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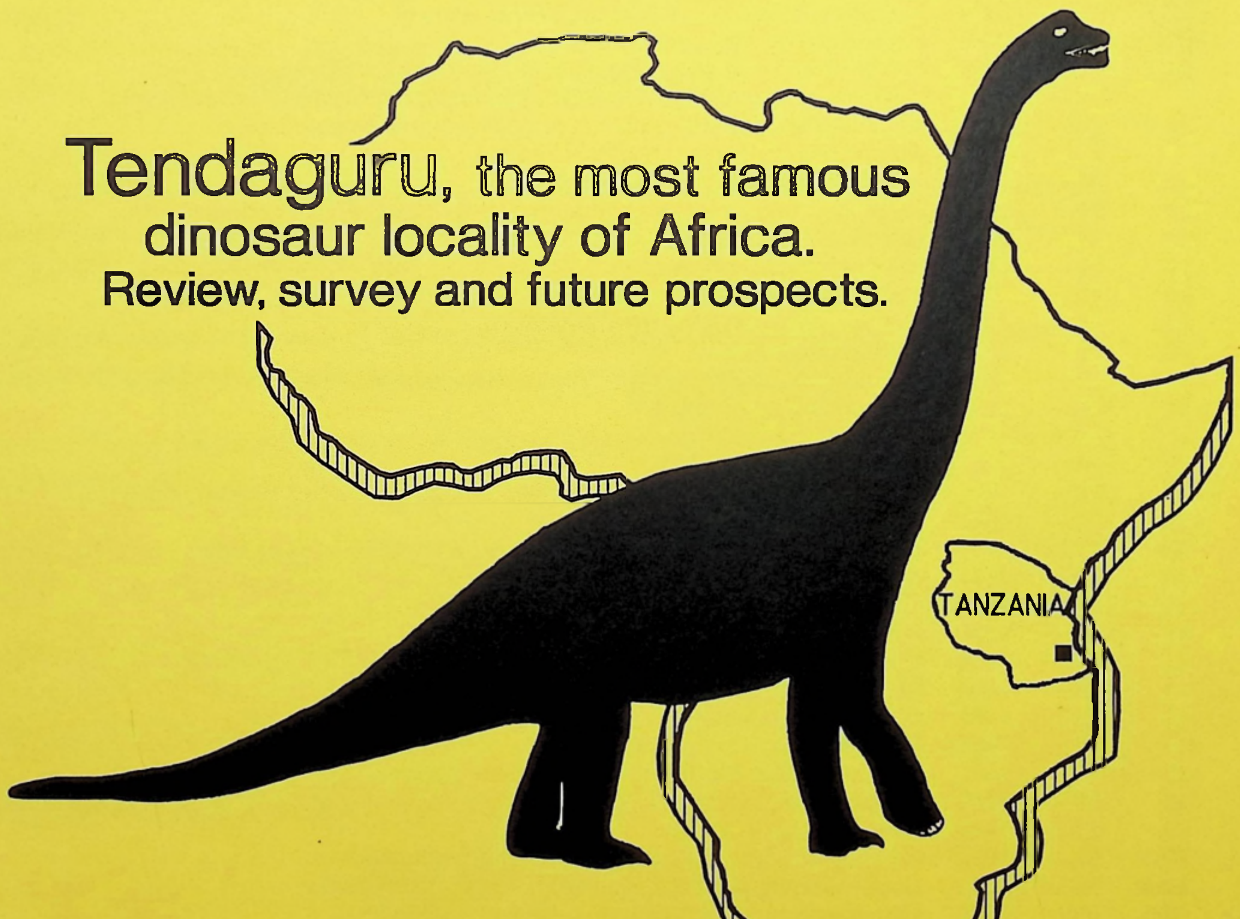

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Tendaguru, the most famous dinosaur locality of Africa. Review, Survey and Future Prospects

by

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Key words: Tanzania, Vertebrates, Dinosaurs, Jurassic

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Abstract: The most famous dinosaurs of Africa were recovered from Late Jurassic sediments of Tendaguru Hill in southern Tanzania. In a historical review, the discovery of the locality and the execution of the important excavations of the Berlin Naturkundemuseum from 1909-1913 as well as the succeeding activities of the British Museum are briefly presented. The most significant geoscientific results, including more recent ones, are discussed. Own experiences and information on the current situation obtained during two field trips in 1994 to Tendaguru are presented as well as some scientific objectives for a possible future Tendaguru project are outlined.

Dibaji: Masalia ya mifupa ya jamii ya mijusi wakubwa sana, „dinosaurs", ambao waliishi na kupotea dunaini mamia ya mamilioni ya miaka iliyopita, yalipatikana Afrika katika eneo la Tendaguru, Mkoani Lindi, kusini mwa Tanzania. Masalia hayo yalipatikana katika matabaka ya ardhi, kulingana na utaalamu wa kupima umri kwa kutumia elimu ya Jiolojia, yenye umri wa „Late Jurassic". Lengo la mswada huu ni kutoa maelezo kwa ufupi, yanayohusu historia ya utafiti katika maeneo ya Tendaguru, utafiti ambao ulihusisha ubukuzi katika maeneo hayo chini ya uongozi wa wataalamu kutoka Makumbusho ya Elimu Viumbe, Berlin, „Berlin Naturkundemuseum", Ujerumani kuanzia mwaka 1909 hadi mwaka 1913. Utafiti mwingine ulifanyika katika maeneo hayo chini ya wataalamu kutoka Makumbusho ya Uingereza (British Museum East Afrca Expedition), katika miaka ya 1920. Pia tunatoa maelezo ya utafiti huo uliopita pamoja na matokeo na matarajio ya baadaye ya utafiti ulioanzishwa mwaka 1994 katika maeneo hayo hayo ya Tendaguru.

Zusammenfassung: Die berühmtesten Dinosaurier Afrikas stammen aus oberjurassischen Ablagerungen am Tendaguru Hügel in Südtansania. In einem historischen Rückblick werden die Entdeckung dieser Lokalität, die Durchführung der legendären Grabung des Berliner Naturkundemuseums von 1909-1913 sowie die späteren Tätigkeiten des British Museum zusammenfassend dargestellt. Die wichtigsten wissenschaftlichen Ergebnisse werden unter Einbeziehung jüngster Erkenntnisse referiert. Neue, während zweier Geländereisen im Jahre 1994 gesammelte Erfahrungen und aktuelle Informationen zur heutigen Situation vor Ort werden erörtert und moderne Inhalte eines möglichen zukünftigen Tendaguru-Projektes umrissen.

CONTENTS

1. Introduction

Tendaguru, a hill of 310 m in height is situated about 60 km off the Indian Ocean in southern Tanzania and is synonymous of the most important dinosaur-bearing locality in Africa (text-fig. 1). At the beginning of this century, this locality was discovered by the mining engineer B. Sattler and exploited at a large-scale level during the quite legendary excavations carried out from 1909 to 1913 by the Berlin Naturkundemuseum. The so-called Tendaguru Expedition has yielded the most famous dinosaurs of Africa.

After World War I, the British Museum of Natural History carried out the British Museum East Africa Expedition producing additional dinosaur material. Although there was always high international interest in Tendaguru, political and administrative problems hindered new scientific activities. After Independence, the Tanzanian political authorities strictly rejected temporarily even applications for research permits to southern Tanzania, for example in the case of Louis Jacobs (Jacobs 1993). However, Urs Oberli (1982) from Switzerland in the 1970s, Dale Russell and Pierre Béland (Canadian National Museum of Natural Sciences) in 1977 and 1978 and Gundolf Ernst (Freie Universität Berlin) in 1985 were able to visit the locality briefly. Apart from these exceptions the unique locality of Tendaguru Hill (Pl. 1, figs. 4, 5, 7, 8) was therefore considered to be almost "inaccessible", due to the remoteness of southern Tanzania, contamination with tsetse flies and the poor traffic conditions. After the end of civil war and continuous easing of political tension in Mozambique as well as the intensified political and economical relations between Tanzania and the Western World research clearances for southern Tanzania can be obtained, so that a rise of scientific activities is to be expected in future time.

Based on two visits to the site in 1994, we summarise recent information in respect of new palaeontological projects concerning administrative and logistical conditions, possible routes to be taken and aspects of the actual research conditions in the Tendaguru area. In a historical review, the British East Africa Expedition as well as the famous Tendaguru Expedition at the beginning of this century is recapitulated, regarding discovery and excavations as well as conditions and further details of every day life in the field. The most important results of that period are outlined sometimes modified due to new results.

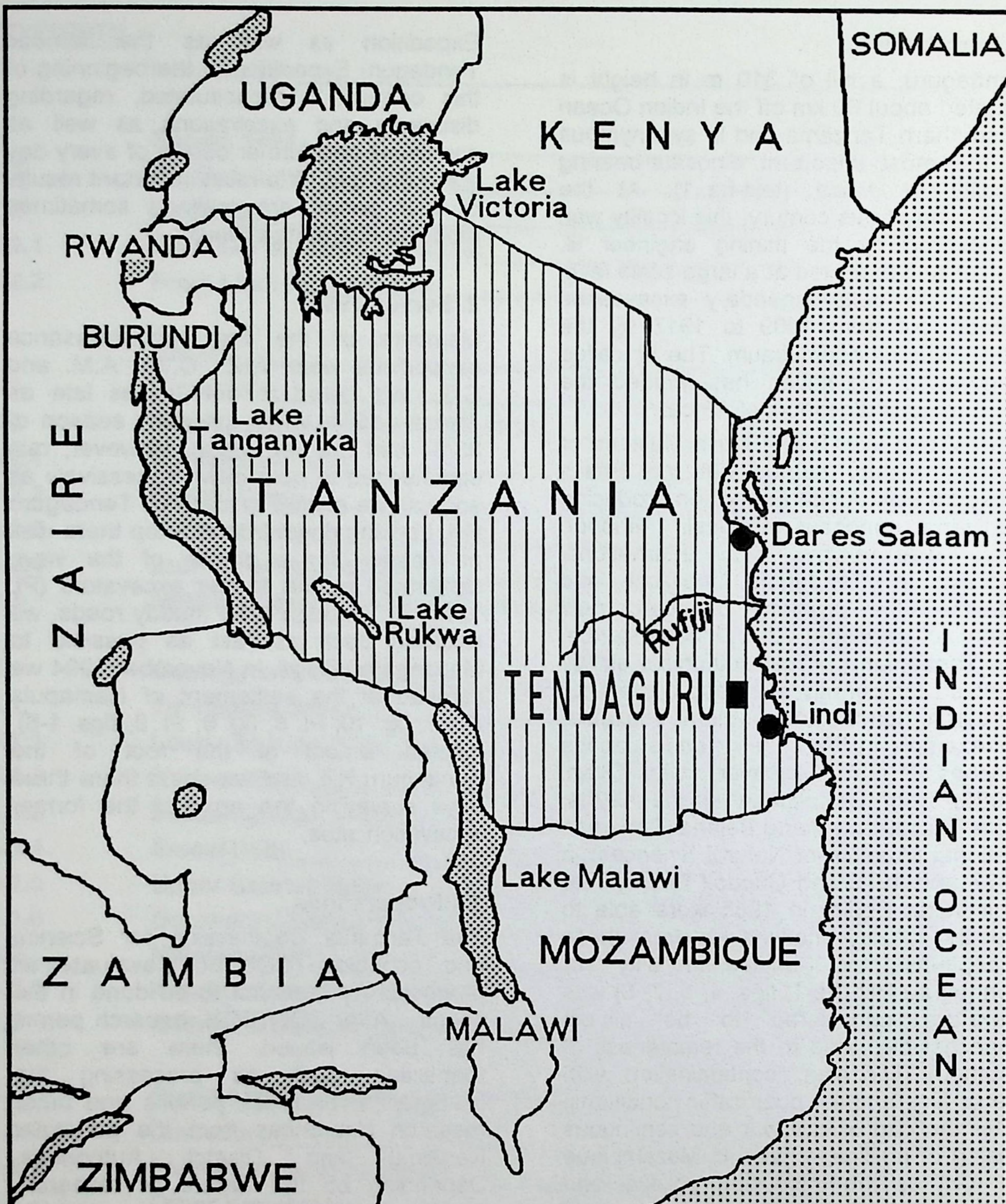
2. Survey 1994

Members of the first reconnaissance expeditions were W.Z., C.W., A.M. and C.S.. We dared to set out as late as January 1994, when the rainy season of 93/94 had not yet begun. However, rain commenced to pour down excessively as soon as we started to climb up Tendaguru Hill. Looking down from the top there was no chance for a glance of the view, celebrated by the former excavators (Pl. 1, fig. 7). Through fairly muddy roads, we returned back as fast as possible to Mnyangara Village. In November 1994 we camped at the settlement of Namapuia (Pl. 1, fig. 10; Pl. 8, fig. 6; Pl. 9, figs. 1-6), located almost at the foot of the Tendaguru Hill, and we spent there three days surveying the area of the former excavation sites.

2.1 Preparations

The Tanzania Commission for Science and Technology (COSTECH) evaluates all proposals for research to be done in the country. After COSTECH research permit has been issued, there are other formalities, such as processing the immigration residence permits and other research clearances from the particular Regional and District Authorities. Depending on the nature of research, additional permits from specific institutions, e.g. the National Park Authorities, are required.

Any expedition should be accomplished in the dry season: Firstly, for several weeks the ferry boat across the Rufiji River does not operate during the rainy season, a fact that complicates the overland route considerably. The road condition in the rainy season becomes very bad to traverse through.



Text-fig. 1: Map of East Africa with the geographical position of Tendaguru Hill

Secondly, field work in southern Tanzania is after the heavy rains practically impossible due to quick vegetation overgrowth on the outcrops. The best period is therefore from July to November.

Although there are regular connections by plane and bus to Lindi and Mtwara, 4 Wheel Drive cars are by far the most promising means to reach Tendaguru Hill. There are car hire services in Mtwara, but it is easier to take the vehicle along from Dar es Salaam.

As a rule, all expedition gear including canned food and bottled drinking water should be acquired in Dar es Salaam. In addition the local Lindi market offers some staple food, vegetables and fruits.

Topographic maps in a scale 1 : 50 000 issued in the sixties by the "Survey Division, Ministry of Land, Settlement and Water" and mostly based on aerial photographs, cover all of Tanzania (see text-fig. 6). These are most helpful to secure topographical orientation. Nevertheless, the position of very small settlements will sometimes remain uncertain due to migrations that have taken place in the meantime.

2.2 Itinerary

2.2.1 From Dar es Salaam to Lindi

Apart from the flight connections to Mtwara or directly to Lindi, there are three ways to go from Dar es Salaam to Lindi. Overland, the preferable route is the one along the coast. When the ferry boat across the Rufiji River is not operating, a choice remains either between the route through the interior via Makambako and Songea, or the steamer along the coast.

By Sea

There are steamer services at least once a week from Dar es Salaam to Mtwara near the Mozambican border and back, transporting passengers and cargo. The voyage takes about 20 hours including a short stopover near Mafia Island, where passengers embark on small boats bound for Mafia Harbour. Tickets are bought in Dar es Salaam or Mtwara, time tables can change unpredictably. The tarmac road from Mtwara to Lindi is in an excellent condition throughout long distance, taking less than two hours by car.

Overland through the Interior

The route through the interior adds up to about 1600 km, about 1000 km more than the route along the coast. Only in case the ferry across Rufiji River is not operating this route should be chosen. The main road from Dar es Salaam to Songea via Morogoro, Iringa and Makambako - about 1000 km - is reasonable. But due to most difficult road conditions it takes eight to ten hours from Songea to Tunduru. The next 200 km up to Masasi need slow and careful driving - but one is rewarded by stunning views of the beautiful landscape along Ruvuma River marking the borderline between Tanzania and Mozambique. The last 150 km up to Lindi are well maintained and in a good condition.

Overland along the Coast

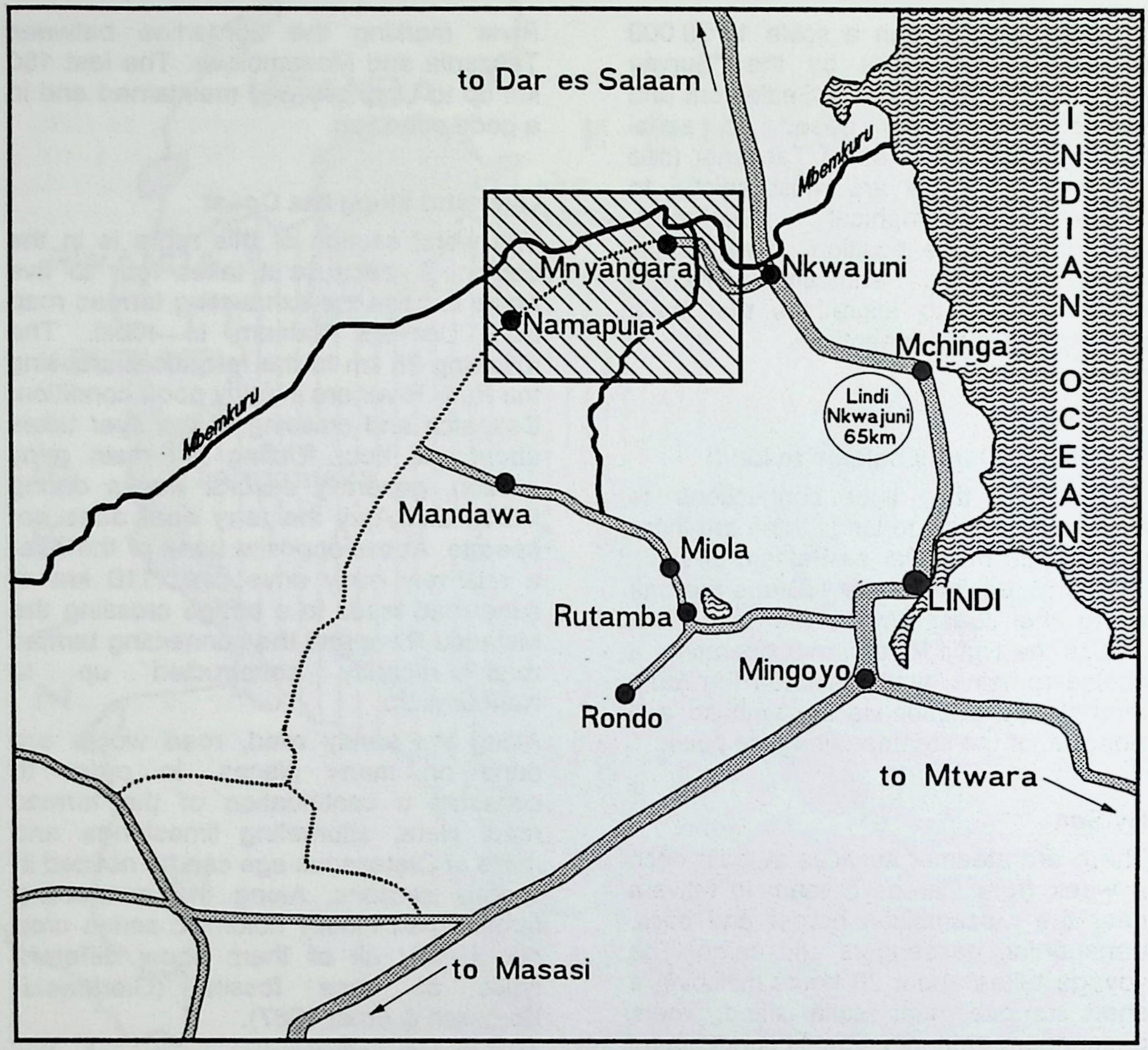
The worst section of this route is in the beginning, because it takes four to five hours to pass the exhausting tarmac road from Dar es Salaam to Kibiti. The following 28 km to the ferry boat crossing the Rufiji River are in fairly good condition. Despatch and crossing of the river takes about one hour. During the main rainy season, generally several weeks during March and April the ferry boat does not operate. At the opposite bank of the river a relatively easy drive over 110 km of sand road leads to a bridge crossing the Matandu River and the connecting tarmac road, recently constructed up to Nangurukuru.

Along the sandy road, road works are done on many places, in order to construct a continuation of the tarmac road. Here, alternating limestones and marls of Cretaceous age can be noticed in various sections. Along the connecting tarmac road mostly dolomitic series crop out. Nearly all of them show different types of trace fossils (Gierlowski-Kordesch & Ernst 1987).

