirmed. On the Koroli lava plateaux, detailed mapping should allow the location of eruptive vents and faults. Comparison of the petrology of the lavas in the different plateaux could confirm that they were once part of a single flow. The white rock of the rolling terrain to the north of Kalacha Goda (and elsewhere on the basin margins) needs further laboratory analysis, in the hope of establishing its origin more precisely. It would also be useful to spend more time in the field in the area north of Kalacha Goda, looking for sediment cross-sections and mapping the contact of these sediments with the lava and with the mud of the Chalbi playa. The horizontally bedded sediments that contain gastropods need analysis to determine their depositional environment; swamp, lake shore, or offshore lacustrine? A few of these sediments contain diatoms; a knowledge of the diatom flora will provide informtion about conditions of deposition, including depth and salinity of water. Mineralogy of the sediments will also provide information on conditions of deposition. Sand ridges; the question here is of origin: aeolian, fluvial, or lacustrine? More detailed fieldwork, studying structures exposed in cross-sections cut in the sand, should help provide an answer to the question. Grain size and shape analyses of sand samples would also be helpful in this respect. Fauna and flora: much work can be done on the various remains of living organisms. Analysis of the gastropods, fossil wood and fossil bone should provide more information on the environmental conditions at the time these organisms were alive, and possibly allow correlation with the fossil record from other sedimentary basins. If pollen can be found within any of the sediments, it should make an important contribution to the knowledge of past conditions in this area. Relatively little work has been done so far on the Chalbi playa itself, and much could be done. It would be interesting to map the playa to show the distribution of the different kinds of surface which may possibly be related to conditions on the playa margins. Observation of the playa in flood conditions would be extremely useful; how long does it take to fill up, how long does it remain flooded, etc.? Another project would be to measure the depth of sediment that lies within the Chalbi basin, if possible plotting a sub-sediment profile across the playa. This might be combined with the taking of a core (or cores) from the sediments underlying the playa. Analysis of such a core for mineralogy, diatoms and pollen should provide a detailed record of fluctuations of the environment within and around the Chalbi basin.

APPENDIX A: RADIOMETRIC DATING

Potassium-argon age determination was carried out by Geochron Laboratories, sample number R-6920. The material submitted was whole rock (basalt lava, my sample number 301283-0) which was treated with dilute HF and HNO_3. The results of the analyses were as follows:

Radiogenic ^{40}Ar, ppm	Radiogenic ^{40}Ar/ Total ^{40}Ar	Ave. radiogenic ^{40}Ar, ppm
.000089	.105	
.000065	.092	.000077

%K	Ave.%K	^{40}K, ppm
0.456		
0.449	0.453	0.540

Radiogenic $^{40}Ar/^{40}K$=.000143 AGE = 2.5±0.3 m.y.

Constants used:

$\lambda\beta$ = 4.962×10^{-10}/year

$(\lambda e+\lambda e')$ = 0.581×10^{-10}/year

$^{40}K/K$ = 1.193×10^{-4} g/g

Radiocarbon age determination was carried out by Geochron Laboratories, sample numbers GX-9765, 9790, 9791, 9792. The material submitted was freshwater gastropod shells which were ultrasonically cleaned and then leached with dilute HCl to remove altered surficial material. The cleaned shells were then hydrolyzed with HCl under vacuum and the carbon dioxide recovered for the analysis. The dates are C-13 corrected and are based on the Libby half life (5570 years) for C^{14}. The age is referenced to the year A.D. 1950.

Values of $\delta C\,13_{PDB}$ GX-9765 = -6.4%, GX-9790 = -4.8%

GX-9791 = -2.4%, GX-9792 = -4.0%

APPENDIX B: TOPOGRAPHIC SURVEYING

In attempting to determine heights of sediment exposures and topographic features, a major problem is that there are very few points of known height around the Chalbi basin. The two survey beacons located on the east side of the basin are Iyole (29 PT 1), which is 17 kilometres from the edge of the Chalbi playa at Maikona, and Maihadad (SKT - A), 40 kilometers from Maikona. One survey beacon (28 PT 1) is said to lie on the crest of the ridge Chari Ache, but it was not located during the course of either my work or that of Swain and Khan (1977). As a result, most parts of the Chalbi playa and the important sediment occurrences around its margins are long distances from points of known height. This is particularly true of those towards Kalacha and North Horr; Kalacha is over 40 kilometres from Maikona and North Horr is another 65 kilometres from Kalacha! These long distances raised particular difficulties since the amount of time and money available to carry out the work of height determination was limited.

Because of the long distances and the lack of time, it was impossible to use the most accurate method of height measurement, namely a surveyor's level. Even with an automatic (self-adjusting) level the work would have taken too long, especially since it would have been necessary to measure in both directions to obtain a check on the accuracy of the work. The gusty winds and strong sunshine would have added to the difficulties of using this method. Therefore, the decision was made to use altimetry (barometric levelling). The instruments used were Wallace and Tiernan altimeters, kindly loaned to me by Mr. Peter Opie-Smith of the Directorate of Overseas Surveys. These instruments, though old, functioned very well under rough conditions. Their major disadvantage was that they read in feet, so that an eventual conversion to the metric system (multiplication by a factor of 0.3048) had to be done. Four altimeters were used for the readings, working in pairs according to the leap-frog method. At the starting point of the day's work, all four altimeters were read together. The altimeters were laid on the ground and were shaded from the strong sun, using the car, an umbrella or a cotton cloth. Two altimeters were then moved by car for a distance of about 5 kilometres along the traverse line; the other two remained in position. The two moving altimeters were then placed on the ground, and, at a prearranged time, the two separate pairs were read by the researcher and her senior assistant respectively. At this time also temperature and humidity readings were taken with wet and dry bulb thermometers at each station. Then, leaving her instruments in the care of a local assistant, the researcher returned to collect the pair that had remained at the starting point. These instruments were brought up and put on the ground next to the forward pair, and readings of all four altimeters were taken at the same time. The next step was to move the 'back' pair forward by another 5 kilometres, to complete the leapfrog. This procedure continued along the roads, with the altimeters being moved at fairly regular 5 - kilometre intervals. All the stations were marked with small stone cairns, to allow their identification on the return traverse, usually a few days later. Reduction of the results was done by the researcher on the same evening, so that if any gross errors had been made the work could be re-done immediately.

The results of the work, and the reduction of heights, are presented in an unpublished report that has been deposited in the library at Kenyatta University. A summary of the results is presented below:

1. The measurements began from two points of known height;
Iyole (29 PT 1) - 1004.9 ft. (580.6 m)
Maihadad (SKT - A) - 1895.6 ft. (577.8 m)

2. The first point to be established was 221205, which lies at the road junction on the lava above Maikona Catholic Mission; 1348.9 ft. (411.1 m)

3. From here measurements were made to the sediment at Maikona which contains gastropods (211203; the upper surface of the sediment); 1229.9 ft. (374.8 m).

4. Measurements were also made down to Gamura waterhole (211201) which lies close to the margin of the Chalbi playa floor; 1202.9 ft. (366.6 m).

5. The height of the land at Maikona Catholic Church was also established, in order to provide an easily locatable point for any future survey work in the area; the steps of the church (010101); 1220.8 ft. (372.1 m).

6. A major traverse was run from Gamura water hole to Kalacha Goda (the Catholic Church), and back. Stations were mostly located on the Chalbi playa, thus

020101 - 1202.9 ft. (366.6 m) - playa near water, Gamura.

020102 - 1204.9 ft. (367.3 m) - playa.

020103 - 1204.8 ft. (367.2 m) - playa.

020104 - 1209.6 ft. (368.7 m) - playa very close to base of lava slope.

020105 - 1207.3 ft. (368.0 m) - playa.

020106 - 1207.7 ft. (368.1 m) - playa.

020107 - 1214.7 ft. (370.2 m) - playa near Kalacha Dida.

Station 020108 lies near the lower part of the terrain of low ridges and hills of white rock, at an elevation of 1222.4 ft. (372.6 m). Kalacha church (020109), on an alluvial/colluvial surface between the white terrain and the lava slope, is at 1253.7 ft. (382 m) according to this traverse across the Chalbi desert.

7. The elevation of Kalacha church was also measured direct from Iyole, down across the lava slopes. From this traverse, the height obtained for the step of the church (the same point as 020109) was 1271.0 ft. (387.4 m). The average of the two values obtained for Kalacha church was 1262.3 ft. (384.8). This is the figure that has been taken as the base for working out the heights of stations around Kalacha and on the road towards North Horr and Laga Ilama.

8. From Kalacha church, a short traverse was carried out towards the gastropod sediments to the south of the village, and this gave a height of 1250.0 ft. (381 m) for the top of the gastropod sediment at mound F. Then a long (about 65 kilometres) traverse was run to North Horr and back. This gave the following heights for the gastropod localities along the Kalacha - North Horr wet weather road:

Kalacha 090102 - 1261.8 ft. (384.6 m).

Kalacha 060106 - 1255.6 ft. (382.7 m).

Kalacha 070104 - 1340.5 ft. (408.6 m).

The edge of the lava slope lay slightly to the east of the road along which the traverse was taken. At station 060106, the gastropods were in a silt in the road surface, and the lava slope was less than 10 metres away and within about 3 metres altitude of the road. Station 070104 lies on the gently sloping surface north of North Horr and to the west of Laga Bulal.

9. The step of the church at North Horr was established at 1267.2 ft. (386 m).

10. From the church, a short traverse was run to the gastropods at Laga Ilama and back. The height of the gastropods on the west bank of the laga was 1312.8 ft. (400.2 m).

The question arises as to the accuracy of these results; can the heights be taken as correct to say, the nearest 2 metres, the nearest 5 metres, or perhaps only the nearest 20 metres? A number of factors were operating which would tend to lower the accuracy of the results. Altimetry of its very nature is not a highly accurate method of height determination; the variability of atmospheric conditions, which cannot be predicted or allowed for, is a basic source of error. A leap-frog traverse of the kind that was done should eliminate some sources of error, but some will still remain. Short-term and short-distance variations in atmospheric pressure, as are likely to occur because of topographic influences such as the alignment of the lava slope, were almost certainly operative in this work. The instruments, though of good quality and apparently in good condition, were over 30 years old; in contrast, several of the field assistants were very young and inexperienced in their work. Conditions in the field were hard; very hot, dusty and with gusty winds which caused the needles on the altimeters to swing rapidly. Since time was limited, the work had to be done at great speed, and there was little chance of closing the traverses to check the results, except by returning to the starting point.

Despite all this, the results were reasonably consistent. Where a gross error in reading one of the instruments was made, it was noticed very soon, and a repetition of the reading confirmed the correct result. The reduction of heights can also be a source of error, but this was double-checked in the field and later checked again by other people; no errors in method or in arithmetic could be found. However, errors in reading did creep in, as can be shown by looking at the results for the longest traverse made, that between Kalacha and North Horr. The traverse was composed of 13 legs, averaging 5 kilometres each, i.e. a total distance of about 65 kilometres. Four independent results were obtained, one for each pair of aneroids on both outward and return legs. The four figures obtained, converted to read from Kalacha to North Horr, were:

a rise of 12.4 ft.

a fall of 11.0 ft.

a rise of 13.6 ft.

a rise of 4.5 ft.

Thus there is a discrepancy of 24.6 feet (7.5 m) between the 'lowest' and 'highest' results. Along the course of the traverse, there was a total rise of about 103 feet, a total fall of slightly less, thus an overall difference in height of about 200 ft.; over which an error of 24.6 feet (about 12%) arose.

Between Iyole and Maihahad, there is a height difference of 9.3 feet (2.8 m) according to the Survey of Kenya height figures. According to my altimetry, the height difference was 22.4 feet (6.8 m). An error of 13 feet (4 metres) was accumulated during a traverse of over 50 km, whose total height range spanned nearly 1000 ft. (300 m).

The measurement from Iyole to Kalacha church covered a total distance of about 30 kilometres, and a height range of over 1600 ft. (490 m). The measurement to Kalacha church from Maihahad, via Maikona and Gamura, covered a distance of about 90 kilometres, and a height range of the order of 600 feet (180 m). Despite these long distances and the considerable ranges in height involved, the difference between the two heights obtained for Kalacha church was (only) 17.3 ft. (5.3 m).

From the above summary of the results, one can perhaps assume that the survey heights obtained by this altimetry may be accurate to within plus or minus 5 metres, or 7.5 metres at the outside. It would be unrealistic to claim any greater precision for them.

APPENDIX C: THE SPELLING OF PLACE NAMES

Many of the place names in Marsabit District have been spelled in a number of different ways on different maps and in different reports. Often also it seems that the written names did not seem very close to the pronunciation by the local people. After deliberating for some time over Mayidahad - Maihadad - Meidate, I was tempted to follow T.E. Lawrence; "I spell my names anyhow, to show what rot the (transliteration) systems are" (Lawrence 1955 p. 19). However in the end I adopted a more conservative course, and, purely for the sake of consistency, have used the names as they appear on the 1:250,000 maps.

TABLE 1

Gastropod site (see Figure 3)	Altitude in metres	Radiocarbon date
Maikona	375	11,080 ± 270 BP (GX-9790)
Kalacha 1	381	10,590 ± 255 BP (GX-9765)
Kalacha 2	385	-
Kalacha 3	383	-
North Horr	409	-
Laga Ilama	400	9,530 ± 220 BP (GX-9792)
Olturot	541-542.5 m	10,430 ± 250 BP (GX-9791)

Altitude of gastropod site at Olturot obtained by estimation from form lines on the 1:100,000 map, sheet 42. Altitudes of other sites obtained by barometric levelling, carried out from December 1983 - January 1984. Datum is the Survey of Kenya datum, obtained by levelling from the survey beacons at Iyole (29 PT 1) and Maihadad (SKT - A). Expected error by this method under the conditions that prevailed: ± 7.5 metres.