About two kilometres north of the roundabout of Nangurukuru we found an *Inoceramus* about the size of the palm of a hand. Finds of this genus are not yet published from the Tanzanian coastal plateaux.

The way from Rufiji River up to the junction to Kilwa takes about three and a half hours. A stopover in Kilwa Masako is recommended to spend the night at one of the good private guest houses. If there is any time to spare, you should visit the ruins of Kilwa Kiwinje as well as the mangrove swamp.

Back at the roundabout of Nangurukuru, there are 50 km more to go - all along passing middle Cretaceous sediments. From Kiwawa onwards, you can follow the geological details using the map made by Aitken (1961), south of Mbemkuru[1)] River using the geological map drawn by Hennig (1933-1939, text-fig. 3).



Text-fig. 2: Road map of Lindi and surroundings.

Overlooking Mandawa Plain where the marine equivalents of the Tendaguru Series are exposed, there is a clear view of the Makonde Sandstones of the Ngarama Plateau (text-fig. 9). 25 km south of Kiwawa, the road crosses Mandawa River and after another 14 km a wooden bridge crosses Kiswere River. From here at a distance of about ten km to the west, the northern limit of the excavation done during the German expedition 1909-1913 is located. After 12 km along the Lindi road, you enter the depression of Mbemkuru River (Pl. 6 , fig. 3). In the south the Mikadi Hill is visible with its peak of Urgonian limestones (text-figs. 3, 5). Now there are only 7 km left to Nkwajuni Village with the junction to Tendaguru Hill (text-fig. 2; Pl. 1, fig. 1). However, the Regional Authorities in Lindi have first to confirm and then to issue an other research clearance before carrying on to Tendaguru.

From Nkwajuni to Lindi, the road runs parallel to the edge of the Likonde Kitutu Plateau (text-figs. 3, 5), where a north-east directed flexure sets Lower Cretaceous and Tertiary sediments against each other alternatively. After 15 km, the road turns left to the coast. There are only 14 km left to reach the coast at the town of Mchinga (text-figs. 2, 3). Salt pans are abundant throughout the coastal area, sometimes used by youngsters as soccer grounds. Having past the Lindi airstrip some old sisal plantations at Kitulo Height offer a spectacular view over the

Lindi Bay and the slopes of Kitanda Plateau rising at the other side of the bay. The Kitanda Plateau is formed of Oligocene sediments (Pl. 6, figs. 1,2).

Lindi

The Lindi Regional Administration Block is easy to spot, just a little below the peak of the Kitulu Hill (246 m) which is made of Late Paleocene to Eocene limestones.

The modern port of Lindi consists of only one single jetty located exactly at the same place where once the dhaus were used to be loaded with the huge Tendaguru bones to carry them across the shallow bay into deeper waters to the anchoring steamer vessels bound to bring these fossils to Dar es Salaam (Pl. 15, fig. 8). Today, there are dhaus and small engine ferry boats, that transport passengers and some goods for the Lindi market from the other side of the bay (Pl. 6, fig. 2). When the port of Mtwara with its advantage of deeper waters had been established, Lindi Port lost its previous fame.

2.2.2 From Lindi to Tendaguru

From Lindi to Tendaguru today we know two feasible routes: the southern route - taken by Gundolf Ernst in 1985 - via Rutambe, which includes a couple of hours to walk, and the northern route where you can nearly reach the foot of Tendaguru Hill by a 4WD car (text-fig. 2).

Northern Route

Only a half day's time is needed from Lindi to Tendaguru. The first 70 km back along the Dar es Salaam road to Nkwajuni Village can be done in about two hours drive. Near a junction at the left hand side of the road (Pl. 1, fig. 1, text-fig. 4), there is a small but important sign that reads in white letters on a black ground: BARABARA YA TARAFANI MIPINGO POLEPOLE DARAJA (Road in the Mipingo Division, Drive slowly, Bridge). From here you should carry on only in a 4WD car.

This track follows the northern edge of the Mikadi Hill parallel to the outcropping *Smeei* Beds, parallel to the Mbemkuru River. Immediately before entering the depression of Mbemkuru at the western slope of Mikadi Hill, you cross Marihi River, a tributary of Mbemkuru River, passing the outcropping oolithic limestone in a nearly horizontal position (text-fig. 9). These limestones may represent the marine equivalent of the Upper Saurian Beds or "Hangend Oolith" of the *Smeei* Beds. They are much better exposed at the northern slope of the Mbambalala Plateau after about 7 km, behind the Nkwajuni junction at the opposite side of the depression of the Mbemkuru River (text-fig. 9). After three km, the track forms a bifurcation (Pl. 1, fig. 2): The road on the left hand carries on to Mtapwa via Mipingo, the other one to the right leads to Tendaguru (text-fig. 4) - passing through the Ukulinga Plateau that consists of the marine equivalent of the Upper Saurian Beds (Hennig 1914a, Aitken 1961). About 500 m behind this junction, oolithic limestones of these series are exposed (Pl. 6, Fig. 4). After a few kilometres more, there is a steep slope down to the depression of Mbemkuru River and its tributary, Mtshinyiri, following the fault named after it. At the slope, hard conglomerates and cross-bedded calcareous sandstones are exposed. This section ranges from the ooliths of the *Smeei* Beds to the Middle Saurian Beds (Hennig 1914a).

After another 5 km, there is Mnyangara Village (text-fig. 4). Mnyangara is the local village administrative centre up to the Namapuia area, where Tendaguru Hill is located. At the Mnyangara Village Head's office, vehicles and visitors are registered. Having left Mnyangara, the track is reduced to mere foot paths (Pl. 1, fig. 3). Only in the dry season this track can be followed by a 4WD car. Few kilometres behind Mnyangara, there is a bifurcation. It is easier to take the right hand path, but after a couple of kilometres both tracks join together again. Now the Mbemkuru Depression is left while passing the foot of Lipogiro Plateau, where the Tertiary Lipogiro Pebbles or Mikindani Beds (Bornhardt 1900) are made of components as huge as a human fist. The pebbles consist mainly of angular quartzes and sometimes of reworked quartzites and ooliths or bones.

In the depression itself there are no outcrops. However, footprints of elephants and hippopotamus from the preceding rainy season occur in abundance. These footprints probably continue a few kilometres to the north into the Nyangi Swamp. At a distance of three to four hours walk from Tendaguru, this swamp was the favourite hunting ground of the Tendaguru Expedition 1909-1913 (Hennig 1912).

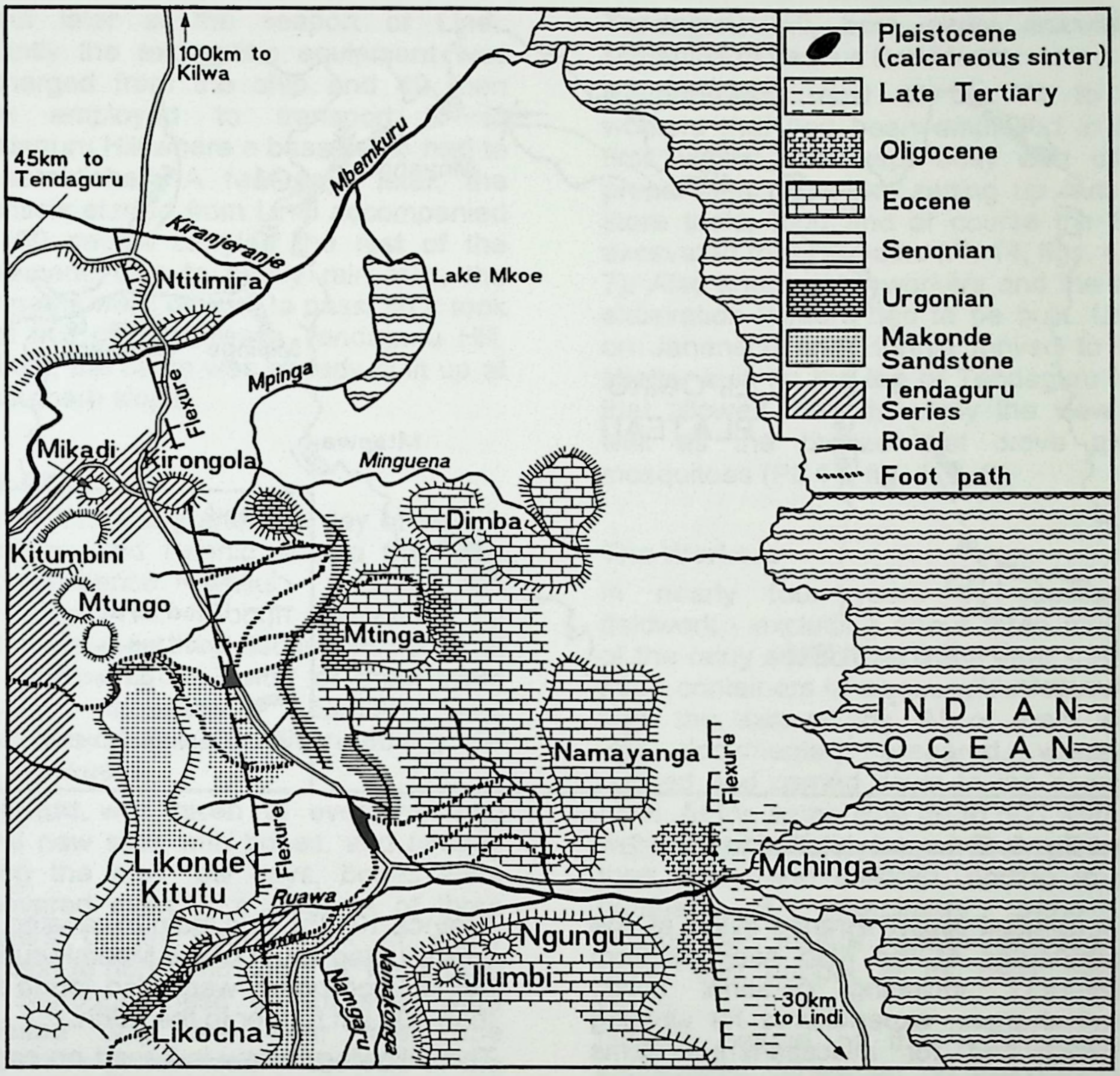
After 13 km - leaving the Mbemkuru Depression behind - the road starts winding up into a gentle slope reaching several well-exposed *Smeei* Beds without having passed the Middle Saurian Beds. Here - at a distance between 15 km to 17 km off Mnyangara - good outcrops of *Smeei* Beds occur (text-fig. 4). The track now continues on the Tendaguru Plateau where the Tendaguru Hill forms the highest part. After another 6 km (23 km behind Mnyangara), the top of Tendaguru Hill can be easily spotted for the first time (Pl. 1, fig. 4). On either side of the road one can recognise traces of the former excavations. After two km, there is another bifurcation: The left path leads to the northern slope of Tendaguru Hill, while the right one continues for about five km to Namapuia Village. From the bifurcation to climb up Tendaguru Hill can be done in less than one hour's time.

The best place to camp is in Namapuia (Pl. 1, fig. 10; Pl. 8, fig. 6; Pl. 9, figs. 1-6), being the village closest to Tendaguru Hill. During the dry season, the nearby water holes provide a substantial amount of water for the villagers (Pl. 9, fig. 3).

3 History

3.1 Discovery

At the beginning of this century, Tanzania, at that time called Tanganyika, was the major part of the German colony "Schutzgebiet Deutsch-Ostafrika". During an exploration field trip in 1907, the mining engineer Bernhard Sattler, who was working in a garnet exploration project, was stopped by huge bones blocking a foot path near Tendaguru Hill. Thus the vertebrate bearing locality was discovered by chance. Sattler immediately informed the director of his company, who passed these news on to the Head of the Commitee for Area Studies in Berlin. A member of the committee gave notice to Prof. Eberhard Fraas, the famous palaeontologist and geologist in Stuttgart, who was supposed to set off to a business trip to East Africa only one day later (Wild 1991b). He had the opportunity to obtain details of the locality in Dar es Salaam and decided to visit the area at the end of his business trip. Although suffering severely from dysentery, he started from Lindi at the end of August and reached Tendaguru after five days of strenuous walking, accompanied by Bernhard Sattler, two colonial authorities and 60 porters, mainly employed to transport some of the bones back to the coast (Wild 1991b). Upon arrival in the Tendaguru area, the crew found numerous bones lying on the weathered surface. On viewing the abundance of bones, the locality reminded Fraas of the famous "Bone Cabin Quarry" in Wyoming (USA), an area he had visited in 1901 with his colleague H.F. Osborn (Fraas 1908). There, cowboys even used to build their shelters by using dinosaur bones due to the fact that other suitable stony materials for building were lacking. Recognising many of the bones as parts of articulated skeletons, Fraas was deeply impressed by the extraordinary quality and immense quantity of dinosaur bones in the Tendaguru area. In order to collect as many important specimens as possible, he immediately started excavations (Fraas 1908). However, after about one week of work, his serious illness forced him to return to Europe. Back there, he proclaimed the significant importance of this fossil-bearing locality. He instantly applied to the colonial authorities for a special protection of the Tendaguru area to enable future palaeontological excavations (Wild 1991b). The authorities gave their sanction to the project and the enthusiastic publication of his scientific findings smoothed the way for further palaeontological projects. Motivated by these extraordinary results, it was Wilhem Branca, the director of the Berlin Naturkundemuseum, who took the chance to initiate the large-scale palaeontological excavations, which yielded the most famous dinosaurs of Africa.



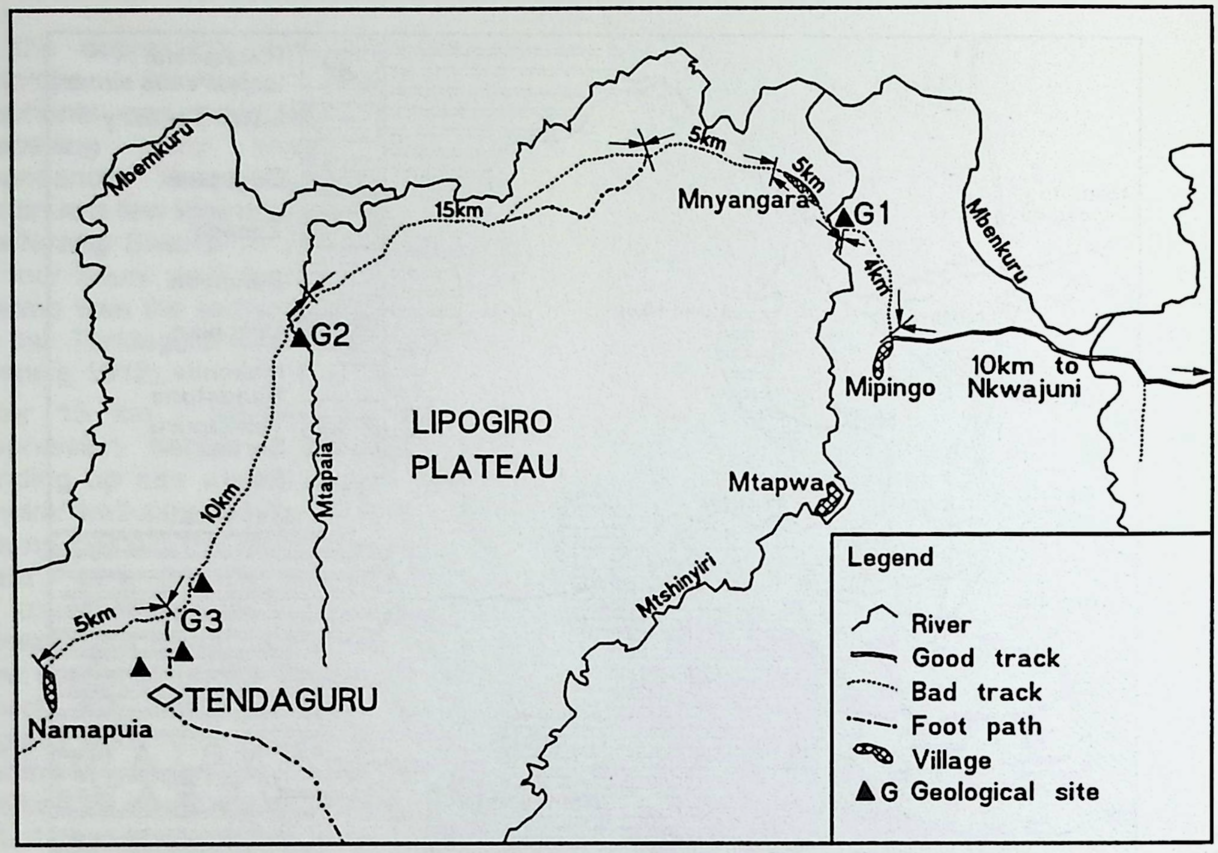
Text-fig. 3: Geological sketch map of the coastal area south of Mbemkuru River after Hennig (1933-1939).

3.2 Tendaguru Expedition 1909-1913

In the relevant literature, the Tendaguru Expedition of the Naturkundemuseum Berlin is considered to have been completed in 1912. Actually, the excavation activities lasted until the end of January 1913 (Branca 1914b).

3.2.1 Sources of Fund

Having heard the news of Fraas' expedition, the director of the Berlin Naturkundemuseum, W. Branca, instantly called some high-ranking personalities to form a financial committee in order to raise money for the immense costs of the Tendaguru project. The committee consisted of private representatives from commerce, banking and industrial institutions. Apart from one major grant to the last field season in 1912, which was given by the Prussian Ministry of Cultural Affairs, Branca succeeded in financing the Tendaguru Expedition mainly by private donations (Branca 1914a). Additionally, many companies provided significant contributions in one or another way to support the expedition, for example, all optical instruments were supplied, a shipping line reduced the transport charges of the bones and the packing material, and a well known producer of soup delivered imperishable canned food for the expedition.



Text-fig. 4: Enlarged detail of text-fig. 2.

In a detailed report, Branca listed all the expenditures of the field seasons from 1909-1911, including personal costs, travel charges, expenditures for working material and for miscellaneous items (Branca 1914a).

3.2.2 Excavations

Recovering dinosaurs was the main target of the expedition. But apart from the fundamental studies in geology and palaeontology, abundant zoological and botanical items were collected (Branca 1914c). As mentioned above, the excavations lasted four years, but strictly reported, the excavation activities took place only in the dry season. Werner Janensch, at that time curator in the Berlin Naturkundemuseum was in charge of the expedition during the first three years. His assistant was Edwin Hennig. Due to the immense enlargement of the excavation area, Hans von Staff supported the field work in 1911. After the return of these colleagues, Hans Reck succeeded as the leader of the last excavation period from 1912 until the end of January 1913 (Branca 1914b). The main excavated area was situated south of the Mbemkuru River but isolated bones were also found more than 100 km further to the north.

The following review is based on concise reports of the excavation, which were published by Hennig (1912) and Janensch (1912, 1914a).

Equipment

Janensch (1914a) listed in detail all the articles imported from Europe: camping equipment; digging tools; tools for repair and maintenance; packing material for the fossils (plaster of Paris, rubber and twines); compasses; barographs; altimeter; thermometer; scientific literature, in addition field glasses; binoculars; exclusive optical instruments with accessories, and canned food, all donated by their respective producers.

Route

Well informed by Fraas, Janensch and Hennig started in Marseilles by ship via Dar es Salaam and arrived about four weeks later at the seaport of Lindi. Instantly the excavation equipment was discharged from the ship and 40 men were employed to transport it to Tendaguru Hill where a base camp had to be established. A few days later, the scientists started from Lindi accompanied by 160 people carrying the rest of the equipment. Due to heavy rain falls, the foot paths were difficult to pass, so it took them five days to reach Tendaguru Hill. By then, the camp was already built up at its southern slope.

First days

The next morning after the day of arrival, Janensch and Hennig started their first reconnaissance walks around the Tendaguru Hill. Though hampered by thick vegetation they discovered bones at ten different sites, some of them were already known to Sattler who accompanied the expedition during the first two weeks.

A reward was given to everyone who found new sites with bones, and already during the next few days, bones were discovered even at a distance of three quarters of an hours' walk in either direction to north and south of Tendaguru Hill. Although these distant sites were exploited only one year later, the excavators got an idea of the size of the area that had to be searched for fossils right from the beginning of the expedition.

At the time the expediton arrived at Tendaguru, the area was scarcely inhabited, for the soil bearing the dinosaur horizons appears to be infertile. Old footpaths crossing the area were found overgrown. However, the government declared the area as protected "Kronland" in order to prevent people from destroying bones while extending their fields. Later on, quite the opposite scenario happened. As soon as it was released that the expedition was looking for huge bones, at many occasions people living at the outskirts of the protected area informed the excavators about bones they had discovered while clearing the bush in order to set up their new fields.

The excavations started at the 20th of April, 1909. The first trenches, all of them near to the base camp close to the Tendaguru Hill, bore partly articulated skeletons of various individuals.

Nevertheless, most of the 70 to 80 workers that had been employed in the first weeks were kept busy with other preparation tasks like setting up huts to store tools, food and of course the first excavated fossil remains (Pl. 14, figs. 4, 5, 7). Also shelters for workers and the two excavation leaders had to be built. Later on Janensch and Hennig moved to the shelter built on the top of Tendaguru Hill, that allowed them to enjoy the view as well as the breeze that drove away mosquitoes (Pl. 14, fig. 4, 5, 8)

The Workers

In nearly four years of successive fieldwork - excluding about three months of the rainy season for each year - about 5000 containers of bones were recovered from the excavations. All of them were well documented, prepared, wrapped, packed and carried down to the coast to Lindi. At the same time up to 500 workers were employed, some of them brought their wives and children, adding to the number of inhabitants living at "Tendaguru Village" which counted for about 900 people at its peak (Pl. 14, fig. 6).

Initially, people of the neighbourhood settlements, tribesmen of the Wamwera and Wandonde were employed. But soon thereafter, people arrived even from far away - especially Wayao and Wangoni who used to live near the southern borders of the country, now Mozambique and Malawi.

The plantations of the north were far away, thus, the excavators offered the only possibility to earn money in this region. Every month more persons applied for work than there could be employed. The regular workers got 9 rupees per month, while foremen and preparators earned 10-11 rupees each month. That was better than the average payments at the plantations. Also, contrary to the work on the plantations, no piece work was paid for, because it was the quality of work that counted for and not the quantity.

According to their skills and special interests, members of different tribes were employed for different jobs, for example one tribe apparently was more prone to do preparatory work, another to digging, etc. (Pl. 14, figs. 1-3). The workers formed units of up to 25 persons and each team was headed by a foreman who was in charge of informing Janensch and Hennig about the work in progress (Pl. 13, figs. 2). The supervisor of the foremen was Mr. Boheti, who subsequently worked for the British Museum East Africa Expedition (Pl. 13, fig. 1). When the first few months of supervision had passed, nearly all the work connected to the excavations as digging, preparation, labelling, packing, transport etc. was done independently by these teams.

Background information about the objectives of the excavation, the life of the dinosaurs, changes of land and sea in the past etc. spread throughout the neighbourhood settlements. E.g. Hennig (1912) refers to a young boy who told him during a visit to in a remote village, that "all this area once had been covered by sea" .

Although prior to the arrival of the scientists, people certainly did not know anything of the existence of dinosaurs in the past, Hennig (1912) noticed that among all tribes living in Lindi District there was a legend about a giant monster, which most probably has been inspired by the giant bones scattered in the Tendaguru area. The giant monster used to feed on humans that were imagined as giants as well and sometimes it swallowed up all people in the villages. Fortunately, most of the humans devoured were stored inside the fingers or toes of the monster. After living through a long period of horror, a group of brave young men eventually killed the monster, the prisoners in the fingers or toes were discovered while uttering human words and finally, were set free.

Food and Water Supply

Water supply has had been a constant problem throughout the whole excavations period. After their arrival it nearly took them four weeks to discover a spring hidden in a kind of grotto in a dry river bed. Another one has been found as late as three months later. Finally, four sources of water were used, but they only provided such a hesitant trickle of water that people had to scoop off water day and night, especially at the end of the dry season at the time when about 900 people had to be supplied.

In the first year of the expedition, after an excellent harvest, farmers of the region offered their surpluses of which some could even be kept in storage for the next year. The following years due to poor harvest, Janensch and Hennig had to buy grain even as far as from Lindi, sometimes they even failed to get a sufficient amount for their camp.

Also a small trade of cloth, tobacco, pots, pans and similar items was established in order to meet the demands of the workers and their families. After some time, a little shop was opened and was run by employees. Additionally, a dispensary that provided for first aid services was established.

The whole area is contaminated by tsetse flies, the source of sleeping disease in humans and domestic animals. Goats and a few chickens were therefore offered only on special occasions. Wild game was shot down on Sunday morning during hunting excursions and then offered as supplements to the diet. Hennig (1912) refers to an antelope he shot down once and supplied a good portion of meat for everyone of the 400 persons employed at that time. The favourite hunting ground was Nyangi Swamp at a three to four hours walk from Tendaguru Hill. Humans were constantly busy at the water holes, so usually neither antelopes nor carnivores came near the settlement.

Daily Work Schedules

Work started at six o'clock in the morning and was signalled by the sound of a drum (Pl. 14, fig. 5). With a short break around noon, work lasted until two o'clock in the afternoon, according to the wish of the workers who preferred the free afternoons and evenings. In later years, however, some of the excavation sites were located too far away to have a lunch break at the Tendaguru Village. Some other workers living in nearby settlements walked home in the afternoon to till their fields. Others did not take their wives along, so they either shared the preparation of food among small groups or they did it all by themselves, an activity that took a long time because the millet had to be pounded with a pestle in a mortar every day in order to get millet flour.

At the same time excavations were going on in a great number of trenches. Trenches were opened mostly at places where bones had been found on the surface (e.g. Pl. 13, figs. 5, 6). The actual excavation work required various systematic steps often followed by different teams. The soil had to be removed by using shovels and pickaxes (Pl. 12, figs. 1-3, 5-6). Sometimes only a small part of a bone was found lying at the surface while the other part was found stuck deep in the sediments. In this case and also whenever deeper layers had to be reached, trenches were dug down to a depth of about 10 meters. Therefore, the walls had to be secured by wooden constructions and mats woven from bamboo sticks (Pl. 12, fig. 4).

Nearly all of the fossil bones were in a fragmentary condition (Pl. 13, figs. 5, 7). Very often the fossil bones were also criss-crossed with fine fissures. In that case, they had to be wrapped on the spot by using Arabic gum. Cloth and layers of plaster of Paris were applied first at the upper side, then after turning over the object carefully, the same procedure was done at the reverse side.

With the excavations in progress many of the trenches were located too far away from the base camp to be visited by Janensch and Hennig every day, some of them they could not even visit for some weeks. To any trench, however, far from the base camp, groups of young boys carried water a couple of times per day. The foremen of the teams working in such trenches regularly reported about the work in progress. Sometimes they prepared sketches of the shapes of the fossil bones or they cut sticks at the length of the discovered bones in question to illustrate the accounts and dimensions in their reports (Pl. 13, fig. 3). Hennig also refers to drawings aimed to reconstruct a living dinosaur by the indigenous people (Hennig 1912).

For identification of the finds, the excavators invented an elaborate system of interconnected letters and numbers. Even if both of the identical catalogues used to register all finds had been lost, it would have been possible to reconstruct the connection of each bone to the related bones of the same individual as well as to the place where it had been found. After the scientists had numbered each bone according to that system, units of men who knew how to write Latin letters marked the finds with ink (Pl. 14, fig. 7).

Packing and Transportation

As packing material, any hollow plant provided by the surrounding nature, for example fruits of the baobab trees and bamboo canes, were filled in with smaller objects, wrapped in grass or anything soft that nature provided. Greater objects were stored in flexible makeshift boxes of bamboo canes bound to each other with wire or ropes. According to size and friability/fragility, layers of grass, cloth, mud and plaster of Paris were added.

Several units of men produced standard containers that porters had to carry to Lindi (Pl. 15, figs. 1-6). The containers had to be light and at the same time shock-proof. This was achieved by nailing bamboo canes all around to thin wooden disks of about 40 cm in diameter (Pl. 14, figs. 9-10). Usually one of these ready packed loads weighed about 30 kg - a load for one man (Pl. 15, figs 1, 4, 5, 6).

Most the bones were found broken into pieces. Anyway, at least as far as some of the bigger bones are concerned, it would have been impossible to carry them as complete ones. But even fractions of bones could by far exceed the standard load. The transport of very heavy loads sometimes required up to 12 men (Pl. 15, figs. 2, 3). In order to make such kind of transport possible, considerable road works had to be done. Narrow foot paths were cleared and broadened, while bridges were erected over river beds. Nevertheless, the caravan sometimes had to cross immense water expanses (Pl. 15, fig. 4).

According to the prevailing conditions at that time, three different routes were used by the porters to carry their loads from Tendaguru to Lindi. First, the route via Noto and Lutende Plateaux, Namembo Plain and the southern Kitulo Plateau was the most convenient and took about three days. A second one was a three days' route that led via Likonde Kitale Plateau, Namgaru Valley, Kikomolela and Kitulo Plateau (text-fig. 5.1). Some porters preferred this route, though it was strenuous due to quite a few steep slopes, but it was easier to get food along this less frequented track. The third route led via Mtapaia and Mikadi Plateau along the eastern slope of Likonde Kitutu Plateau (text-fig. 5.1). However, it took three more days and was used only on rare occasions.

Upon arrival in Lindi the loads were piled up in a huge store room of the German East African Company (Pl. 15, fig. 7). Twice during an excavation term - that is during the dry season - one of the excavation leaders went down to Lindi. On such occasions fossils were shipped to Dar es Salaam. The bamboo containers packed into solid wooden boxes were loaded on dhaus that took them to steamers that had anchored off Lindi Bay in deep waters (Pl. 15, fig. 8) Originally the boxes had to be imported from Scandinavia. They were shipped all the way around the Cape. Now, upon arrival in Berlin the boxes were dismantled and were shipped back to Lindi where they were put together again at the School of Crafts to be used for another time. In Dar es Salaam, the boxes were finally loaded onto ocean steamers bound to Hamburg. From here the fossils were transported to their final destination, the Naturkundemuseum in Berlin.

Altogether about 5000 loads in more than one thousand boxes weighing about 250.000 kg were shipped to Berlin.

Preparations for the Rainy Season

During the last weeks of the dry season, excavation work was gradually reduced. No new trenches were opened, instead, emphasis was put on exploiting the sites already worked on in order to gather all exposed bones before the beginning of the rains. This was necessary because the excessive rain falls were feared to erode anything not protected by a thick layer of soil.

From the beginning of November the only work done was to evacuate the fossils from the trenches, a task that required mainly the skills of the preparatory teams (Pl. 14, figs. 1-3). Therefore, the units in charge of removing the soil with shovel and pickaxe could be already dismissed. They took the opportunity to till their fields before the rains started to fall. During this period, as many as possible of the excavated bones had to be carried down to the dry and secure store room in Lindi.

Towards the end of the dry season also the search for new sites, to be exploited in the following dry season, took place. As a rule people of the region burnt down the dry grasses once a year. There being no conifers around, this method did and still today, does not harm the vegetation except the dry grasses. Meant to act as a kind of pest control, the fires also cleared the ground for the search of fossils. Subsequently, groups of scouts were set out to survey the area systematically detaching for bones, with excellent results. A special reward was promised and given to everyone who discovered a new site. The scouts marked their finds by fixing empty white shells of the gastropod genus *Achatina* - scattered all over the area - high up in the tree branches and bushes (Pl. 5, fig. 4).

Usually the leaders of the excavations left Tendaguru during the first days of January by heading for the north of the country. Only a small group of caretakers stayed behind.

In the report of the fourth field season Branca (1914b: 62) quoted a letter written by Hans Reck, who led the excavation period 1912/1913, that dinosaur remains easily to be discovered, might nearly completely be exploited in the Tendaguru area. That was probably the reason why the German expedition abandoned the localities already in January 1913.

3.2.3 Publications

The field reports of the Tendaguru Expedition 1909-1913, e.g. Janensch

(1912), have been published in the proceedings (= Sitzungsberichte) of the Berlin Scientific Association "Gesellschaft Naturforschender Freunde". Additionally, this scientific society edited a special series "Archiv für Biontologie", where all scientific results concerning Tendaguru should have been published under the topic of "Wissenschaftliche Ergebnisse der Tendaguru-Expedition 1909-1912". But World War I and its aftermath interrupted the series. Later, Janensch, in the name of J. F. Pompeckj, at that time director of the Berlin Museum, was the editor of the Supplement VII of the famous "Palaeontographica - Beiträge zur Naturgeschichte der Vorzeiten". The first volume of this supplement was dedicated to Wilhelm von Branca, on the occasion of his 80th birthday (September 9th, 1924), the former director of the museum, who untiringly organised and promoted the Tendaguru Expediton. More than half a century after the discovery of the locality, the series of publications with numerous works concerning these productive excavations were finished in 1961 by a report on how the smallest Tendaguru dinosaur skeleton has been put up in the exhibition of the museum (Janensch 1961).

With the exception of a few copies, privately donated by one of us (W.Z.) in 1984, these reprints are unfortunately not available in the library of the Department of Geology of the University of Dar es Salaam or the library of the National Museum of Tanzania.

The best guide to the literature of Tendaguru including the German and British expeditions as well as subsequent results up to 1989 is given by Maier (1989) in an annoted bibliography including 330 references.

3.2.4 Storage of the material

The first bones discovered in Tendaguru were transported to the State Museum of Natural History of Stuttgart, where all specimens described and illustrated by Fraas (1908) are now housed (written commun. R. Wild).

Most of the material excavated by the Tendaguru Expedition 1909-1913 is stored in the Naturkundemuseum of the Humboldt University of Berlin, where the most spectacular specimens are mounted in the public exhibition. The majority of the fossil material, namely the sauropods are housed in the scientific collection of this museum. Some of the old findings are not yet analysed and still untouched packed in the original bamboo containers stored in the cellar of the museum. This offered the chance for W.-D. Heinrich, curator in the Berlin Naturkundemuseum, to process the sediments coating the bones, in order to look for microvertebrates. Such an undertaking recently led to the significant discovery of the first mammal tooth from Tendaguru (pers. commun. W.-D. Heinrich). According to statistical evaluations of the findings, about 400 remains and 80 partly articulated skeletons of dinosaur individuals are stored in the Berlin Naturkundemuseum (Russell et al. 1980). The fossils from Tendaguru, both vertebrates and invertebrates, account for more than 10 000 specimens. In addition, other biological objects, namely recent insects, lizards and plants, were collected during the Tendaguru Expedition 1909-1913 and are also stored in the Berlin Naturkundemuseum.

Due to the immense stock of the Tendaguru fossils, which exceeded the capacity of the space and preparatory man power in the Berlin Naturkundemuseum, donations were given to other German palaeontological institutions. By 1927, the State Museum of Natural History of Stuttgart obtained about 30 isolated bones, partly as casts, of *Kentrurosaurus aethiopicus* (written commun. R. Wild). In 1933, more material arrived there, mainly unprepared and showing traces of fire. According to Maisch (written commun.) similar traces of fire have been observed in the Tendaguru material, which arrived in Tübingen. Therefore, Wild assumes, that there was a fire in the Berlin Museum probably in 1929, but the annuals of the Naturkundemuseum Berlin do not indicate a fire event (pers. commun. W.-D. Heinrich).

Hennig, who was a specialist in ornithopods, overtook a professorship in Tübingen. Therefore, numerous ornithopod material, namely small vertebrae, tarsi and other phalangeal elements of ornithischians, including the type material of *Kentrurosaurus aethiopicus*, were taken to Tübingen (written commun. H. Hölder, M. Maisch).

During World War II, the types and other specimens of *Dryosaurus lettowvorbecki* were destroyed by fire (see below), but there was an immense stock to replace it. A skull of *Dryosaurus lettowvorbecki* bearing the field number K 71 60, N 71 54 and the registration number AS I 834 is stored in the Bayerische Staatssammlung für Paläontologie und historische Geologie in Munich (written commun. H. Mayr).

To compensate the financial support given to the Tendaguru Expedition by R. von Passavant-Gontard, member of the Senckenbergische Naturforschende Gesellschaft in Frankfurt am Main, a rib and a left fore limb as well as a cast of a scapula of *Brachiosaurus brancai* came into the possession of the Senckenberg Museum, where the specimens are exhibited until today (written commun. G. Plodowski).

In addition, minor important Tendaguru dinosaur bones should be kept in the collection of the geological and palaeontological department and museum of Göttingen (Janensch 1955).

3.3 British Museum East Africa Expedition

In the mid-twenties, when then Tanzania was a part of the Tanganyika Territory of British East Africa, the British Museum (Natural History) sent out a paleontological expedition to the Tendaguru area. The only objective of the British Expedition was to yield duplicates of the huge dinosaurs already found there (Leakey 1925).

The leader of the British Museum East Africa Expedition was the Canadian dinosaur hunter W. E. Cutler from Manitoba University (Pl. 17, fig. 3). Since he had never been in Africa before, he looked for a talented assistant with experience in Africa. He selected the Kenyan palaeoanthropologist L.S.B Leakey who was by then a student at Cambridge University. Due to an accident in a rugby match with after-effects of head aches, Leakey with his considerable knowledge of East Africa and Kiswahili language, was forced to interrupt his studies for one year and therefore, was an excellent chief assistant in the British expedition (Jacobs 1993).

By the 16th of April, 1924, Leakey started from Lindi with a guide and a couple of porters, trying to follow the old German trail. After four days the group reached a settlement very close to Tendaguru Hill. The village chairman beat the drum in order to attract workers to be engaged. With such a help, Leakey prepared immediately the excavation properly by clearing away the vegetation, cutting a trail through the bush to Lindi as well as building up the camp including the stores. After Cutlers' arrival on 24th of May, 1924, bone digging in conjunction with hardening, plastering, labelling, parcelling of the fossils (Pl. 17, fig. 1, 2, 5) started instantly and then ended up in having removed 600 isolated bones by October, when Leakey left for London. Cutler continued with the excavations, but unfortunately, he died on the 30th August, 1925 from malaria.

In November of the same year, it was F.W.H. Migeod, who took over the leadership of the excavations (Pl. 17, fig. 4). He was a civil servant and he had stayed in Africa before, but he was not a palaeontologist (Jacobs 1993). His team comprised Major Deacon and 50 local workers (Migeod 1927a,b). In his first annual field report, Migeod (1927a,b) rendered excited accounts that excavations at 13 different places produced "possibly enough material partly to reconstruct some two dozens skeletons representing a considerable number of different species". In addition, he considered that "the dinosaur field of Tendaguru is by no means yet worked out".

As already done in 1909 by the authorities of German East Africa, in 1928 again, the government of the Tanganyika Territory proclaimed to protect the Tendaguru area for palaeontological research (Migeod 1930). In this respect, however, there were no more funds to hire a European assistant and furthermore, it was "now becoming increasingly difficult to locate deposits of bones" (Migeod 1930:185).

In 1930, Migeod and his assistant F.R. Parrington from the Museum of Zoology at Cambridge resumed excavating near Tendaguru Hill until the end of August (Migeod 1931). Later, they left for an expedition to Nyasaland, now Malawi, in order to compare the dinosaur-bearing layers of Tendaguru with vertebrate bearing horizons of Nyasaland (Migeod 1931). After that survey, the British Museum East Africa Expedition abandoned Tendaguru finally in January 1931 (Jacobs 1993).

In addition to the field reports of the British expedition, an preliminary overview of the Tendaguru dinosaurs was recorded by Parkinson (1928, 1930) and geographical notes concerning the dinosaur-bearing area were given by Hobley (1925).

Detailed studies of the material collected during the British expeditions have never been published (Russell et al. 1980).

4. Geology

In this chapter, the geological and stratigraphical results of former authors are briefly summarised, in addition, our own observations concerning sedimentary, biostratigraphic and palaeoenvironmental aspects are presented.

4.1 Tendaguru Series

Janensch (1914c) and Hennig (1933-1939) described the Tendaguru Series as being composed of terrestrial and shallow marine sediments, unconformably overlaying Precambrian gneisses. The relatively soft, sandy and silty marls and silts which have produced the famous Tendaguru Dinosaurs are interbedded by hard calcareous and sandy strata including marine organisms.

The continuous and mostly complete section of the Tendaguru Series - only the upper part of the *Bornhardti Schwarzi* Complex is lacking - crops out exclusively at the Tendaguru Hill having given the name for the whole series. The maximum thickness of the Late Jurassic to Early Cretaceous Tendaguru Beds is 140 m at the Tendaguru Hill. The Tendaguru Series is composed of the following units from the bottom to the top: Lower Saurian Beds, *Nerinea* Beds (=„Nerinellen-schichten" of Hennig 1933-1939), Middle Saurian Beds, *Smeei* Beds, Upper Saurian Beds and *Bornhardti Schwarzi* Complex.