TABLE 2

Mollusc species	0-22183-6	0-22183-7	0-26183-1	0-J-7	0-J-8	L-29183-2	M-31183-4	K-00782-2	K-06882-5	K-04882-2	K-22782-6	C-10883-6	C-15883-1
Melanoides tuberculata	c	c	c	3	c	c	c	c	c	c	c		
Biomphalaria	p	p			p	p	p	p	p	p	p		
Lymnaea	3	p			p		3				1		
Opeas suavissima		p											
Opeas marsabitensis		p											
Achatina			1										
Gyraulus					p								
Segmentina or Segmentorbis					p		1	1					
Succinea					p								
Zonitidae					?								
Cleopatra (approx. athiensis)						1							
Anisus								?					
Zootecus insularis												p	p
Bloyetia													p
Bellamya unicolor													c

Samples Olturot J-7 and J-8 identified by the Department of Macro-palaeontology, Netherlands Government Geological Service.

All other samples identified by Martin Pickford, National Museums of Kenya.

0 - Olturot
K - Kalacha
L - Laga Ilama
C - Chari Ache
M - Maikona
c - common
p - present
1,3 - numbers of specimens identified
? - identification uncertain

TABLE 3

Faunal List: Marsabit Road/Algas

	1940s	1983
Lates niloticus	c	c
Clariidae	c	c
Trionyx	p	p
Pelusios	p	p
Crocodylus niloticus	c	c
Euthecodon		p
Cercopithecinae		p
Elephas recki	p	p
Deinotherium boazsi	p	p
Rhinocerotidae	p	
Equus oldowayensis	c	c
Mesochoerus limnetes	p	
Metridiochoerus andrewsi (II)	p	p
Hippopotamus of imaguncula	c	c
Camelus	p	
Sivatherium maurusium	c	
Tragelaphini	p	
Alcelaphini	p	p
Menelikia lyrocera	c	p

c-common p-present

Faunal List:Olturot

Equus grevyi	common
Diceros bicornis	1 specimen
Gazella granti	3 or 4 specimens
Gonnochaetes taurinus	3 or 4 specimens
Bovidae spp	moderately common
Giraffa sp	1 specimen or more
Phacochoerus aethiopicus	4 specimens

(all identifications by Martin Pickford)

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LIST OF FIGURES

Fig. 1: The location of the Chalbi playa in Kenya

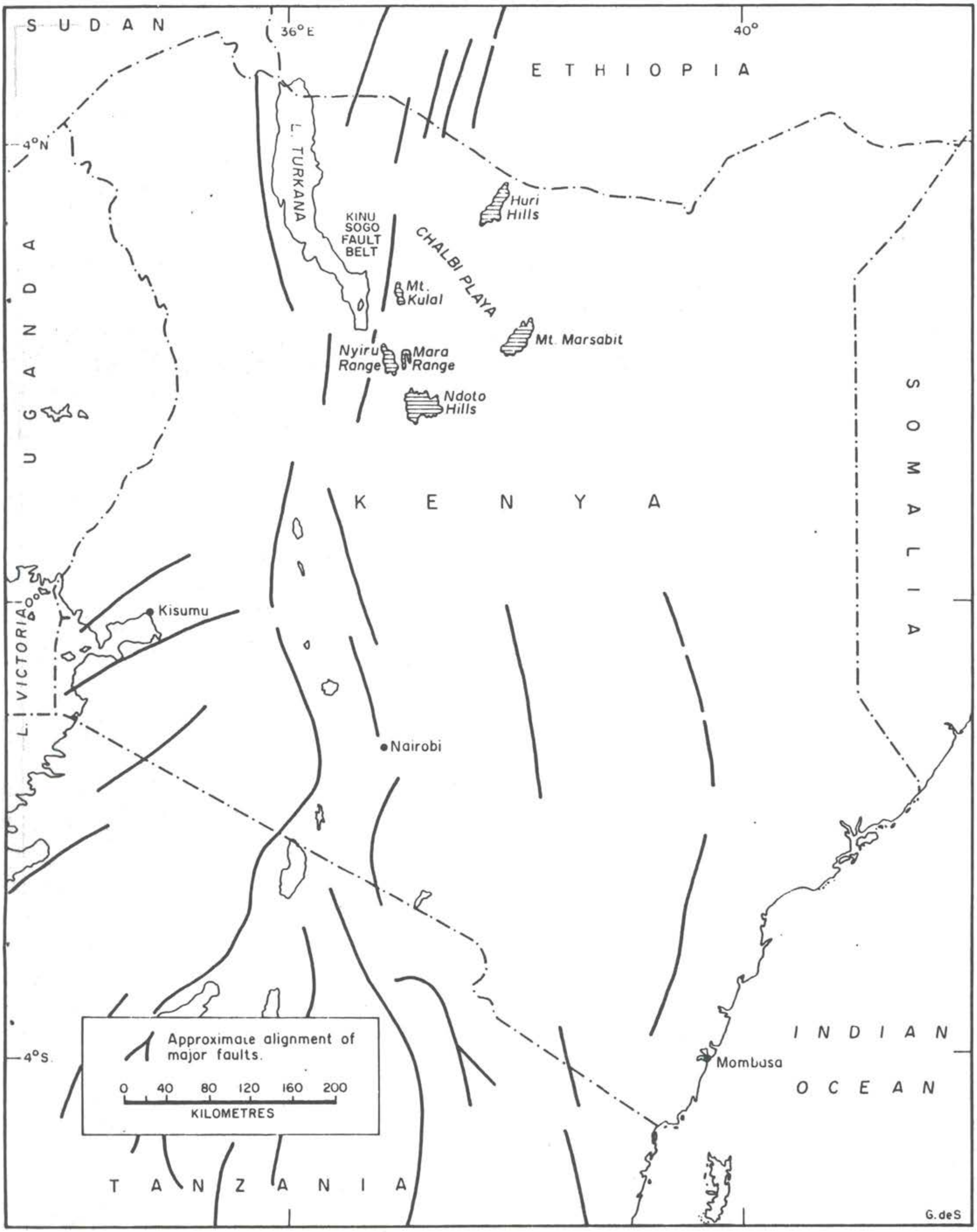


Fig. 2: The Chalbi playa and its surroundings

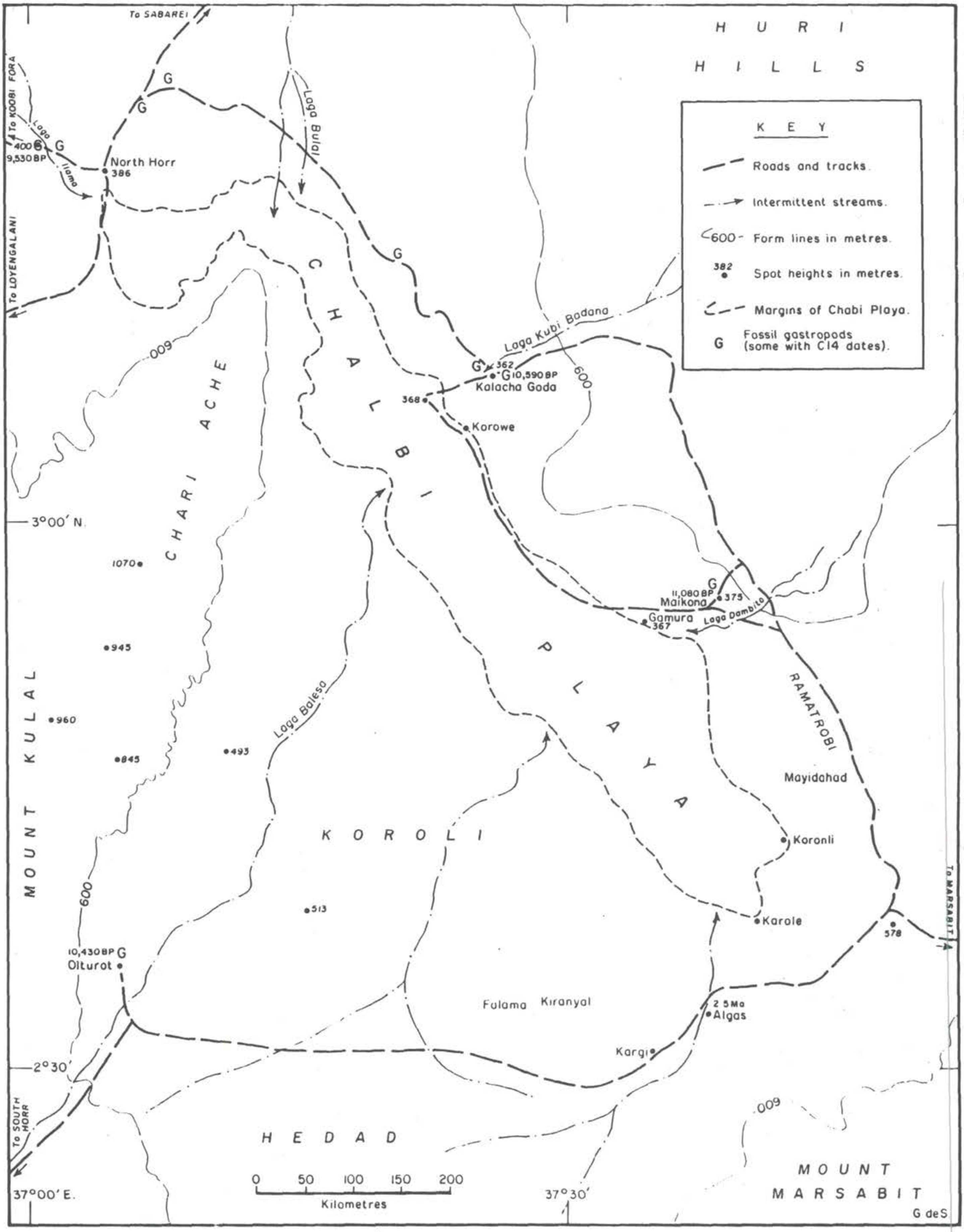