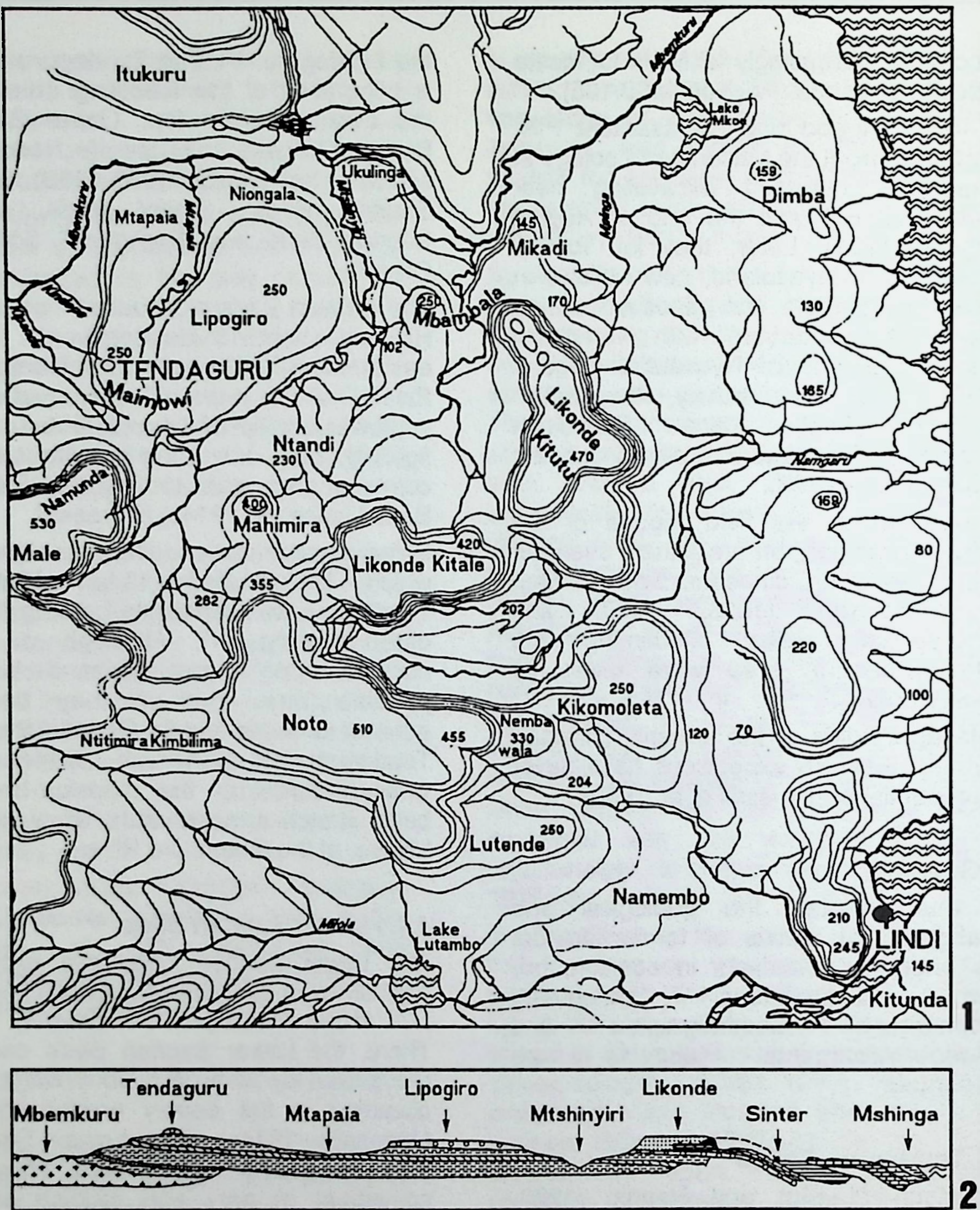
The Saurian Beds crop out at Tendaguru Hill and about 15 km eastwards. In its easternmost point at the Nambango River, which is situated at the southwestern tip of Likonde Kitutu (text-fig. 5.1), only one bone-bearing horizon corresponding with the Upper Saurian Beds (Janensch 1914c) is present.

In the westernmost occurrence at Ubolelo, which is situated 15 km NW of Tendaguru, two vertebrate-bearing layers occur (text-fig. 5.1). Although a clear correlation of these horizons is not possible, one of them may be the equivalent of the Middle Saurian Beds at Tendaguru Hill (Janensch 1914c). The western border of the dinosaur-bearing beds stretches northwards to Nanundo Village, at the Mbemkuru River.

4.1.1 Lower Saurian Beds

The Lower Saurian Beds are exposed exclusively in the Mbemkuru Plain, W and NW of the Tendaguru Hill (text-fig. 5.2). There, the Lower Saurian Beds can be recognized by numerous bony fragments occurring in the deeply eroded creeks (Janensch 1914c). The Lower Saurian Beds are less than 20 m thick. They are composed of grey and reddish sandy marls with a low calcareous content.

They have not yielded spectacular dinosaur remains (see below). Most probably, the bad outcrops in the Mbemkuru Plain have given rise to doubts about the existence of the Lower Saurian Beds (Kitchin 1929, Parkinson 1930). But this suspicion could persistently be dispelled out by the results of Hennig (1933-1939).

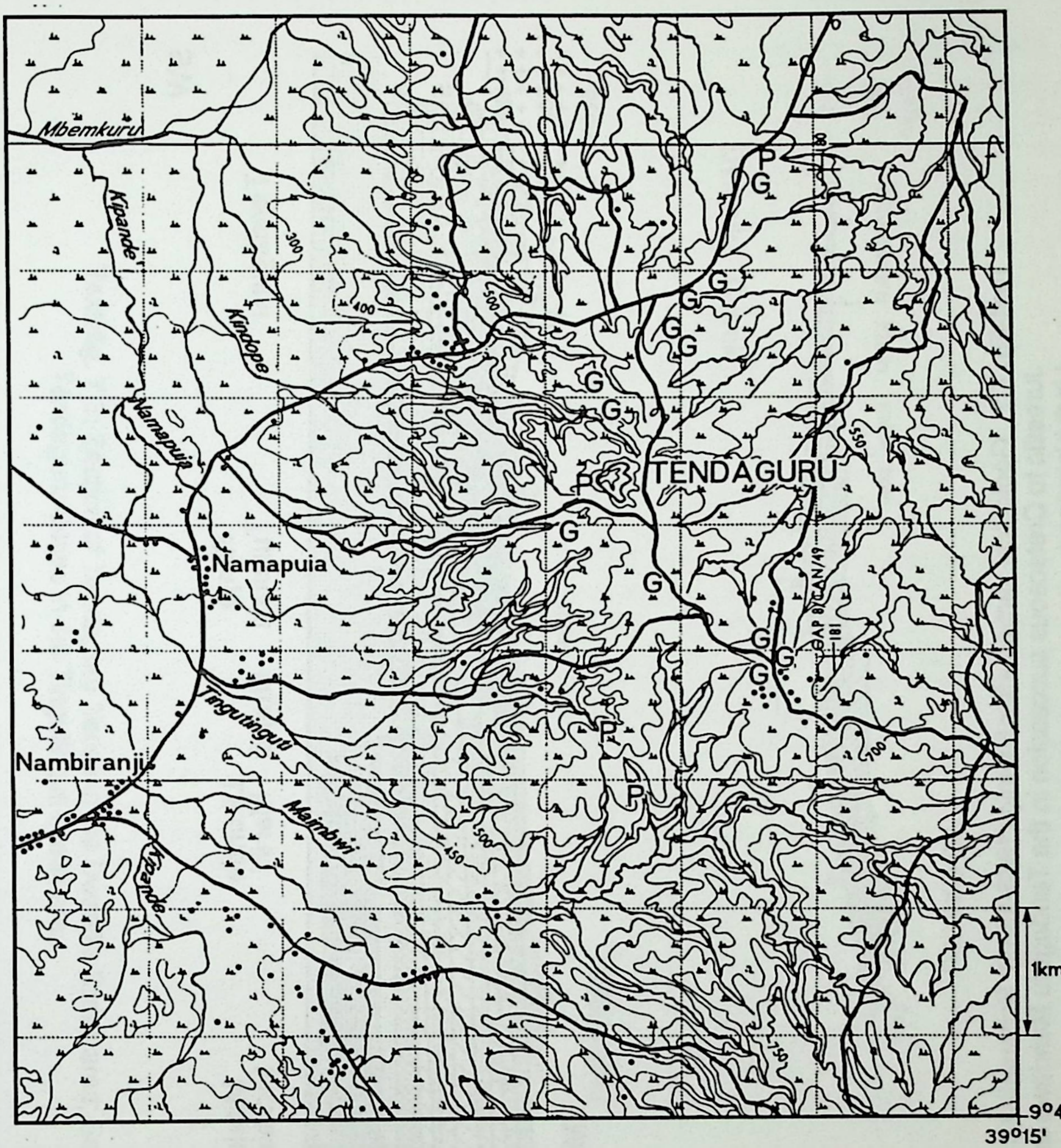


Text-fig. 5: 1. Detail from the morphological map of the area south of Mbemkuru River; scale about 1 : 400 000 from Hennig (1914a); **2.** Schematised geological section of the Mesozoic sediments south of Mbemkuru River from Hennig (1914a).

4.1.2 *Nerinea* Beds

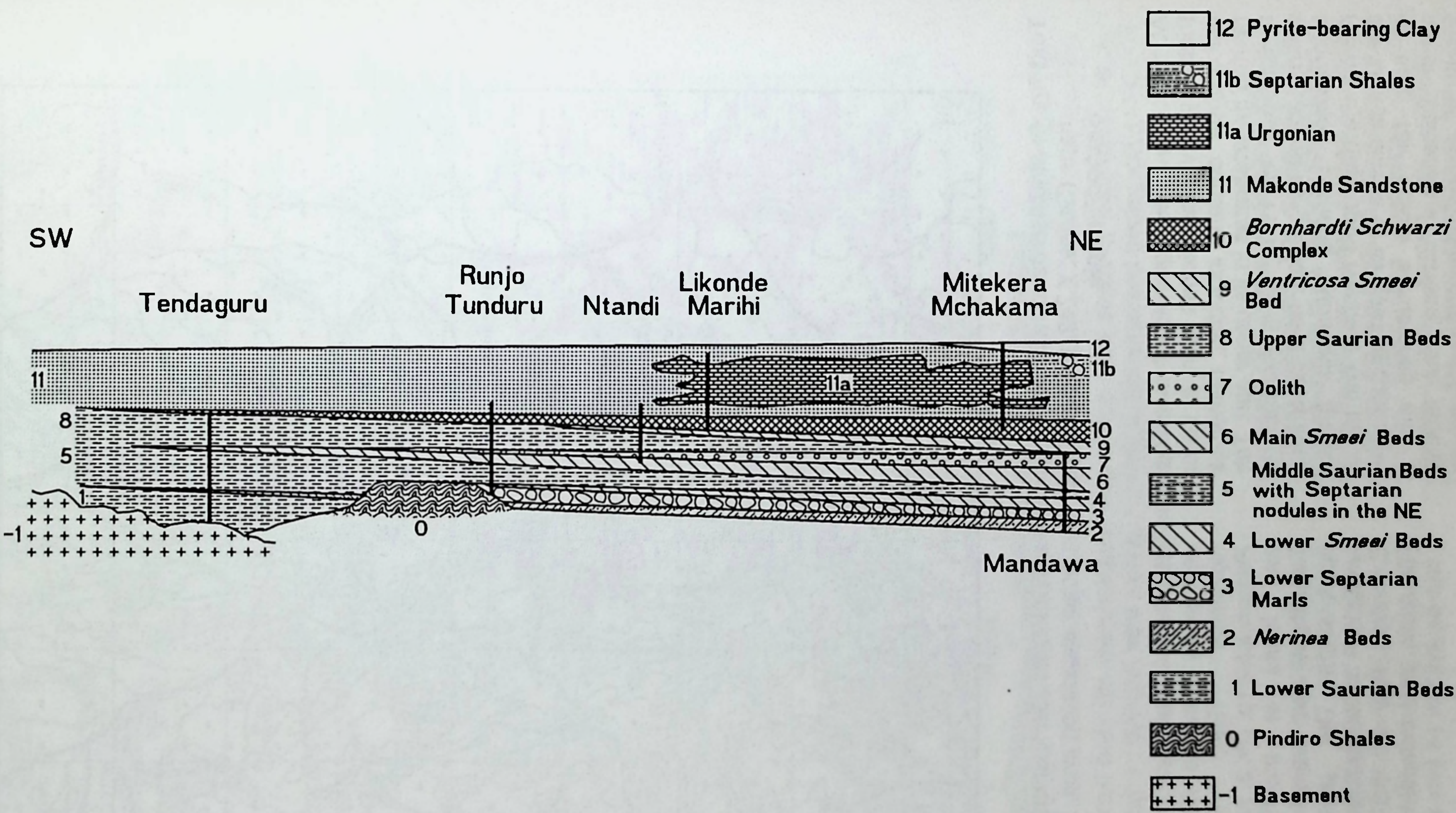
The *Nerinea* Beds are exposed in the Tingutinguti Creek, its neighbouring valleys and in Maimbwi Creek. According to Janensch (1914c), this lithological unit stretches along the western foot of Tendaguru Hill as well as in Kindope and Dwanika Creeks.

The term "*Nerinea* Beds" may be a little bit misleading, since the occurrence of this gastropod genus is not only restricted to these sediments. The gastropod genus *Nerinea* occurs in all marine intercalations of the Tendaguru Series as well as in the so-called Kiturika Beds of Late Aptian age (Aitken 1961). The thickness of the *Nerinea* Beds, named by Janensch (1914c) the "Lower sandstone zone", is 25 m.

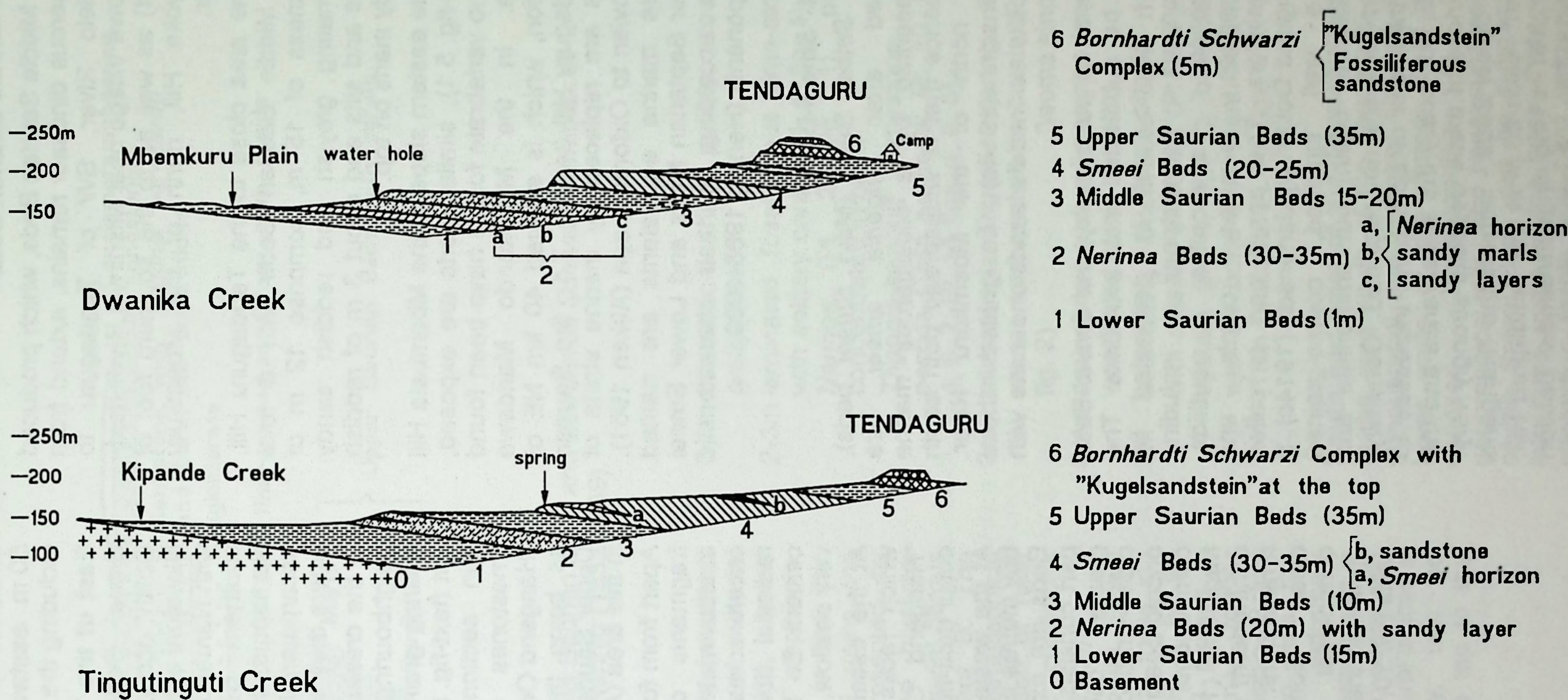


Text-fig. 6: Modified detail from the "Nanjirinji" sheet (Number: 283/1) of the topographic maps (Series: Y 742, Edition: I-TSD); G = former excavation sites, P = Section/Sample.

At the base, there are 6 to 7 m of fair friable yellow sandstones with a minor calcareous content including numerous marine invertebrates in its upper part. The middle part of 11 to 13 m thickness is characterised by greyish, hard calcareous sandstones showing numerous fossils, mainly the gastropod *Nerinea*. The top of this unit is similar to its base in consisting of soft, fair friable sandstones with a minor calcareous content, but lacking fossils in the top layers. Apart from the gastropod and bivalve faunas (Dietrich 1914, 1933-39), Zwierzycki (1914) described various nautilids and ammonites from the *Nerinea* Beds. In November 1994, the ammonite *Perisphinctes* sp. (Pl. 3, fig. 4, Pl. 7, fig. 4) was found in the area between Tingutinguti and Maimbwi Creeks (text-fig. 6, 7.1). The presence of this ammonite is indicative for a Middle Oxfordian age of the *Nerinea* Beds (Gröschke, pers. commun.).



Text-fig. 7.1: Geological section after Hennig (1933-1939): Schematised section of the Jurassic to Cretaceous succession in the Tendaguru Mandawa area of the Kilwa Lindi hinterland;



Text-fig. 7.2: Section of Tendaguru Series in the Dwanika Creek area; Section of Tendaguru Series in the Tingutinguti Creek area.

4.1.3 Middle Saurian Beds

The Middle Saurian Beds, which produced numerous dinosaur remains, extend from Ubolelo River, SW of Tendaguru to Mtapwa Village near Mtshinyiri River (text-fig. 4) as well as to the southern foot of Minyoka Hill, north of the Mbemkuru River.

In the area close to the Tendaguru Hill, the Middle Saurian Beds with a total thickness of 15 m, comprise 12 m of alternating greyish and reddish sandy marls and silts and about 3 m of reddish sandy marls on top.

At the eastern slope of the Mbambala Hill (text-fig. 5.1), similar marls are exposed, but no vertebrate fossils have been found there. In the Mahokondo Mandawa Section, which is situated 40 km NE of Tendaguru Hill (text-fig. 7.1), the Saurian Beds are replaced by marine strata of Callovian to Oxfordian age (Aitken 1961). These marine equivalents are named Lower Septarian Marls and Lower Smeei Beds according to their characteristic components (Hennig 1933-1939).

4.1.4 "*Smeei*-Beds"

The *Smeei* Beds (Main *Smeei* beds), named after *Trigonia smeei,* are represented by a fossiliferous marine sequence that is widespread both south and north of the Mbemkuru River. Janensch (1914c) designated these deposits as "middle sandstone zone with *Trigonia smeei*".