Fig. 3: Geomorphology of the Chalbi playa and surrounding area

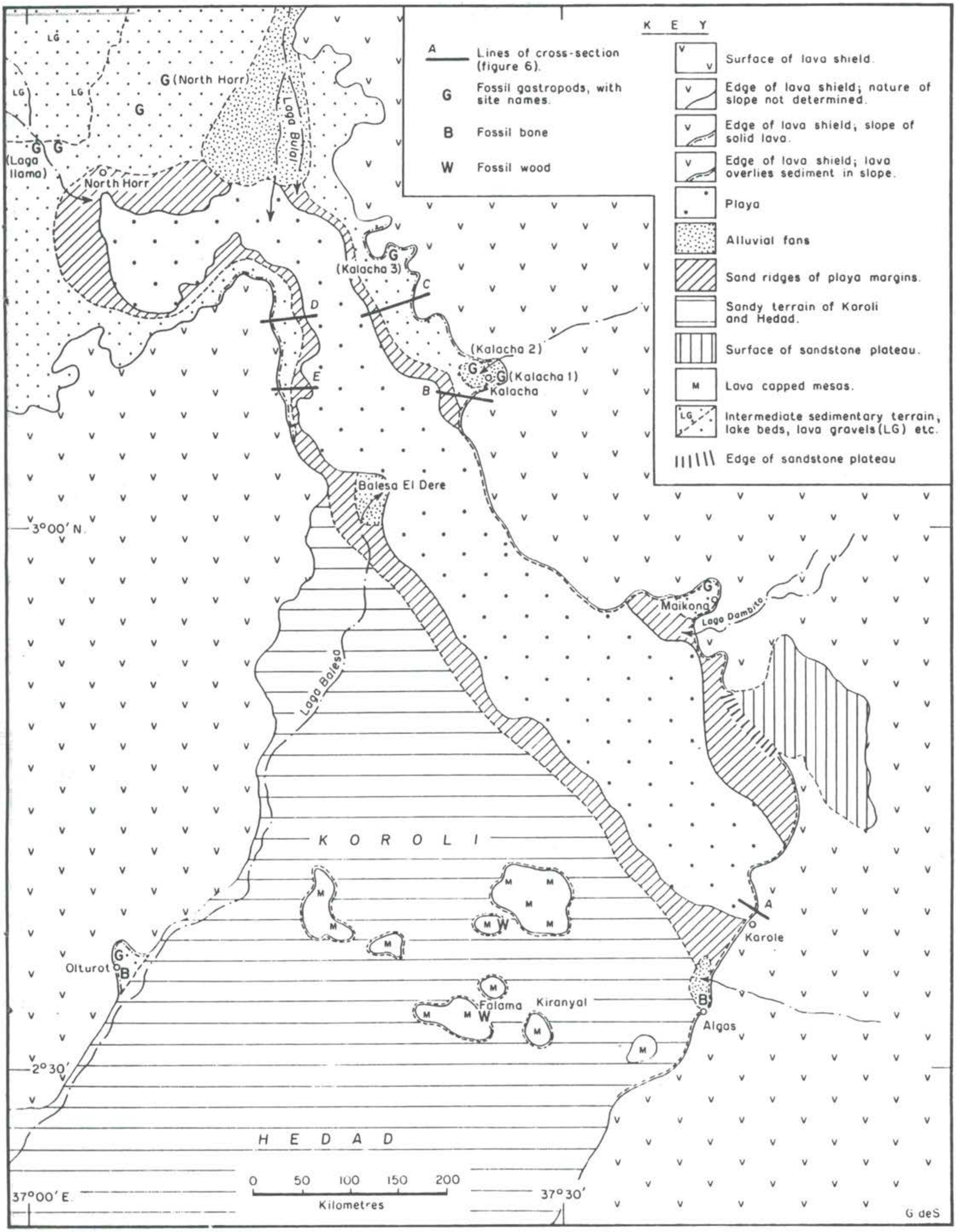


Fig. 4: Cross-sections of rocks in the walls of Laga Dambito

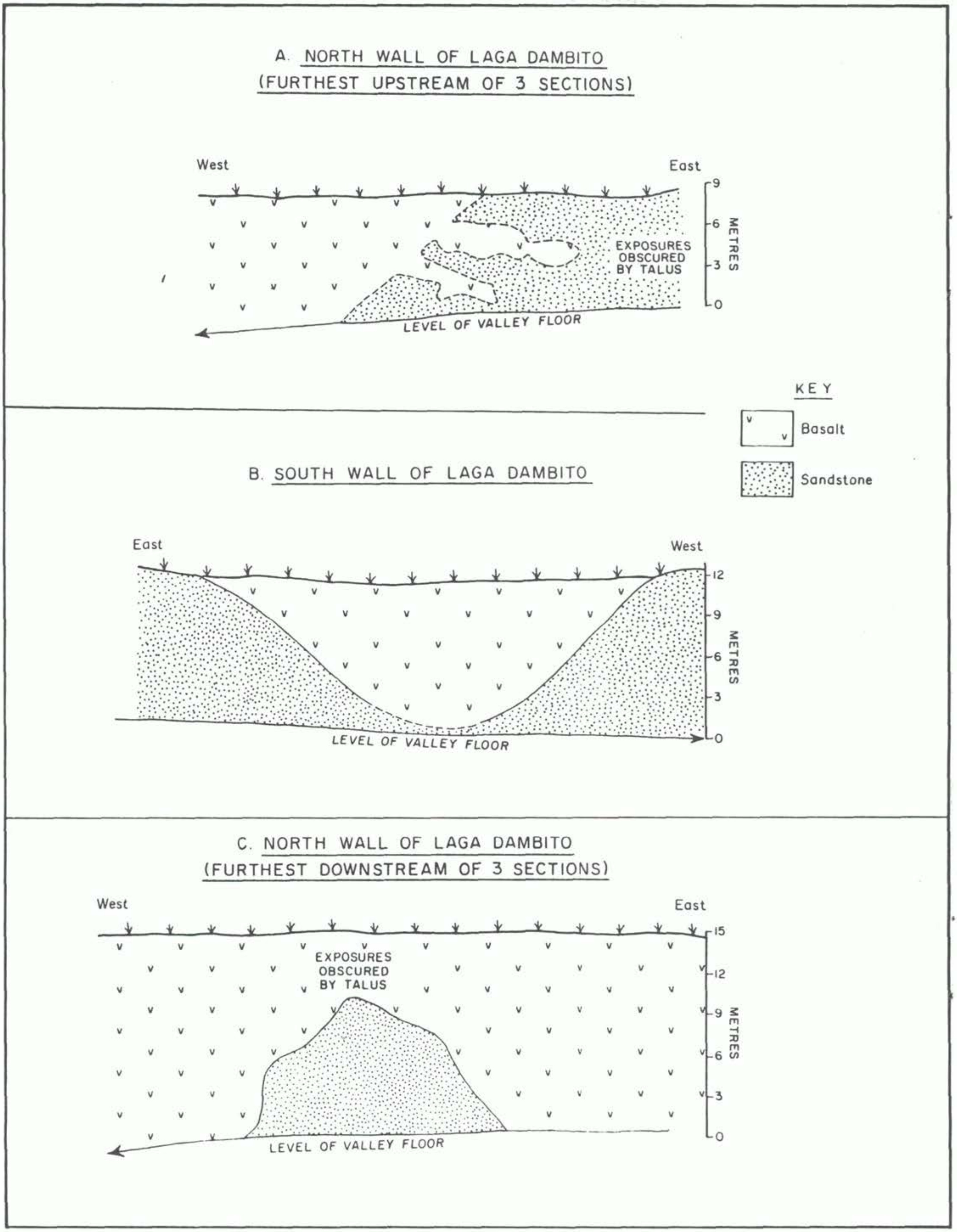