In terms of petrography, the *Smeei* Beds can be subdivided into two units. The lower clastic part is dominated by calcareous sandstones including belemnites, ammonites, nautilids, gastropods, bivalves, corals and foraminifers. The upper part is called "Hangend Oolith" by Janensch (1914c). It is a well stratified, coarse-grained fossiliferous oolith, but ammonites and belemnites are not recorded. Generally, the thickness of both parts increases to the E, but locally the appearance and the thickness of these deposits strongly vary. The *Smeei* Beds - without the "Hangend Oolith" reach 20 m at the Tendaguru Hill, and 25 m at Tingutinguti Maimbwi Section (text-fig. 7.2). Further to the E, the thickness exceeds 30 m and more than 50 m eastwards near Mtshinyiri Creek, including the "Hangend Oolith"

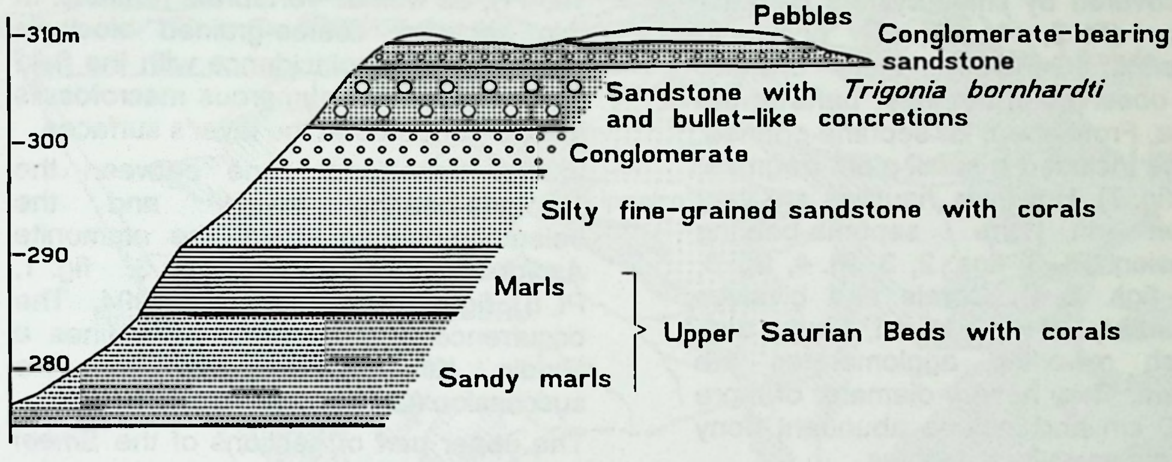
East of the Tendaguru Hill: Outcrops of *Smeei* Beds including the "Hangend Oolith" occur at the main path connecting Nkwajuni at the Dar es Salaam Lindi Road with Namapuia near Tendaguru. From the southern part of the Mikadi Hill to Namapuia, they may either be exposed in escarpment-like relief or in flat areas, where they serve as road pavements.

In the creeks N of Mbambala Hill and the neighbouring Ukulinga Plateau oncoid-bearing grainstones and packstones crop out (text-fig. 5.1). In the field as well as in thin section (Pl. 10, figs. 1, 2), these limestones look very similar to the "Hangend Oolith", but they are interpreted as being the marine equivalent of the Upper Saurian Beds, which is not proved in this area (Aitken 1961).

Apart from foraminifera, small gastropods, fragments of bivalves and echinoids, abiotic material is predominant in the oncoid cores. The cement is built up by radiaxial fibrous cement A and block cement B. These characters indicate a very shallow, but high energy facies.

At the escarpment of Ukulinga Plateau, which faces the Mtshinyiri Valley, the "Hangend Oolith" of the *Smeei* Beds occur (text-figs. 5.1, 5.2, 7.1)

At the western rim of Ukulinga Plateau a few metres of the upper part of the *Smeei* Beds are exposed (Hennig 1914a). This part consists of brownish, coarse- to fine-grained calcareous sandstones with cross-stratification (Pl. 2, fig. 3) and oncoid-bearing limestones. Biogenetic components are dominated by oyster fragments (10 cm in length), bivalve and echinoderm debris, as well as lenticuline foraminifers. Although generally there is a clear dominance of subangular continental quartz, oncoids seem to appear in the whole section even in sandy parts (Pl. 10, fig. 2).



Text-fig. 8: Upper part of Upper Saurian Beds and *Bornhardti Schwarzi* Complex at Tendaguru Hill after Hennig (1933-1939).

Other continental components (reworked basement) or coated grains of euhedal shape (probably glauconite), green components, such as amphibole, chloritized mica are visible in the thin section. Apart from terrestrial grains, the cores of oncoids are represented by fragments of echinoids and bivalves. Cement is made of early radiaxial fibrous cement A and block cement B. The interpretation of these petrographical features led to the assumption of near shore, moderately energetic conditions (Pl. 10, fig. 4,6,7, Pl. 11, Fig. 1,3,5).

A detailed section of the main *Smeei* Beds can be observed one to three km west of Mtapaia (text-fig. 4, Pl. 2, fig. 9). The path to Tendaguru Hill passes a minor hill, whereby some former excavation sites are clearly visible. Below one of the former excavation sites, the *Smeei* Beds, which are extremely fossiliferous in this locality, crop out in a small creek. A rough section, composed of several parts, taken at several places a few hundred metres away, can be outlined as follows (from the top to the base):

0,5m bioclastic-bearing pebbly, coarse-grained sand

2-3m laminated fossiliferous lime-stones with solitary corals (Pl. 4, fig. 1) and *Nerinea* (Pl. 2, fig. 1), partly concentrated in nests.

Trigonia-bearing limestone with pectids (Thin sections: Pl. 10, figs. 4, 6, 7; Pl. 11 figs. 1, 3, 5)

3m alternating *Trigonia*-bearing lime-stones and marls with corals (Pl. 2, fig. 2)

0,4m ammonite-bearing limestone (deeply weathered at the surface)

5m alternating limestones and marls with masses of corals (Pl. 2, fig. 2), oysters (Pl. 4, fig. 2), bivalves as well as bone and plant fragments (Thin sections: Pl. 10, figs. 3, 5, 8)

South and west of the Tendaguru Hill: In the area south of the Tendaguru Hill (Tingutinguti and Maimbwi Creeks), the lower parts of the *Smeei* Beds are exposed. Corresponding to the geographical relief, the basal succession of the *Smeei* Beds can be subdivided into three units: at the base, there are alternating friable and hard calcareous sandstones upwards increasing in hardness. In the upper part of this series, numerous septaria (geodes) of fist size often covered by small oysters or other bivalves (Pl. 2, figs. 5, 7) occur in abundance. Generally, there are no fossils observed in the inner parts of the septaria. From about 20 septaria opened, only one included a small plant fragment (Pl. 2, fig. 7). However, nautilids are very common in the septaria-bearing succession (Pl. 3, figs. 2, 3, Pl. 4, fig. 3, Pl. 11, figs. 2, 4). Corals and bivalves have rarely been found, but dark brownish reworked agglomerates are abundant. They have a diameter of more than 40 cm and include abundant bony fragments as well as pebbles.

In thin sections (Pl. 10, fig. 9, Pl. 11, figs. 9, 10)of the calcareous sandstone, the content of terrestrial components varies from 70 to 95%. There is a striking large content of yellowish-brownish to greenish weathered, well-rounded grains as well as a high content of mica and glauconite. The well sorted subangular quartz grains (0,1 -0,2 mm) are generally finer-grained than the other components.

Biogenetic components are textulariid, lenticuline (Pl. 10, fig. 9) and nodosariid foraminifers, ostracods (Pl. 11, fig. 9) fragments of corals, bivalves (Pl. 11, fig. 10), echinoids, vertebrate remains, serpulid sections as well as woody fibres. The matrix is made of greyish sparitic cement.

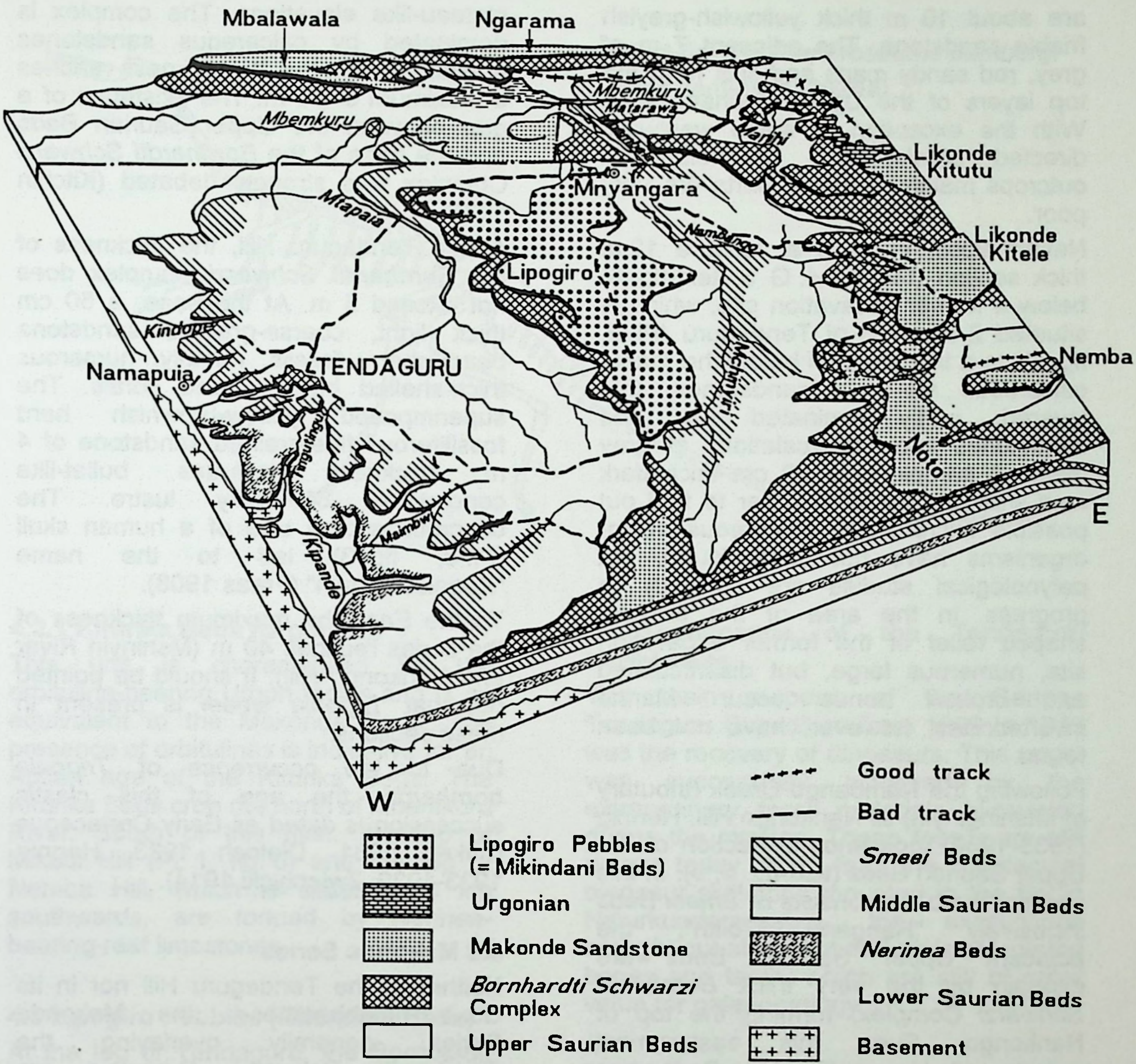
Fossiliferous sandy limestones of about 10 m in thickness follow on the top. These layers are characterised by the presence of numerous belemnites which are mainly concentrated in nest-like accumulations at the surfaces of the strata (Pl. 2, fig. 8). In addition, bivalves, e.g. *Trigonia* sp., as well as trace fossils and reworked bony fragments are visible. Horizons of 20 to 40 cm thick alternate with 5 to 10 cm thick friable strata.

Some of the layers split strikingly into fine laminae. In thin sections, the components of the belemnite-bearing horizon are well sorted subangular quartz grains (0,1-0,2 mm). The percentage of other terrestrial material such as mica (partly chloritized) and green hornblende is definitely high. Biogenetic components are represented by fragments of plants (Pl. 11, fig. 8) and serpulids and in rare cases textulariid and nodosariid foraminifers (Pl. 10, figs. 10, 11), as well as vertebrate remains. In thin sections, coarse-grained bioclasts lack. This is in coincidence with the field observations that numerous macrofossils are concentrated at the layer's surfaces.

In the transitional zone between the "septaria-bearing layers" and the belemnite-bearing strata, the ammonite *Aspidoceras richthofeni* (Pl. 3, fig. 1, Pl. 8, fig. 5) was found in 1994. The occurrence of this ammonite defines a Middle Kimmeridgian age for the succession (Gröschke & Kapilima 1995).

The upper part of sections of the *Smeei* Beds in Tingutinguti-Maimbwi area includes a remarkable, thickly layered, calcareous sandstone complex with coarse-grained components and pebbles (Pl. 2, fig. 4). This complex shows a high amount of bioclast, mainly fragments of bivalves, whereas biomorpha (= shell-bearing organisms) could not be identified. This sandstone complex may be considered to be an equivalent of the pebbly calcareous sandstone below the former excavation site near Mtapaia River (text-fig. 4: G2). However, in the area of Tingutinguti and Maimbwi Creeks, sandstones rich in bioclasts prevail. The total thickness of the upper part of the *Smeei* Beds in the Tingutinguti-Maimbwi area is 6 m.

The interpretation of the lithological features of the "*Smeei* facies" led to the reconstruction of very shallow sedimentary conditions north and south of the Tendaguru Hill. A striking fact in the northern sections is the repeated mass occurrence of large solitary corals (Pl. 2, figs. 1, 2, Pl. 4, fig. 1,) and oncoid-rich limestones, whereas the south is strongly influenced by a continental input. The close neighbourhood of the continent is proven mainly by subangular quartz and a high amount of hornblende and biotite. The sedimentation was probably highly influenced by some neighbouring river mouths.



Text-fig. 9: Block diagram of Tendaguru area after Hennig (1933-39).

4.1.5 Upper Saurian Beds

At the Tendaguru Hill, the continental deposits of the Upper Saurian Beds reach 40 m. At the base, 3 m thick, grey sandy marls and silts include stratified bones, which are locally associated with marine fossils. The adjacent grey and red marls of 10 m thickness extend up to the foot of the Tendaguru Hill. These sediments produced many dinosaur remains (see below). Many of the former excavation sites can still be traced north and south of the Hill (Pl. 2, fig. 6, Pl. 5, fig. 7, Pl. 7, fig. 5, Pl. 8, fig. 4). Locally, in the lower part of the marls and silts, lenticular hard sandstone layers, where the first mammal remain has been recorded (Branca 1916, Dietrich 1927, Heinrich 1991), occur.

The foot of the Tendaguru Hill consists of about 5 m thick, reddish marls and silts, comprising a high amount of clay. On top of a superimposed friable yellowish sandstone of 1,5 m thickness, 2 m of reddish clay-rich, sandy marls and silts are alternating (text-fig. 8). On top, there are about 10 m thick yellowish-greyish friable sandstone. The adjacent 7 m of grey, red sandy marls and silts form the top layers of the Upper Saurian Beds. With the exception of some westward directed creeks and channels, the outcrops mainly in friable parts are very poor.

Nevertheless, there is at least a 12 m thick section (text-fig. 4: G 3, text-fig. 6) below a former excavation site, which is situated 2-3 m NE of Tendaguru (Pl. 8, fig. 1). In a tiny channel below the friable calcareous silt- and sandstones, thin layered, partly laminated silt- and sandstones show intercalations of grey marls. A sample of a 60 cm thick dark marl was processed in order to find out possible microfossils; calcareous micro-organisms have not been found, but palynological studies are currently in progress. In the area of the terrace-shaped relief of the former excavation site, numerous large, but disarticulated and broken bones occur. Marine invertebrates, however, have not been found.

Following the Nambango Creek (tributary of Mtshinginyiri) till Nankongo Hill, Hennig (1933-1939) took another section of the Upper Saurian Beds (text-fig. 5, 9). In this section, the base consists of *Smeei* Beds inclusively "Hangend Oolith", the adjacent Upper Saurian Beds are overlain by the very thick *Bornhardti Schwarzi* Complex, forming the top of Nankongo. Even this easternmost outcrop of Upper Saurian Beds has produced bones (Janensch 1914c).

4.1.6 *Bornhardti Schwarzi* Complex

On top of the Upper Saurian Beds, the following marine cycle is represented by the *Bornhardti Schwarzi* Complex, which is called after both species of *Trigonia,* namely, *bornhardti* and *schwarzi*. Both species have never been found in association and their stratigraphic succession was never exactly established. Therefore, the *Trigonia*-bearing layers were designated as *Bornhardti Schwarzi* Complex (Lange 1914, Hennig 1933-1939). In terms of geomorphology, the *Bornhardti Schwarzi* Complex forms escarpments of the plateau-like elevations. The complex is dominated by calcareous sandstones and conglomerates. Its thickness reaches a maximum of 50 m. The existence of a gap between the Upper Saurian Beds and the base of the *Bornhardti Schwarzi* Complex was strongly debated (Kitchin 1929).

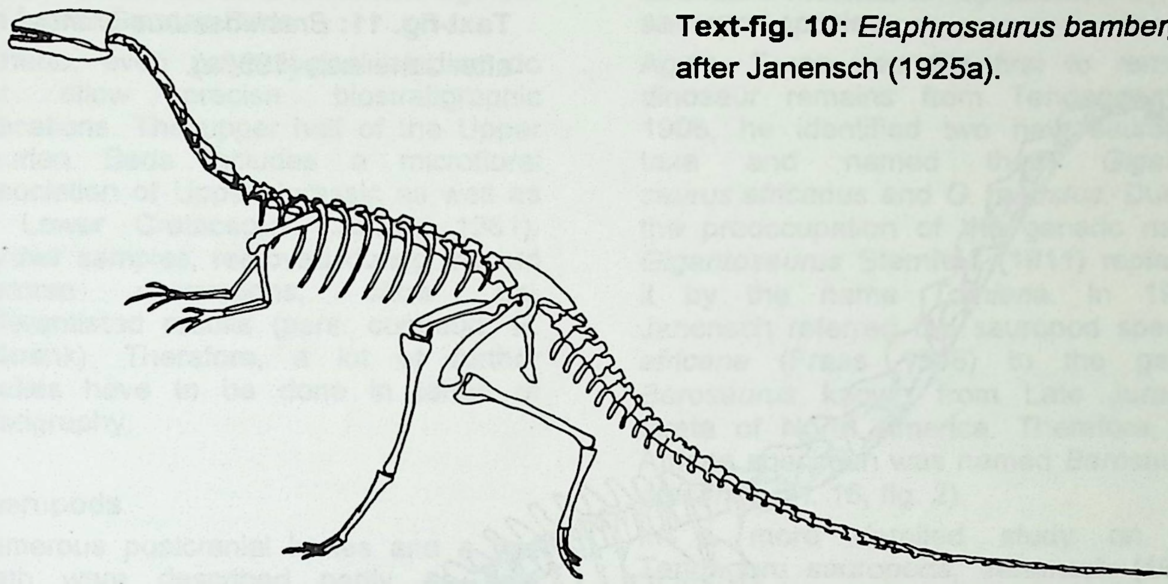
At the Tendaguru Hill, the thickness of the *Bornhardti Schwarzi* Complex does not exceed 5 m. At the base, a 50 cm thick light, coarse-grained sandstone bears many fossils, namely, numerous thick-shelled bivalves and corals. The superimposed yellow-brownish hard fossiliferous fine-grained sandstone of 4 m thickness includes bullet-like concretions of silky lustre. The concretions of a size of a human skull (Pl. 8, fig. 3) led to the name "Kugelsandstein" (Fraas 1908).

To the East, the maximum thickness of the series reaches 40 m (Mshinyiri River and Nankongo Hill). It should be pointed out that *Trigonia smeei* is present in these sections.

Due to the occurrence of *Trigonia bornhardti*, the age of this clastic succession is dated as Early Cretaceous (Aitken 1961, Dietrich 1933, Hennig 1933-1939; Zwierzycki 1914).

4.2 Makonde Series

Neither at the Tendaguru Hill nor in its close neighbourhood, the Makonde Series, generally overlaying the *Bornhardti Schwarzi* Complex are preserved. These series again represent a terrestrial episode. Although fossils are not recorded from the sandstones, they are thought to be of Aptian age (Hennig 1933-1939). The maximum thickness of these brick-red sandstones with white and reddish brown, coarse- to pebble-grained intercalations is described with a thickness of 200 m at the northern escarpment of the Likonde Kitale Plateau as well as at the north-western tip of the Noto Plateau (Hennig 1933-1939). The Makonde Series are devoid of calcareous materials. This fact, in comparison with the generally more or less calcareous Tendaguru Series, marks a fundamental change in the sedimentary regime.