Fig. 5: Cross-sections of lava slopes on the margins of the Chalbi basin

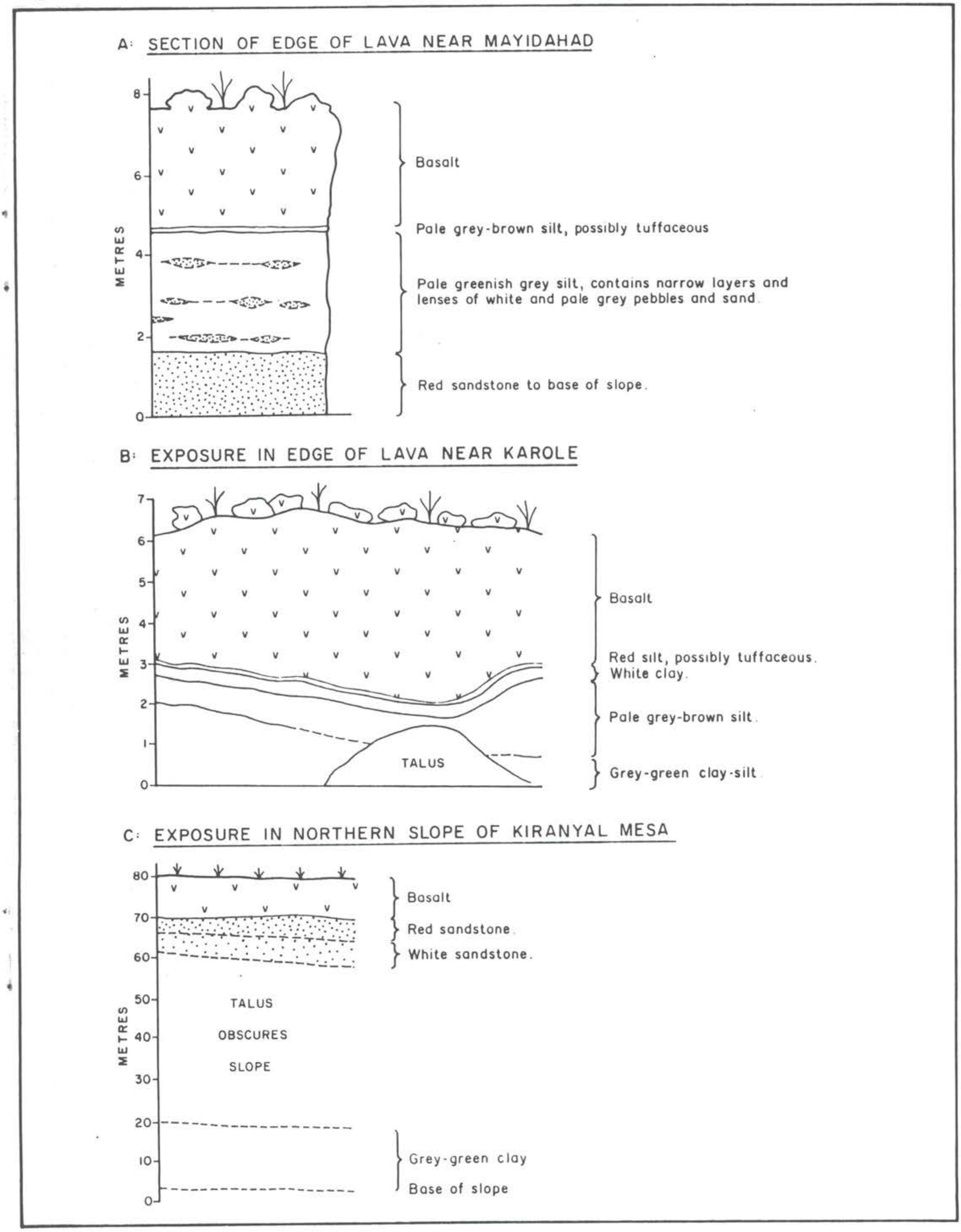


Fig. 6: Cross-sections of Chalbi playa margin

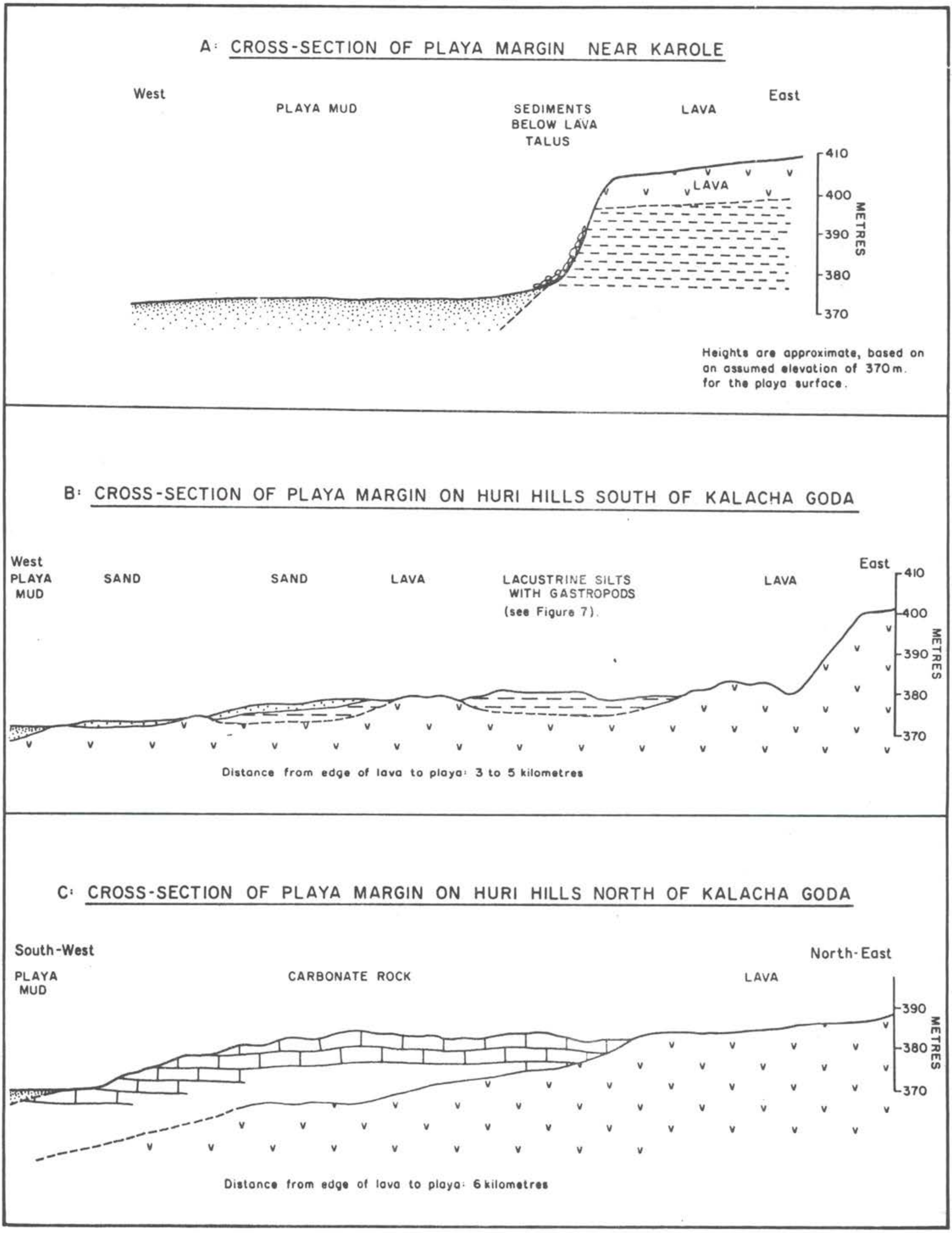
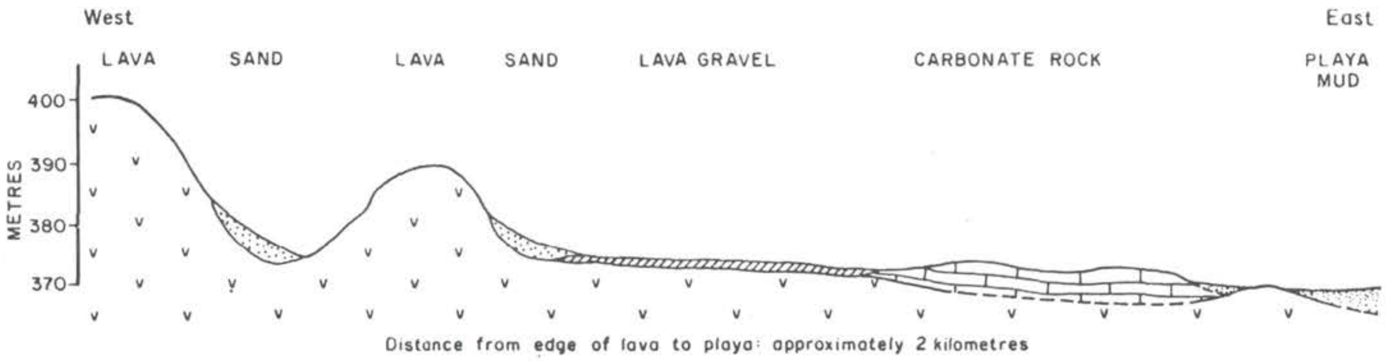