Text-fig. 10: *Elaphrosaurus bambergi* after Janensch (1925a).

4.2.1 Kiturika Beds (Urgonian)

This unit is characterised by the orbituline-bearing Urgon facies and is an equivalent to the Makonde Beds. The presence of orbitulines is indicative for an Aptian age of the Kiturika Beds. The Kiturika Beds crop out north of Mbemkuru River. South of this river, the top of Mikadi Hill (Pl. 1, fig. 6) and the top of Nemba Hill, which is situated 30 km southwards, are formed by *Nerinea*-bearing reef limestones.

4.3 Lipogiro Pebbles (Mikindani Beds)

At the top of Tendaguru, the *Bomhardti Schwarzi* Complex is unconformably overlain by brownish sands and bright pebbles of fluviatile origin.

The same pebbles (Makonde quartzite and pure quartz) cover the top of the Lipogiro Plateau. Apart from other sediments, these clastics have eroded major parts of the *Bomhardti Schwarzi* Complex at Tendaguru. These conglomeratic series are called Mikindani Beds and locally are named Lipogiro Pebbles. Due to the lack of fossils, the age of the Lipogiro Pebbles is still under debate. Janensch (1914c) assumed a Late Cretaceous age, Hennig (1933-1939), however, proposed a Tertiary age. A Pliocene to early Pleistocene age seems most probable (Schlüter 1996).

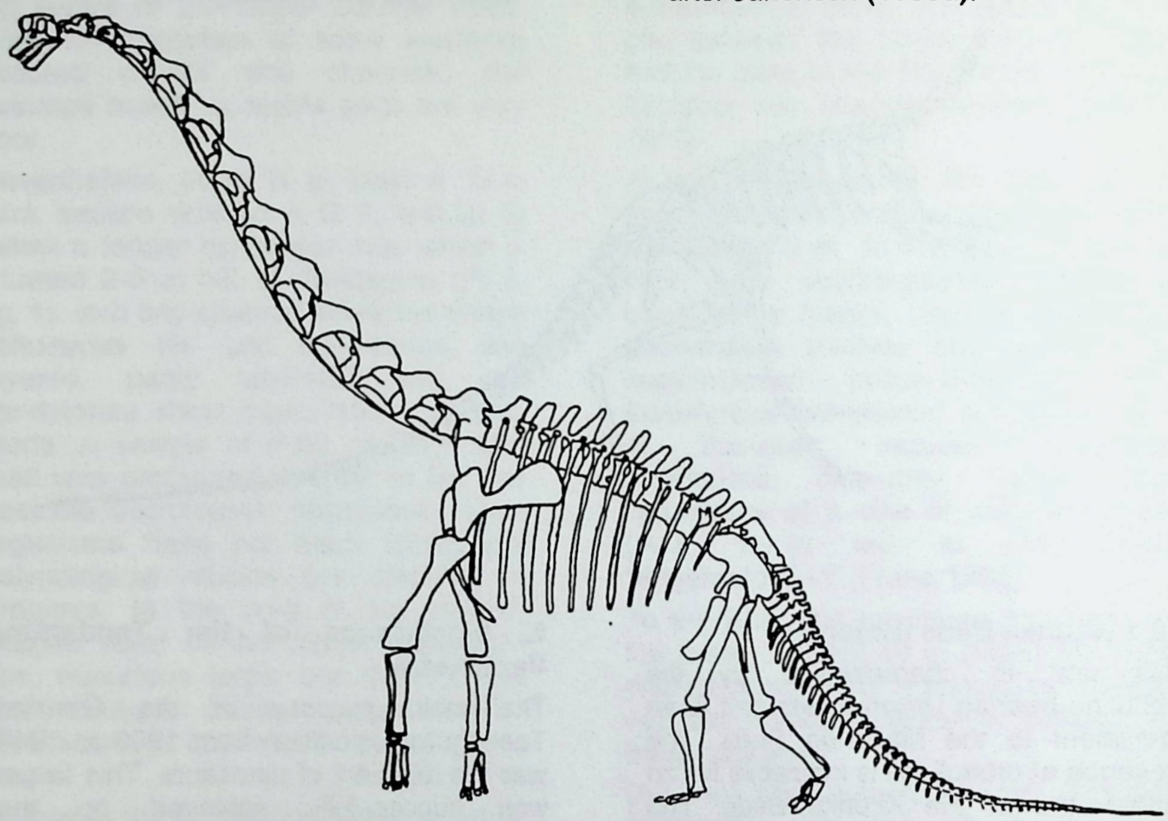
5. Significance of the Tendaguru Vertebrates

The main purpose of the German Tendaguru Expedition from 1909 to 1913 was the recovery of dinosaurs. This target was successfully achieved by the extraordinary fossil materials excavated during the mission. These fossils are still unique today. Apart from the spectacular dinosaur skeletons mounted in the Berlin Naturkundemuseum, the excavations brought out abundant materials of isolated bones and teeth, which are still of great value for palaeontology.

5.1 Dinosaurs

Most of the dinosaur remains of Late Jurassic age originate, as mentioned above, from the Middle Saurian Beds, the Upper Interlayers and the Upper Saurian Beds of the Tendaguru Series, which is nearly completely exposed only in the proximity of the Tendaguru Hill. Generally, the isolated or concentrated bones occur in grey-greenish, rarely reddish-calcareous-silty strata.

The bones and partly articulated skeletons found at or near the surface were deeply weathered. The trenches, however provided well preserved findings (Janensch 1914a). Usually the bones were slightly crushed and compressed.



Text-fig. 11: *Brachiosaurus brancai* after Janensch (1950a).

Only the highly complicated constructions of the processes of the neural arches were often dislocated. Basically all the bones showed fractures and cracks. But this feature has an advantage of its own, the huge bones naturally dissected could easily be packed into the bamboo containers of standard sizes and therefore, could comfortably be transported to Lindi (Janensch 1914a).

With the exception of one locality, about 500 m north of the Tendaguru Hill, where a few bones are associated (Pl. 8, figs. 4, 5), these have been rarely observed in situ during the 1994 field trip. As mentioned above, the conditions of exposure in the Tendaguru area are generally poor. The old excavation places are still recognisable by the artificial terrace-like relief of the landscape (Pl. 5, fig. 7; Pl. 7, fig. 5). In or around the former excavation zones, numerous skeletal fragments or bony splinters can be found assembled by men (Pl. 5, figs. 1-3, 5, 6, 8). These remnants obviously represent the residue of the excavations which due to poor preservation or lack of connection to other finds, have been left behind.

The exact stratigraphic positions of the dinosaur-bearing layers are still under debate. As mentioned above, the presence of *Trigonia bornhardti* defines an Early Cretaceous age for the *Bornhardti Schwarzi* Complex which overlays the Upper Saurian Beds (Dietrich 1933, Hennig 1933-1939, Lange 1914, Zwierzycki 1914). The Middle and Upper Saurian Beds which yielded most of the dinosaur materials are designated to Late Kimmeridgian-Tithonian age according to their ammonite contents (Aitken 1961, Russell et. al. 1980). However, the occurrence of *Aspidoceras richthofeni* (Pl. 3, fig. 1, Pl. 7, fig. 4) is indicative for a Middle Kimmeridgian age of the *Smeei* Beds (Kapilima & Grösche 1995). Therefore, at least the Middle Dinosaur Beds should be Middle Kimmeridgian or older in age. The record of *Perisphinctes* sp. in the *Nerinea* Beds indicates a Middle Oxfordian age (pers. commun. M. Gröschke in Zils et al. 1995), implying

Middle Oxfordian as a minimum age for the Lower Saurian Beds.

Hitherto, even palynological studies do not allow precise biostratigraphic indications. The upper half of the Upper Saurian Beds includes a microfloral association of Upper Jurassic as well as of Lower Cretaceous (Jarzen 1981). Further samples, removed during the old German excavations, show undifferentiated results (pers. commun. E. Schrank). Therefore, a lot of further studies have to be done in terms of stratigraphy.

Theropods

Numerous postcranial bones and a few teeth were described partly as new species by Janensch (1914b, 1925a, 1929). According to Rowe & Gauthier (1990), these specimens do not show diagnostic characters and therefore, are considered as early theropods of an unknown systematic position. However, there are two exceptions, a femur figured by Janensch (1925a: Pl. 5: fig. 2a-c) is indicative for the presence of a ceratosaur of an unknown genus. The occurrence of an allosaurid carnosaur in the Tendaguru Beds is documented by a tibia (Janensch 1925a, Molnar & Farlow 1990).

The skeleton of *Elaphrosaurus bambergi* Janensch 1920 is mounted in the Berlin Naturkundemuseum (text-fig. 10). This theropod was a relatively huge, more than 5 m long, bipedal cursor. The figure of *Elaphrosaurus bambergi* resembled modern ground birds, like recent African ostriches. Many modern palaeontologists such as Galton (1982b), Barsbold & Osmólska (1990) attribute this form to ornithomimosaurs. Therefore, the Late Jurassic *Elaphrosaurus bambergi* is on one hand the oldest known ornithomimosaur and on the other hand the only representative of this group known from Gondwanian continents, whereas it is widespread in Cretaceous sediments of North America and Asia.

Sauropoda

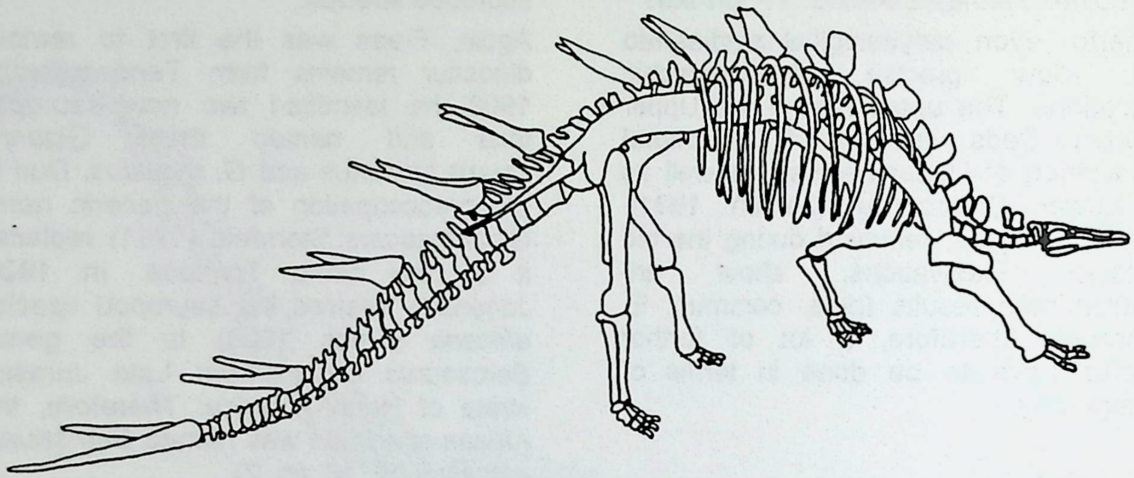
The Tendaguru dinosaur assemblage is dominated by sauropods. The most abundant material is represented by six sauropod species.

Again, Fraas was the first to remove dinosaur remains from Tendaguru. In 1908, he identified two new sauropod taxa and named them *Gigantosaurus africanus* and *G. robustus*. Due to the preoccupation of the generic name *Gigantosaurus* Sternfeld (1911) replaced it by the name *Tornieria*. In 1929, Janensch referred the sauropod species *africana* (Fraas 1908) to the genus *Barosaurus* known from Late Jurassic strata of North America. Therefore, the African specimen was named *Barosaurus africanus* (Pl. 16, fig. 2).

In a more detailed study on the Tendaguru sauropods, Janensch (1961) recognized the variety *Barosaurus africanus* var. *gracilis* which subsequently was considered to represent the species *gracilis* by Russell et al. (1980) and McIntosh (1990) so that the diplodocid sauropod *Barosaurus* is recorded by two species in the Tendaguru Series. Both specimens are associated in the *Smeei* Beds lying between the Middle and the Upper Saurian Beds, but the species *gracilis* is exclusively known from the Middle Saurian Beds, whereas *Barosaurus africanus* (Pl. 16, fig. 2), is exclusively recorded from the Upper Saurian Beds (Janensch 1961).

In the Tendaguru Series, the sauropod family Diplodocidae is represented by another genus, *Dicraeosaurus*, which is only known from this locality. In the Middle Saurian Beds the remains of the species *D. hansemanni* Janensch 1914b occur. The more lightly-built form, *D. sattleri* Janensch 1914b, was removed from the Upper Interlayers and the Upper Saurian Beds. As early as during the excavations, Janensch (1914a, 1935) considered the most complete skeleton of *Dicraeosaurus hansemanni* worth to be mounted in the Berlin Naturkundemuseum.

Since *Gigantosaurus africanus* = *Tornieria africana* = *Barosaurus africanus* was the type species of *Tornieria*, this name was no longer valid for the sauropod *robusta* (Fraas 1908). Therefore, Wild (1991a) introduced the new name *Janenschia*,



Text-fig. 12: *Kentrurosaurus aethiopicus* after Janensch (1925b).

which is dedicated to W. Janensch, the leader of the Tendaguru Expedition from 1909 to 1913 and the explorer of most of the Tendaguru dinosaurs (Pl. 16, fig. 1, 3). The sauropod *Janenschia robusta* (Fraas 1908) does not show diplodocid characters, but features similar to titanosaurids. Therefore, *Janenschia robusta* is the oldest known member of this African sauropod family (Pl. 16, Fig. 1, 3).

The most spectacular dinosaur from Tendaguru is the sauropod *Brachiosaurus brancai* Janensch 1914b (text-fig. 11, Pl. 16, figs. 4, 5). Although *Brachiosaurus brancai* is not the largest known dinosaur, the specimen, mounted in the Berlin Naturkundemuseum, is the biggest dinosaur, which has ever been exhibited in a museum. With its long neck and its long fore limbs, which are higher than the hind legs (Pl. 16, figs. 4, 5), the animal of 22,5 m in length has the figure of a gigantic giraffe. Taking into account the total size of *Brachiosaurus brancai*, its head is relatively small and lightly built by largely expanded cranial openings (Janensch 1935-36, 1950a,b). Based on photogrammetric methods, the volume and consequently the dimensions of *Brachiosaurus brancai* were recently redetermined in order to give information on thermoregulatory and cardio-circulatory patterns of this fossil (Gunga et al. 1995).

Ornithischia

Ornithischians are represented by two different groups in the Tendaguru Series, huge quadruped armoured and small bipedal non-armoured forms.

The stegosaur *Kentrurosaurus aethiopicus* Hennig 1915 (text-fig. 12) was the first Tendaguru dinosaur mounted in the Berlin Museum in 1924 at the occasion of the 80th birthday of Branca, the manager of the Tendaguru Expedition from 1909 to 1913 (Janensch 1925b). From the head to the mid-trunk, *Kentrurosaurus* (text-fig. 12) bore a row of paired triangle plates. This character is common to the African and the North American species. But there is a striking difference compared to the American representative the former one having triangle plates in the caudal part, the African species showing slender pointed spines in this part of the body. Even the tail of *Kentrurosaurus aethiopicus* ends in two spines (Hennig 1925). Furthermore, there are pointed, distally backwards directed spines. Whereas Janensch (1925b) placed these spines laterally near the pectoral girdle, Galton (1982a) located it in the pelvic region. The latter recently studied the cranial morphology of *Kentrurosaurus aethiopicus* in detail (Galton 1988).

In contrary to the heavy ponderous *Kentrurosaurus aethiopicus*, the bipedal ornithopod *lettowvorbecki* (Virchow 1919) is lightly-built and shows long slender hind limbs with three toes. With a length of 1,10 m, this cursorial animal represents the smallest Tendaguru dinosaur. During World War I, J. F. Pompeckj, at that time director of the Museum in Berlin, started the scientific study of this ornithopod. Unfortunately, he died too early to finish his work. During World War II, a large part of the already opened material, including the types, were destroyed. But due to the immense stock, Janensch could arrange new preparations of the remaining specimens (Janensch 1950c). He finished the description of *Dysalotosaurus lettowvorbecki* in 1955 and illustrated the reconstruction of its skeleton some years later (Janensch 1955, 1961). Due to significant morphological similarities, Galton (1980b, 1981, 1983) attributed the Tanzanian species *lettowvorbecki* to the genus *Dryosaurus*, known from North America. The systematic position of this genus is still under debate (Galton 1980b, 1981, 1983, Milner & Norman 1984, Sues & Norman 1990).

However, recent studies on limb bones of *Dryosaurus lettowvorbecki* revealed details on femoral ontogeny and locomotion biomechanics (Heinrich et al. 1993) as well as histology (Chinsamy 1995). The most important condition for the reconstruction of these histological changes through ontogeny is the availability of numerous individuals at different stages of growth, a fortunate circumstance obtained from the material of the Tendaguru Expedition.

To sum up, the dinosaur assemblage of the Tendaguru Series includes theropods, ornithischians and sauropods (text-fig. 13). The theropods were rarely found, the ornithischian remains were accumulated in a few localities, whereas the sauropods occurring in abundance predominate with six species.

Apart from *Dicraeosaurus*, *Barosaurus* and *Janenschia*, the giraffe-like *Brachiosaurus* is the largest sauropod from the Tendaguru Series (text-fig. 11). Small vegetarians are the ornithischians *Kentrurosaurus* and *Dryosaurus*, the latter representing one of the smallest Tendaguru dinosaurs. According to their rarity in the ecosystem, theropods were only removed by a few fragments, especially teeth and the skeleton of *Elaphrosaurus* from the Tendaguru area.

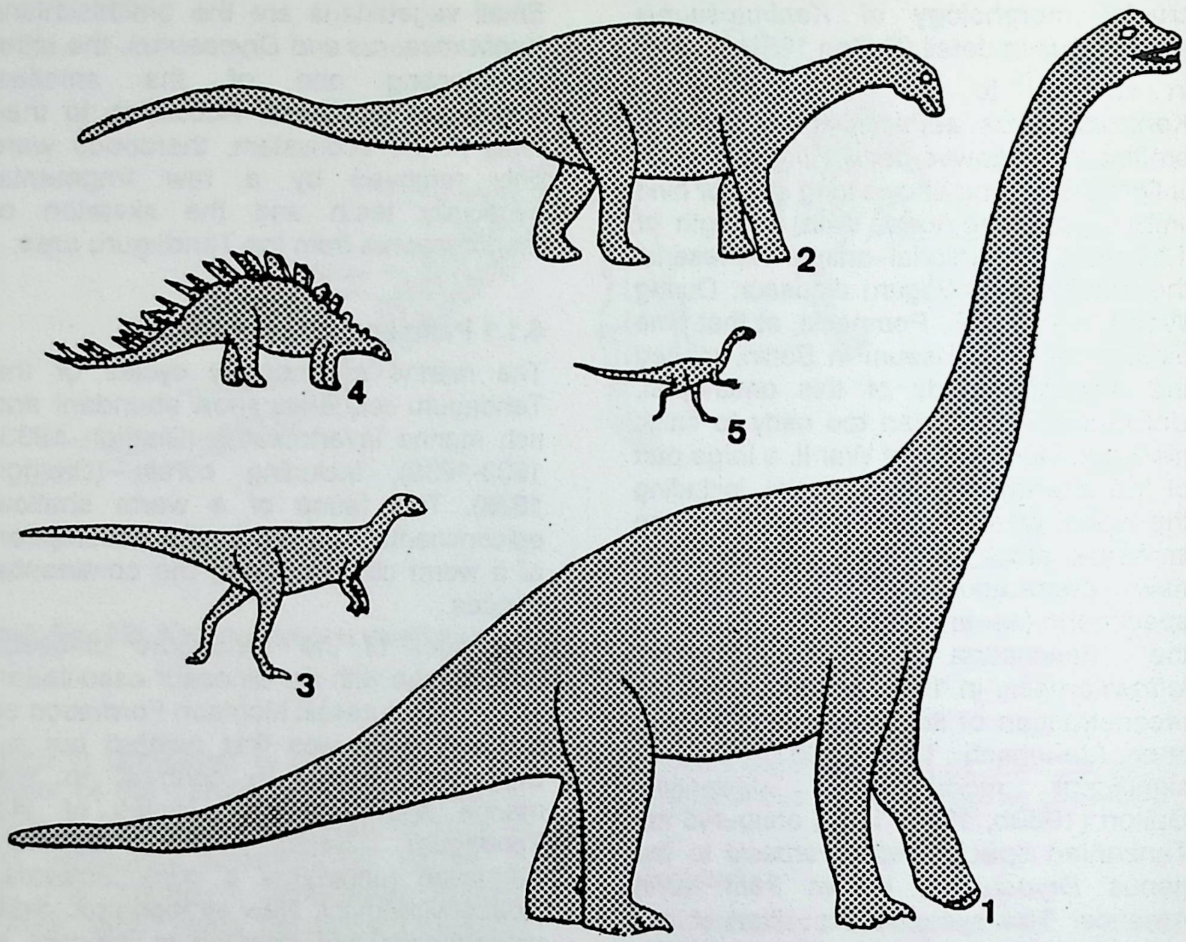
5.1.1 Paleoecological Aspect

The marine sedimentary cycles of the Tendaguru sequence show abundant and rich marine invertebrates (Dietrich 1933, 1933-1939), including corals (Dietrich 1926). This fauna of a warm shallow epicontinental sea led to the assumption of a warm climate during the continental periods.

Similarities of the Tendaguru dinosaur assemblage with the dinosaur association of the Late Jurassic Morrison Formation of North America was first pointed out by Schuchert (1918). In contrast to the marine and continental cycles of the Tendaguru Series, the Morrison Formation represents a pure terrestrial paleoenvironment. New stratigraphic data of ostracods and charaphyts indicate a Kimmeridgian age for the Morrison Formation, whereas the top layers might include Tithonian age (Schudack 1995).

In an exhaustive recapitulation Russell (1989) reconstructed an impressive image of the Late Jurassic life in the western interior plain of North America. In his graphic description, he illustrated the Late Jurassic ecosystem of the ancient Morrison World by including comparisons with the recent Wild Life in Africa. According to the feeding behaviour, Russell (1989) categorised the dinosaurs and made sometimes comments on the Tendaguru dinosaurs.

Theropods rarely found in the Tendaguru Series, but more common in the Morrison Formation, include the large carnivorous bipeds, like a ceratosaurid and an allosaurid form. *Elaphrosaurus* is classified as a small carnivorous bipedal predator, though it lived like the running omnivores of today, the ostriches (Russell 1989).



Text-fig. 13: Outlines of the most important Tendaguru Dinosaurs (after Cox et al. 1989) in their relative size: **1.**: *Brachiosaurus brancai*, length: 22,70 m, height: 11,90 m; **2.**: *Dicraeosaurus hansemanni*, length: 13,20 m, height: 3,20 m; **3.**: *Elaphrosaurus bambergi*, length: 5,4 m, height: 2,25 m; **4.**: *Kentrurosaurus aethiopicus*, length: 4,7 m, height: 1,60 m; **5.**: *Dryosaurus lettowvorbecki*, length: 2,35 m, height: 1,10 m.

In the Tendaguru Series, plant-eating bipeds are represented by *Dryosaurus lettowvorbecki* in the Middle Saurian Beds. The skeletal fragments of this animal are concentrated in one locality in the Middle Saurian Beds (Janensch 1914c). Therefore, it can be deduced that these animals herded and that they died by a single event, perhaps a flash flood (Russell 1989). Similar to *Dryosaurus*, the remains of the quadruped low-browsing stegosaur of Africa, *Kentrurosaurus aethiopicus,* were mainly accumulated in two localities in the Middle Saurian Beds. This also suggests herding behaviour and a mass extinction by a disaster. In the Morrison Formation, fragments of these ornithischian animals were never recorded in abundance.

The Lower Saurian Beds which crop out very poorly and were therefore long time under debate (see above), have yielded only a few vertebrate fragments, e.g. two limb bones of *Brachiosaurus brancai* and six theropod teeth (Janensch 1961).

Apart from the herbivore ornithischians, in the Middle Saurian Beds huge plant-eating quadrupeds, such as *Brachiosaurus brancai*, *Barosaurus gracilis* and *Dicraeosaurus hansemanni* occur (Janensch 1961, Russell 1989). Many sauropods are documented by distal parts of the limbs. Relatively often, mostly all elements of the foot were associated in a natural upright position (Pl. 13, fig. 6). This taphonomic feature suggests that the sauropods died by being stuck in the mud of a flood disaster.

In the transitional zone of the Middle Saurian Beds and the basal horizons of the *Smeei* Beds, as well as the uppermost part of this complex and the Upper Saurian Beds many sauropod limb bones were reworked (Janensch 1914c). The concentration of these bones, especially the high amount of those of *Barosaurus*, may suggest seasonal migrations of these sauropod herds along the coastline (Russell et al. 1980).

The Upper Saurian Beds are characterised by the predominance of plant-eating quadrupeds, *Brachiosaurus brancai*, *Dicraeosaurus sattleri*, *Barosaurus africanus* and *Janenschia robusta* (Russell et al. 1980).

The occurrence of a conchostracan (Janensch 1933-39) and of pulmonate gastropods (Dietrich 1914) as well as numerous remains of pterosaurs (Reck 1931) confirms the assumption that the sedimentation of the Upper Saurian Beds took place in a pure terrestrial environment. The abundance of the pollen *Classopollis* in the upper part of the Upper Saurian Beds, suggests a relatively warm and dry climate in the coastal area. The plants producing the *Classopollis* pollen, have grown on the slopes in the hinterland and in coastal plains under warm and dry climatic conditions (Jarzen 1981). Seasonal or regional drought is indicated by mass mortality (Janensch 1914c, Russell et al. 1980) as well as by palynological results (Jarzen 1981). Although there are the remains of only one plant known from the Tendaguru Series (Gothan 1927) which is found in the Upper Saurian Beds, the diversity of the sauropods in this sedimentary complex is indicative of a dense rich vegetation, most presumably near to the river courses and permanent lakes in a relatively dry lowland. Since 60% of the articulated feet in upright position (Pl. 13, fig. 6) originate from the Upper Saurian Beds (Russell et al. 1980), the climate was characterised by numerous flood disasters.

During the Late Jurassic period, an ecosystem of a transitional zone of a flat coastal lowland and a flat epicontinental sea can be drawn. By periodic movements of the coastline, a cyclic sedimentation took place. The marine intervals showing varying continental influence were characterised by flat, high energy near shore sediments. During the continental periods, the flat coastal lowland was affected by occasional inundation (fluvial and monsoonal overflow). In these situations the numerous dinosaurs were imbedded.

5.2 Other Vertebrates

As mentioned before, recovery of dinosaurs was the main objective of the expedition of 1909-1913 so that the attention of the excavation was directed to spectacular fossils, huge bones and articulated skeletons. This gives the certainly wrong impression that the Tendaguru Fauna included exclusively large or very huge animals. There was no methodical search for smaller vertebrates, such as fishes, amphibians, tiny reptiles and mammals. The microvertebrates, nevertheless known from the Tendaguru Series, were found by chance.

In contrast to many other Mesozoic localities, where crocodile skutes were found abundantly, there are a few crocodilian remains in the Tendaguru Series (Janensch 1914b, written commun. R. Wild). Even shell fragments of turtles, which often occur in Mesozoic vertebrate-bearing localities, could not be proven in the Saurian Beds.

Fishes

Fish remains occur in the Upper Saurian Beds. One locality yielded two nodules each with a more or less complete specimen of *Lepidotus minor* Agassiz, numerous remains of a swarm of this fish was found in another locality (Hennig 1914c). In addition, Hennig (1914c) described elasmobranchian teeth and a fragment of a fin spine from the basal parts of the Middle and the Upper Saurian Beds.

The fish *Lepidotus* and the mentioned elasmobranchian could have lived in marine as well as continental environment and therefore, can characterise the transitional zone between the continental and marine environments.

Pterosaurs

Although there was a preliminary note on the occurrence of bird remains (Janensch 1914b), no avian fragment has been identified. However, the Middle and the Upper Saurian Beds yielded more than 150 isolated characteristic bones of pterosaurs (Reck 1931). These fragments are attributed to three genera, two of them known from Late Jurassic sediments of Solnhofen (Germany). In Africa, the long-tailed form *Rhamphorhynchus* is represented with the species *tendagurensis* Reck 1931, and the short-tailed genus *Pterodactylus* is documented by the species *amingi* Reck 1931 and *maximus* Reck 1931. According to Galton (1980a), the Tendaguru species *brancai* Reck 1931 should be assigned to the genus *Dsungaripterus*, which is known from the Lower Cretaceous of China.

Mammals

The Mesozoic evolution of African mammals is quite unknown. Although there are intensive activities in prospecting for mammal teeth in Africa (Werner 1995) and Madagascar, only five localities produced scarce mammal remains up to now (Krause et al. 1994; Brunet et al. 1988; Sigogneau-Russell et al. 1988, 1990; Sigogneau-Russell 1989, 1991a, 1991b; Crompton 1974). Therefore the record of a mammal jaw fragment from the Upper Saurian Beds, which was already mentioned in 1916 by Branca and confirmed by Dietrich (1927) as *Brancatherulum tendagurense* is very important. Recently the specimen underwent careful new preparations, which brought out many informative details. According to these characters the Tendaguru mammal remains can be referred to as a representative of the eupantotherian families Paurodontidae or Peramuridae (Heinrich 1991). Since the Tendaguru jaw fragment was found without teeth, W.-D. Heinrich started to look for mammalian teeth by processing sediment samples from the Middle and Upper Saurian Beds which have been taken during the Tendaguru Expedition in 1908-1913. Apart from numerous reptilian teeth and a lizard jaw, which is referred to the Paramacelloididae (pers. commun. A. Richter), Heinrich succeeded in isolating a second mammalian jaw fragment as well as a single mammalian tooth currently under study (pers. commun. W.-D. Heinrich).

6. Future Prospects

In the report of the fourth field season Branca (1914b: 62) quoted from a letter of Hans Reck, who led the last excavation period of the Berlin Museum, "that the occurrence of dinosaurs, which were easy to find, might mainly be exploited in the Tendaguru area. "Twelve years later, the British Museum started again though on a small-scale, successful digging for more than five years. Due to these enormous and lengthy operations, the frequency of bones is of cause reduced. According to our observations, however, weathered fossils, both bones as well as invertebrates occur in abundance at the surface today in the Tendaguru area. But good outcrops do not exist, and therefore investigations should be prepared by artificial intervention of the landscape in order to collect the fossils systematically and horizon by horizon.

New Targets

Apart from essential questions in terms of paleoenvironment and stratigraphy, a new palaeontological enterprise in the Tendaguru area would have targets different from that of the former excavations aimed on dinosaur skeletons. Modem vertebrate palaeontology now focuses also on microvertebrates, since the fossil history of these groups is not yet really understood. A new project in the Tendaguru area therefore should aim less at removing big dinosaurs, but at winning of small vertebrates. Since dinosaurs as faunal element dominating the Mesozoic terrestrial ecosystems were associated with the rare mammals, the big bones are strongly indicative for the occurrence of microvertebrates. In contrast to many other fossils, mammalian remains can only be found by using special methods because of their rarity in the sediment and their microscopic size. In the beginning of the century, the discovery of the mammal fragment was by mere chance and therefore represents a lucky exception; this is especially valid in the sediments of Africa where the Mesozoic evolution of mammals is till today fairly unknown. The presence of large vertebrates in the Tendaguru Series proposes basically the occurrence of small vertebrates in this sequence and promises the producing of a rich microvertebrate assemblage from the Late Jurassic of Tanzania by using the well-tried micropalaeontological methods.

Methods

The first step in recovering microvertebrates is to look for the place suitable for large-scale sampling (several tons of sediment). The best sample is from sediments showing many tall and tiny bones. Since the sediments of the Saurian Beds of the Tendaguru area are calcareous, this content should be dissolved by acetic acid before being washed and sieved. The residue should be treated with heavy liquid, in order to concentrate the phosphatic components (bones and teeth). This concentrate has to be screened under the binocular in order to isolate the microvertebrates.

Logistics

While in the beginning of the century, the enormous earth-movements were managed exclusively by human power, these could be coped up now by machinery. For the chemical treatment of the samples and the washing of the concentrate, high quantities of water would be necessary, which would require a modern ground water development.

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In principle, a new project should take place on a large-scale level entailing great expenses, which could only be with the intensive co-operation of Tanzanian partners for example, the University of Dar es Salaam and the Antiquities Unit. The participation of international organisations would be very desirable as well. A new excavation by using modern paleontological methods would probably provide immense progress in our knowledge of vertebrate evolution and especially in the history of mammals in Africa and the entire world.

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Tendaguru Expedition 1994

Plate 1

Tendaguru Hill and Surrounding Area

Fig. 1: Main road from Lindi to Dar es Salaam at Nkwajuni Village with the junction to Tendaguru Hill on the left

Fig. 2: Track from Nkwajuni to Tendaguru Hill -left to Mipingo Village, right to Tendaguru Hill

Fig. 3: Track from Mnyangara to Namapuia Village

Fig. 4: Northern view of Tendaguru Hill

Fig. 5: Western view of Tendaguru Hill

Fig. 6: Urgon facies at the top of Mikadi Hill

Fig. 7: View from Tendaguru Hill overlooking Mbemkuru Depression

Fig. 8: Upper Saurian Beds at the foot of Tendaguru Hill

Fig. 9: Survey caravan of Tendaguru Expedition 1994 (November) in Tingutinguti Maimbwi area

Fig. 10: Camp of Tendaguru Expedition 1994 (November) in Namapuia

PLATE 1

Tendaguru Expedition 1994

Plate 2

***Smeei* Beds and Upper Saurian Beds**

Fig. 1: Fossil-rich limestone with *Nerinea* and solitaire corals from *Smeei* Beds, west of Mtapaia River

Fig. 2: Anthozoa indet. from *Smeei* Beds, west of Mtapaia River

Fig. 3: Cross-bedded, coarse-grained horizon of "Hangend Oolith" of *Smeei* Beds at the western rim of Ukulinga Plateau

Fig. 4: Bioclasts-bearing conglomerate from top of *Smeei* Beds of the Tingutinguti and Maimbwi area

Fig. 5: Septaria covered with bivalves from the "Septarian horizon" of *Smeei* Beds in the Tingutinguti and Maimbwi area

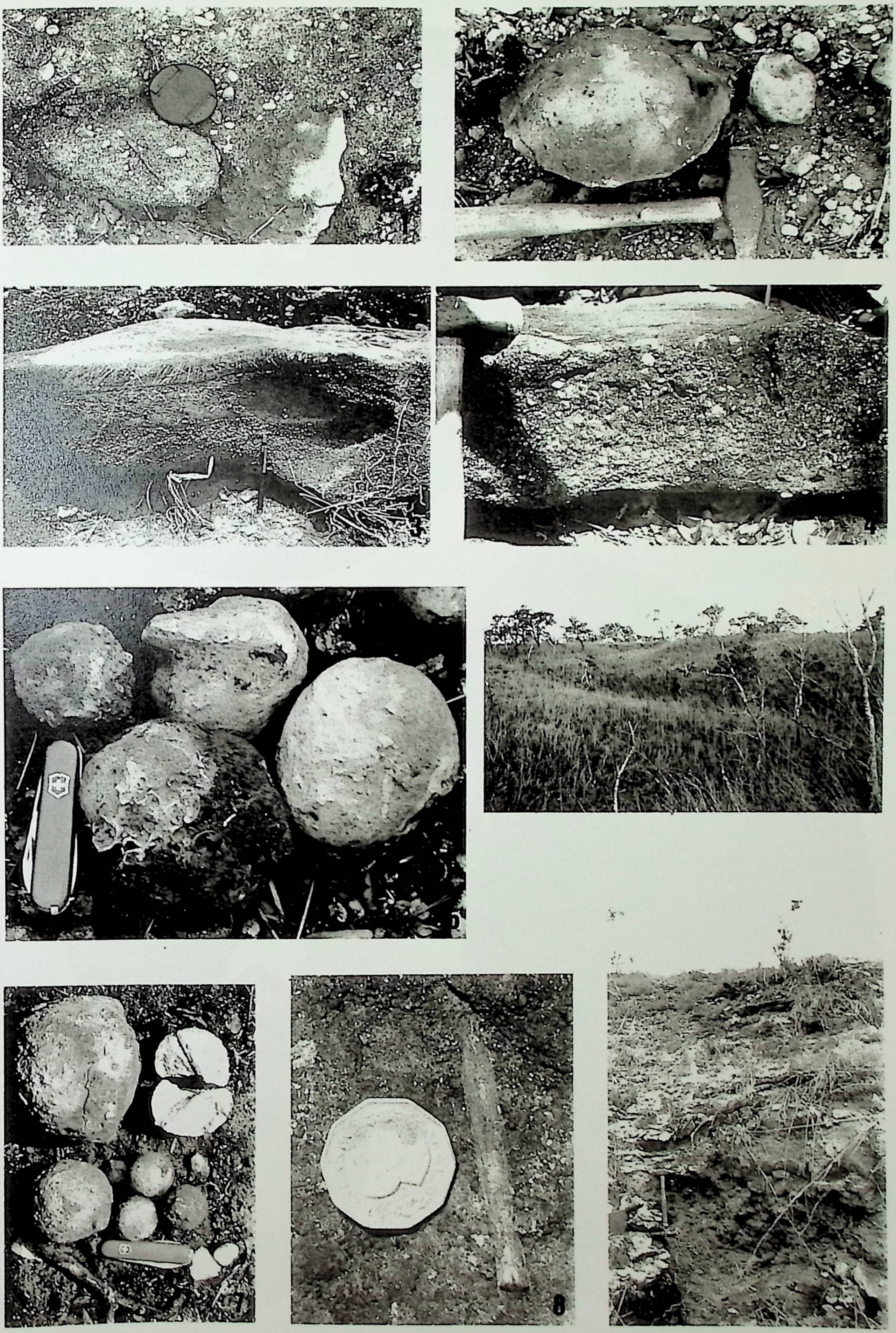
Fig. 6: Former excavation site in the Upper Saurian Beds, north of Tendaguru Hill

Fig. 7: Septaria from the "septaria-bearing layers" of *Smeei* Beds in the Tingutinguti Maimbwi area: opened septarium including plant remains

Fig. 8: Belemnite rostrum from the „belemnite-bearing layers“ of *Smeei* Beds in the Tingutinguti and Maimbwi area

Fig. 9: Outcrop of *Smeei* Beds, below a former excavation site, north of Tendaguru Hill

PLATE 2



Tendaguru Expedition 1994

Plate 3

Cephalopods from the Tingutinguti and Maimbwi Area

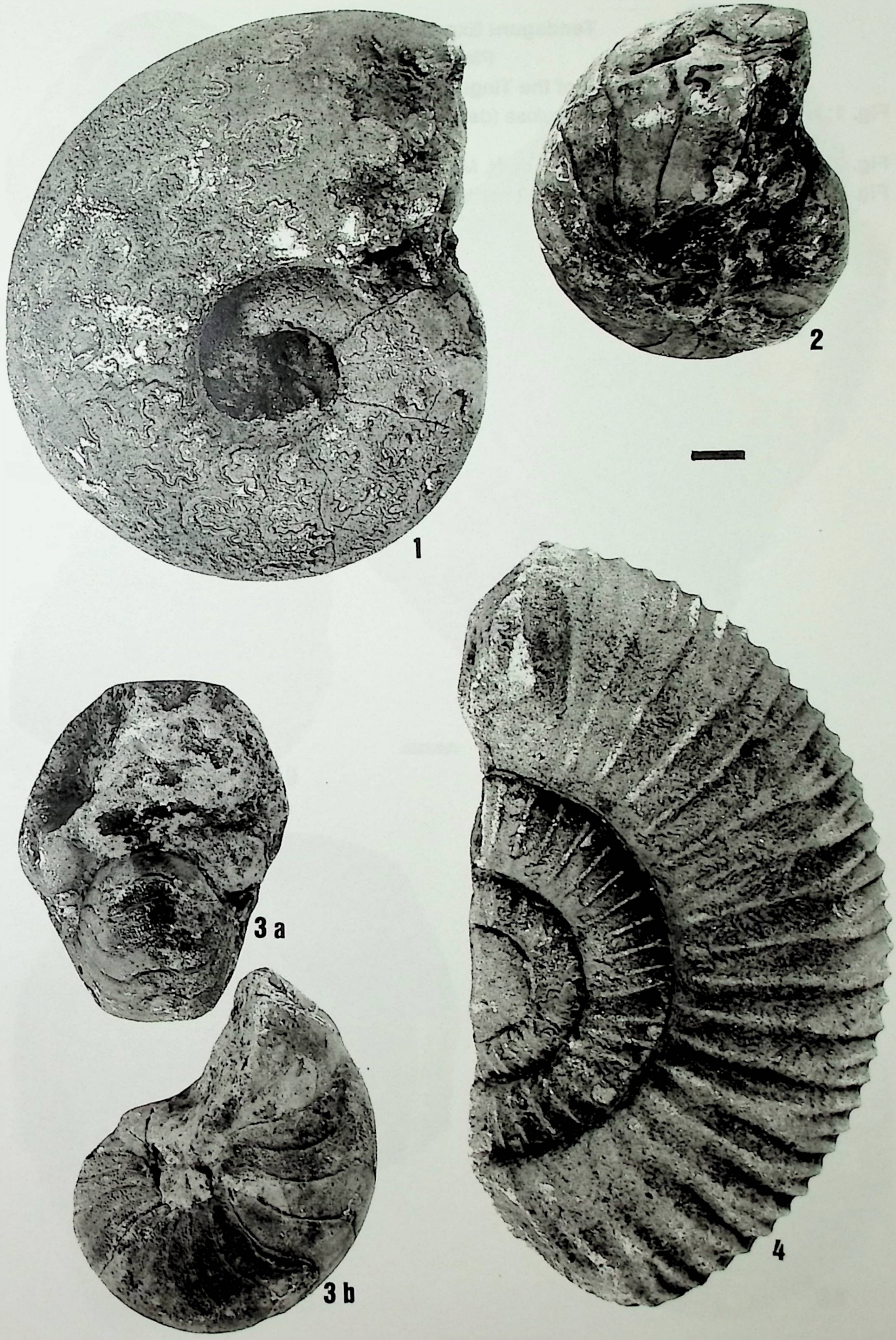
Fig. 1: *Aspidoceras richthofeni*, Middle Kimmeridgian (see Gröschke & Kapilima 1994) from *Smeei* Beds