Fig. 6 continued

D. CROSS-SECTION OF PLAYA MARGIN AT NORTHERN END OF CHARI ACHE



E. CROSS-SECTION OF PLAYA MARGIN ON CENTRAL PART OF CHARI ACHE

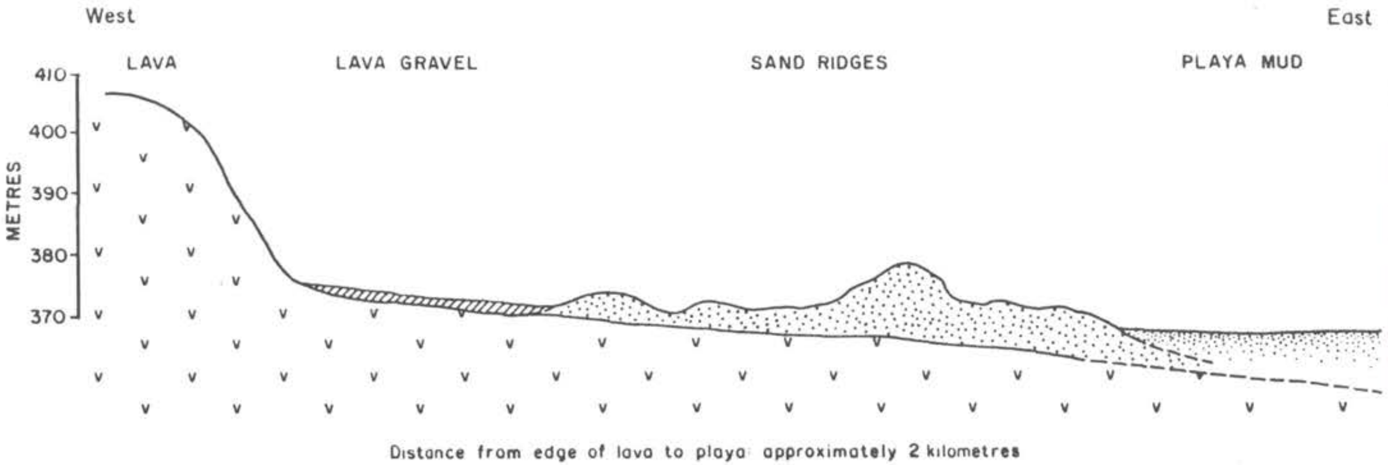
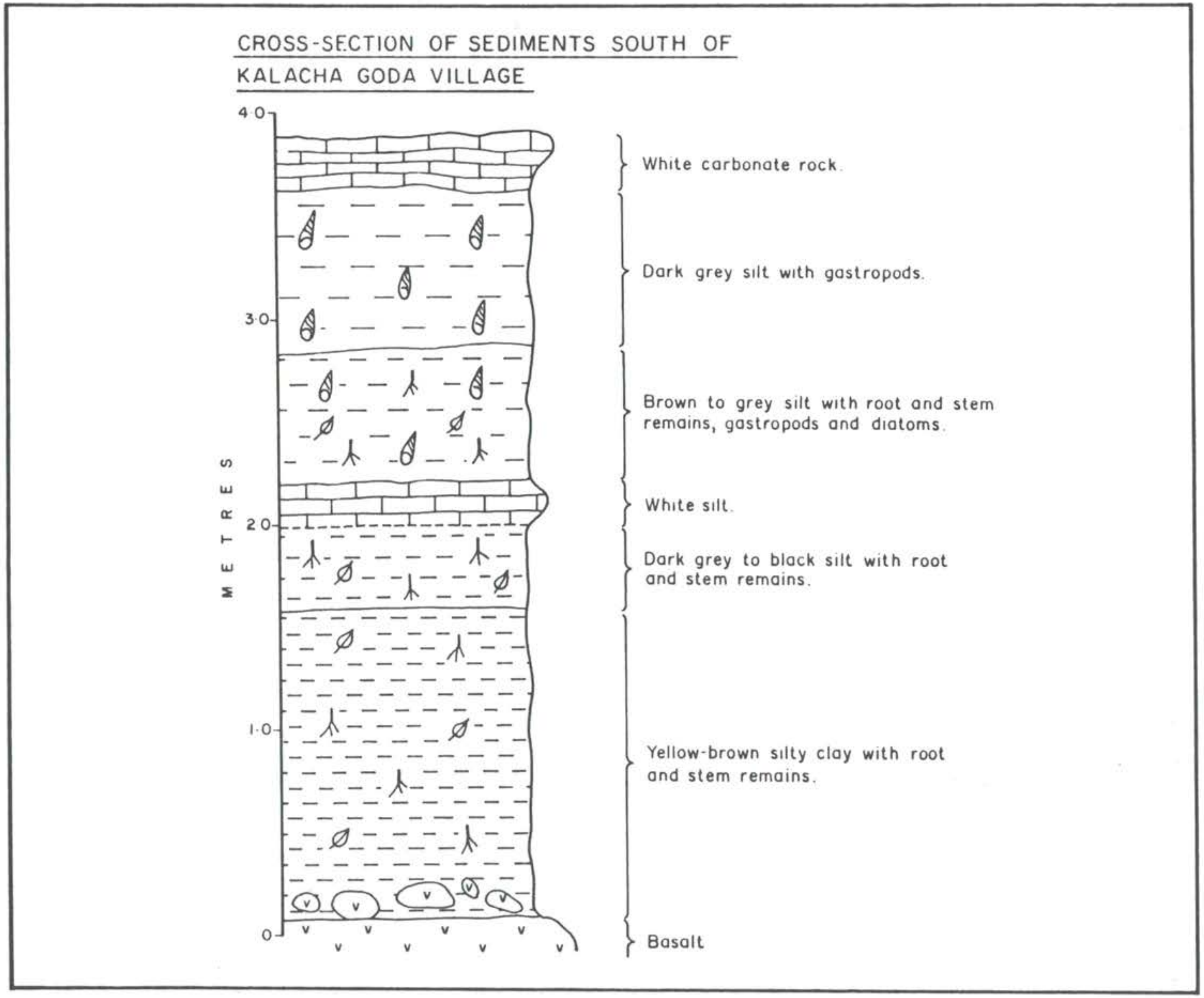


Fig. 7: Cross-section of sediments south of Kalacha Goda village



LIST OF PLATES

1. Floor of the Chalbi Playa, about 10 km south of North Horr. Water in wheel marks resulted from one night's rain in August 1983. Surface is of brown mud with polygonal cracks.

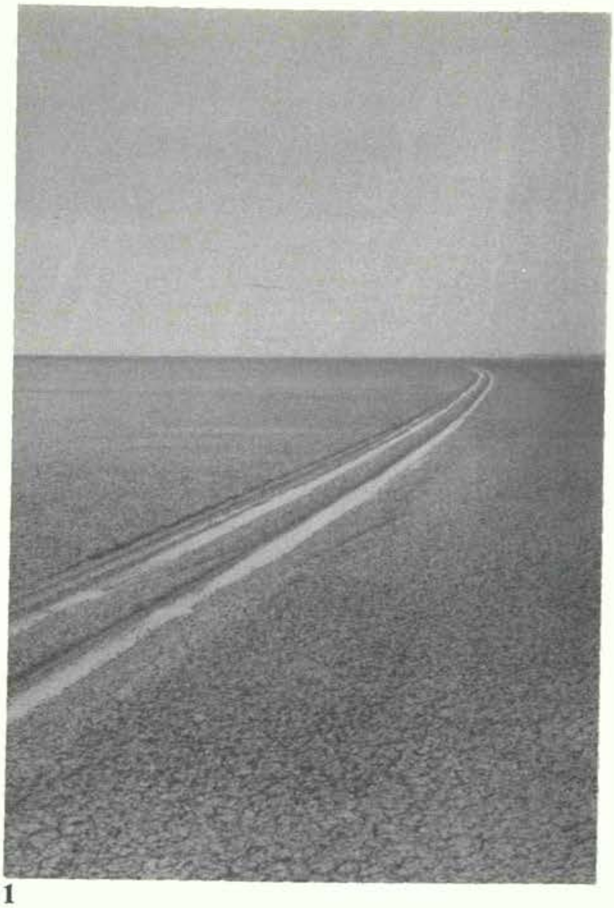
2. Erosional remnant of fine-grained, horizontally-bedded sediments at Olturot. Fresh-water gastropods found at a level just below the children's feet.

3. Barchan dune north of North Horr. Wind direction is from right to left.

4. Fossil gastropods (Melanoides tuberculata) from near Kalacha Goda.

5. Fossil bone from Algas. Included are the vertebrae of Nile perch (upper left), tortoise scutes (lower left), crocodile teeth (upper right) and fish bones (lower right).

6. Fossil wood from Falama.



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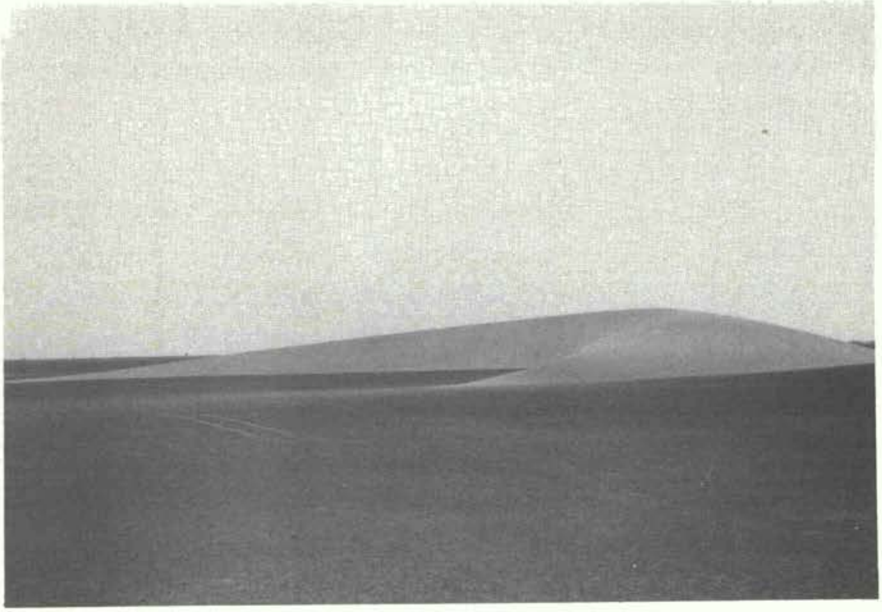
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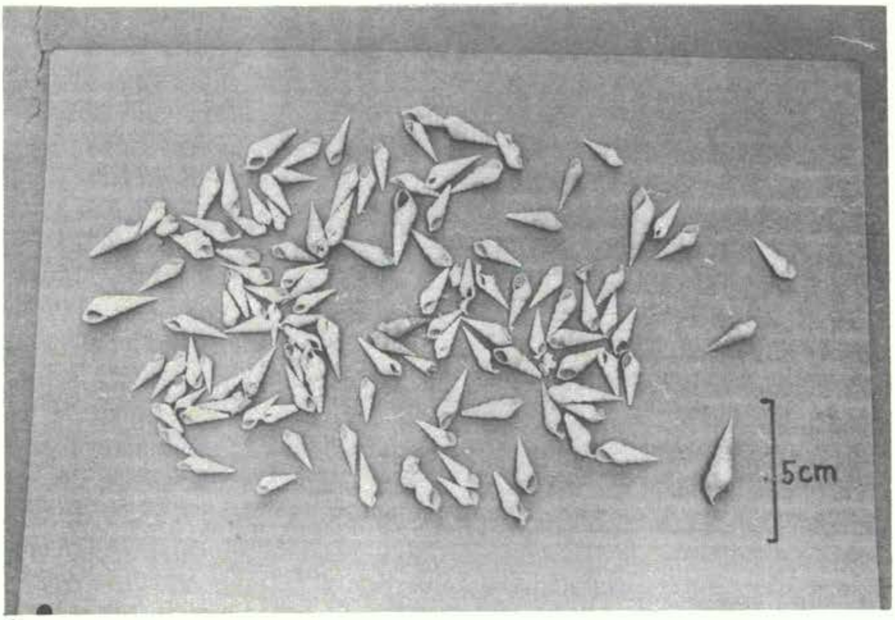

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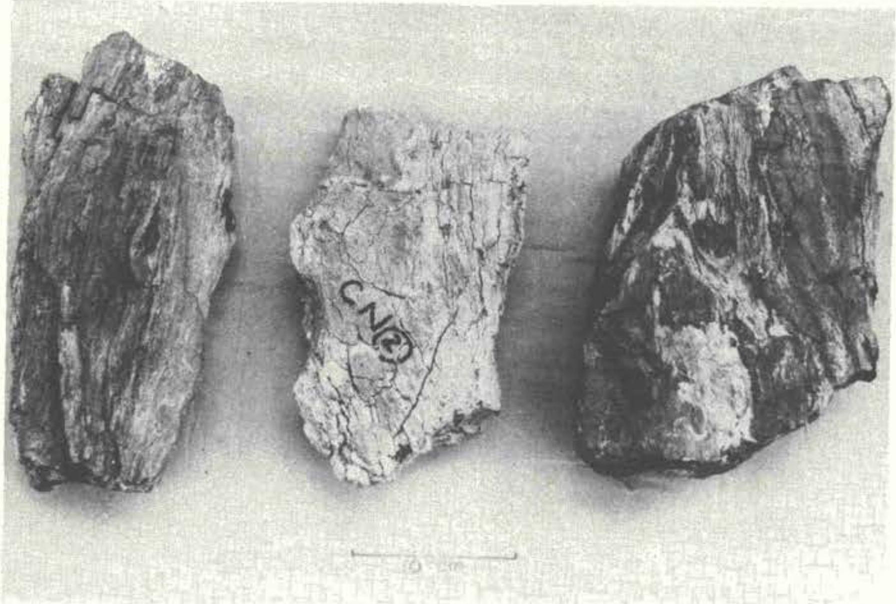

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