Fig. 2: *Nautilus* sp. from "septaria-bearing layers" of *Smeei* Beds

Fig. 3: a+b: *Nautilus* sp. from "septaria-bearing layers" of *Smeei* Beds

Fig. 4: *Perisphinctes* sp., Middle Oxfordian (pers. commun. M. Gröschke) from the *Nerinea* Beds

PLATE 3



Tendaguru Expedition 1994

Plate 4

Invertebrates of the Tingutinguti and Maimbwi Area

Fig. 1: a+b: Coral: *Astocoenia colliculosa* (determined after Dietrich 1926: Pl. 14, fig. 1), west of Mtapaia River

Fig. 2: *Lopha*-like oyster (pers. commun. N. Malchus), west of Mtapaia River

Fig. 3: a+b: *Nautilus* sp. from "septaria-bearing layers" of *Smeei* Beds

PLATE 4

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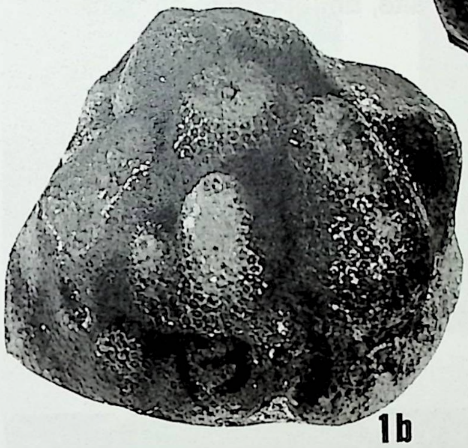

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3b

Tendaguru Expedition 1994

Plate 5

Dinosaur bones from the Upper Saurian Beds, a former excavation site and a recent gastropod

Fig. 1: Distal parts of limb bones found in a former excavation site, about 500 m north of Tendaguru Hill

Fig. 2: Further distal parts of limb bones found in a former excavation site, about 500 m north of Tendaguru Hill

Fig. 3: A vertebra centre and other indeterminable bone fragments found in a former excavation site, about 500 m north of Tendaguru Hill.

Fig. 4: Shell of a the recent snail genus *Achatina* put high up in the branches of a three. This sign was used during the Tendaguru Expedition 1909-1913 to mark a bone-bearing locality.

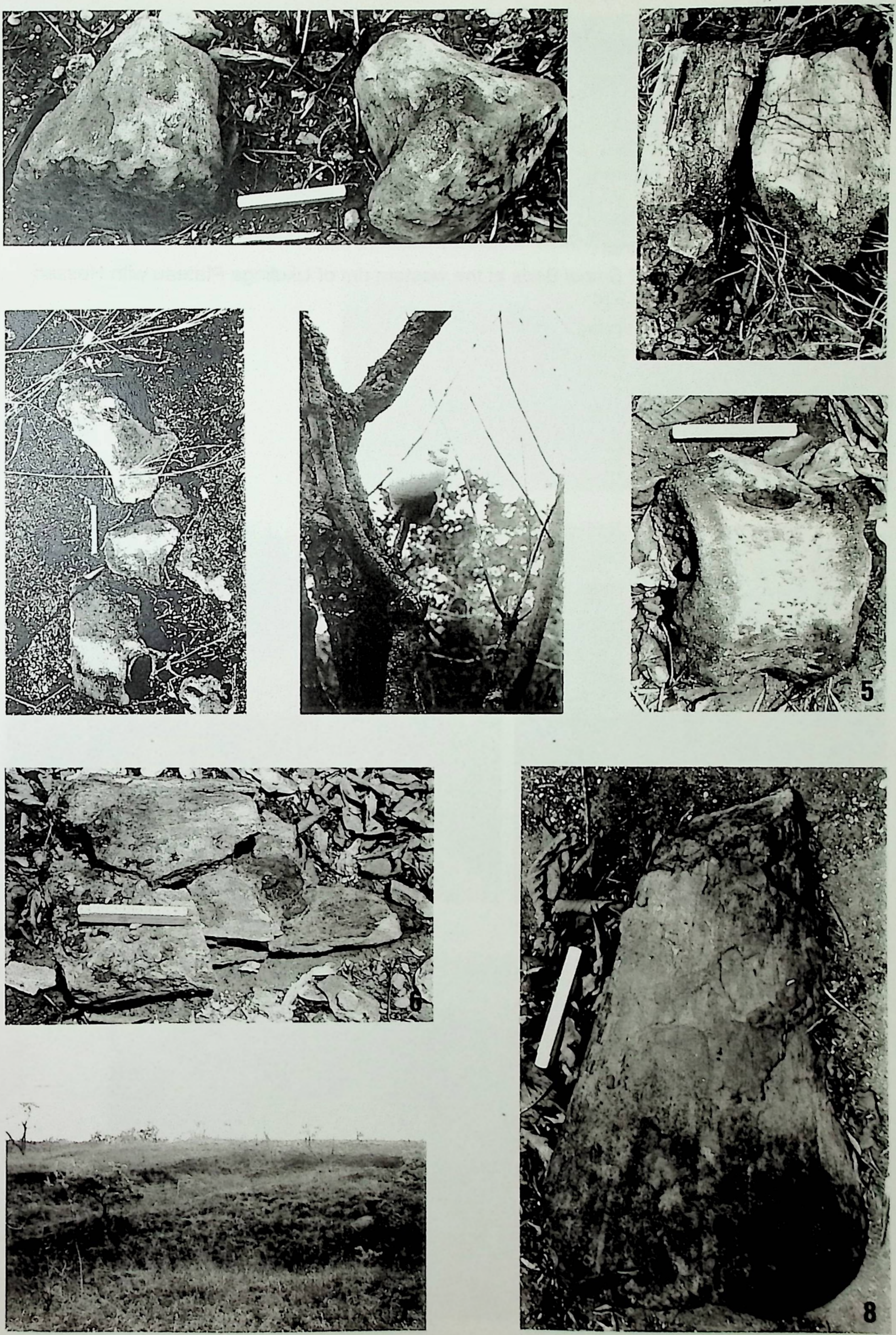
Fig. 5: Vertebra centre found in a former excavation site, about 500 m north of Tendaguru Hill

Fig. 6: Bone fragments found north of Tendaguru Hill

Fig. 7: Former excavation site about 500 m north of Tendaguru Hill

Fig. 8: A distal part of limb bones found in a former excavation site, about 500 m north of Tendaguru Hill

PLATE 5



Tendaguru Expedition 1994

Plate 6

From Lindi to Tendaguru Hill

Fig. 1: View of Lindi Bay from the north and its opposite site namely Kitanda Hill, which consists of Oligocene sediments

Fig. 2: View of Kitanda Hill from Lindi Beach Hotel, in front a dhau and the pier of the local ferry

Fig. 3: Mbemkuru River in the dry season of January 1994, near the main road from Dar es Salaam to Lindi .

Fig. 4: "Hangend Oolith" of *Smeei* Beds at the western rim of Ukulinga Plateau with Hassan S. Ntile in January 1994

Fig. 5: Northern slope of Tendaguru Hill

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Orientierende Tendaguru-Expedition 1994
Tafel 7
Tendaguru und Ammoniten

Fig. 1: Westhang der Tendaguru-Kuppe.

Fig. 2: Obere Saurierschichten am Westhang der Tendaguru-Kuppe.

Fig. 3: Obere Saurierschichten am Westhang der Tendaguru-Kuppe.

Fig. 4: *Perisphinctes* sp. (unten) aus den "Nerineen"-Schichten und *Aspidoceras richthofeni* (oben) aus den "Septarien-Bänken" der *Smeei*-Schichten aus dem Bereich des beiden Bäche Tingutinguti und Maimbwi.

Fig. 5: Alte Grabungsstelle in den Oberen Saurierschichten nördlich des Tendaguru.

Tendaguru Expedition 1994
Plate 7
Tendaguru Hill and Ammonites

Fig. 1: Western slope of Tendaguru Hill

Fig. 2: Upper Saurian Beds at the western slope of Tendaguru Hill

Fig. 3: Upper Saurian Beds at the western slope of Tendaguru Hill

Fig. 4: *Perisphinctes* sp. (below) from the *Nerinea* Beds and *Aspidoceras richthofeni* (at the top) from "septaria-bearing layers" of *Smeei* Beds in the Tingutinguti Maimbwi area.

Fig. 5: Former excavation site in the Upper Saurian Beds, north of Tendaguru Hill.

PLATE 7 TAFEL 7

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Orientierende Tendaguru-Expedition 1994
Tafel 8
Im Gebiet der alten Grabungstellen

Fig. 1: *Smeei*-Schichten im Liegenden einer alten Grabungsstelle westlich des Flusses Mtapaia (Abb. 4: G2) mit Autoren (hinten C.S., vorne C.W.).

Fig. 2: Westrand der Tendaguru-Kuppe.

Fig. 3: "Kugelsandstein" aus den *Bornhardti-Schwarzi*-Schichten vom Top des Tendaguru.

Fig. 4: Dinosaurier-Knochenfragmente aus einer alten Grabungstelle nördlich des Tendaguru (re. Autor C.S.).

Fig. 5: Dinosaurier-Knochen aus einer alten Grabungstelle nördlich des Tendaguru

Fig. 6: Südlicher Dorfeingang von Namapuia.

Tendaguru Expedition 1994
Plate 8
Former Excavation Sites

Fig. 1: *Smeei* Beds below a former excavation site west of Mtapaia River (text-fig. 4: G2) with authors (in the back C.S., in front C.W.)

Fig. 2: Western rim of Tendaguru Hill

Fig. 3: "Kugelsandstein" from *Bornhardti Schwarzi* Complex at the top of Tendaguru Hill

Fig. 4: Dinosaur fragments in a former excavation site north of Tendaguru Hill (right: author C.S.)

Fig. 5: Dinosaur fragments in a former excavation site north of Tendaguru Hill

Fig. 6: Southern entrance of Namapuia Village

PLATE 8 TAFEL 8

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Orientierende Tendaguru-Expedition 1994
Tafel 9
Namapuia

Fig. 1: Dorfbewohner von Namapuia.

Fig. 2: Unsere lokalen Führer und zwei Autoren (1. von re.: W.Z., 3. von re.: C.S.).

Fig. 3: Wasserloch von Namapuia.

Fig. 4: Von rechts ein lokaler Führer aus Namapuia, der Bezirksbürgermeister von Mnyangara Herr Mohammed Hassan Sepetu und der Autor C.S..

Fig. 5: Herr Ahmed Bahari Kiwamu beim Transport eines Autoreifens.

Fig. 6: Zwei Autoren (C.S. und C.W.) im Gespräch mit den Bewohnern von Namapuia.

Tendaguru Expedition 1994
Plate 9
Namapuia Village

Fig. 1: Inhabitants of Namapuia Village

Fig. 2: Two authors (1. person at right hand: W.Z., 3. person from the left hand: C.S.) and our guides in November 1994

Fig. 3: Water hole of Namapuia

Fig. 4: From the left: one of our a local guides from Namapuia, the Village Chairman of Mnyangara Mohammed Hassan Sepetu and the author C.S.

Fig. 5: Ahmed Bahari Kiwamu (Mnyangara) transporting a tire of our vehicle

Fig. 6: Two authors (C.S. and C.W.) discussing with inhabitants of Namapuia Village.

PLATE 9 TAFEL 9

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Tendaguru Expedition 1994

Plate 10

Thin Sections

Fig. 1: Oncoid-bearing grainstone (about 25 x) from the marine equivalents of the Upper Saurian Beds from Ukulinga Plateau

Fig. 2: Arenitic grainstone showing oncoids, an ostracod shell and a section of a spine of echinoderm (about 60 x) from the "Hangend Oolith" of the *Smeei* Beds from the western rim of the Ukulinga Plateau

Fig. 3: Bone-bearing arenitic wackestone with ostracod (about 60 x) from the „coral-bearing layers" of the *Smeei* Beds below excavation site G2 (text-fig. 4)

Fig. 4: Fine-grained arenitic wackestone with lenticuline foraminifer, pelecypod fragments and subangular quartzes (about 80 x) from the "*Trigonia*-bearing layers" of *Smeei* Beds below excavation site G2 (text-fig. 4)

Fig. 5: Oncoidic packstone (about 50 x) from the "coral-bearing layers" of *Smeei* Beds below excavation site G2 (text-fig. 4)

Fig. 6: Arenitic floatstone with oncoids, pelecypod fragments, lenticuline foraminifer and subangular quartzes (about 60 x) from the "*Trigonia*-bearing layers" below excavation site G2 (text-fig. 4)

Fig. 7: Arenitic floatstone with oncoids, pelecypod and echinoderm fragments, lenticuline foraminifer and subangular quartzes (about 50 x) from the "*Trigonia*-bearing layers" below excavation site G2 (text-fig. 4)

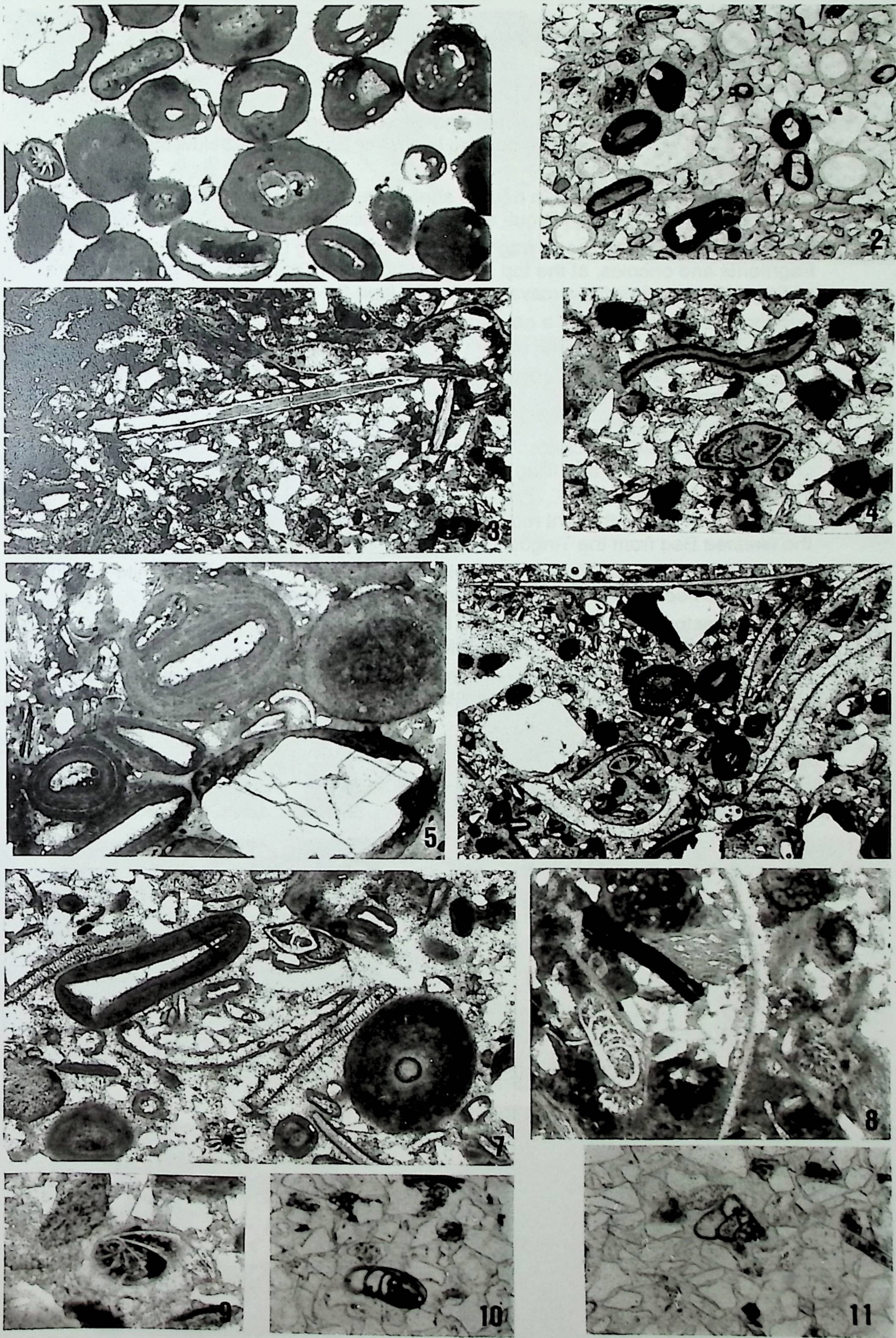
Fig. 8: Fine-grained arenitic wackestone with nodosariid foraminifer and plant fragments (about 80 x) from the "coral-bearing layers" of *Smeei* Beds below excavation site G2 (text-fig. 4)

Fig 9: Arenitic grainstone with lenticuline foraminifer (about 80 x) Arenitic grainstone with lenticuline foraminifer (about 80 x) from the "septaria-bearing layers" of *Smeei* Beds from the Tingutinguti and Maimbwi area

Fig. 10: Arenitic grainstone with nodosariid foraminifer (about 80 x) from the "belemnite-bearing layers" of *Smeei* Beds from the Tingutinguti and Maimbwi area

Fig. 11: Arenitic grainstone with textulariid foraminifer (about 80 x) from the "belemnite-bearing layers" of *Smeei* Beds from the Tingutinguti and Maimbwi area

PLATE 10



Tendaguru Expedition 1994

Plate 11

Thin Sections

Fig. 1: Arenitic floatstone with bivalve shells and oncoids (encrusted oyster fragments) (about 40 x), from the „*Trigonia*-bearing layers“ of *Smeei* Beds below the excavation site G2 (text-fig. 4)

Fig. 2: Section (about 15 x) through a nautilid shell from the "septaria-bearing layers" of *Smeei* Beds from the Tingutinguti and Maimbwi area

Fig. 3: Arenitic floatstone with oyster fragments showing boring features, other bivalve shell fragments and oncoids, at the top silty grainstone from the „*Trigonia*-bearing layers“ of *Smeei* Beds below the excavation site G2 (text-fig. 4)

Fig. 4: Section trough siphuncle of a nautilid (about 15 x) from the „septaria-bearing layers“ of the *Smeei* Beds (Pl. 10, fig. 8)

Fig. 5: Arenitic floatstone with shell fragments of echinoderms and bivalves as well as oncoids from the „*Trigonia*-bearing layers“ of *Smeei* Beds below the excavation site G2 (text-fig. 4)

Fig. 6: Section trough *Perisphinctes* sp. internally filled with block cement, externally covered with serpulids and filled with sediment (about 25) from the *Nerinea* Beds of Tingutinguti Maimbwi area

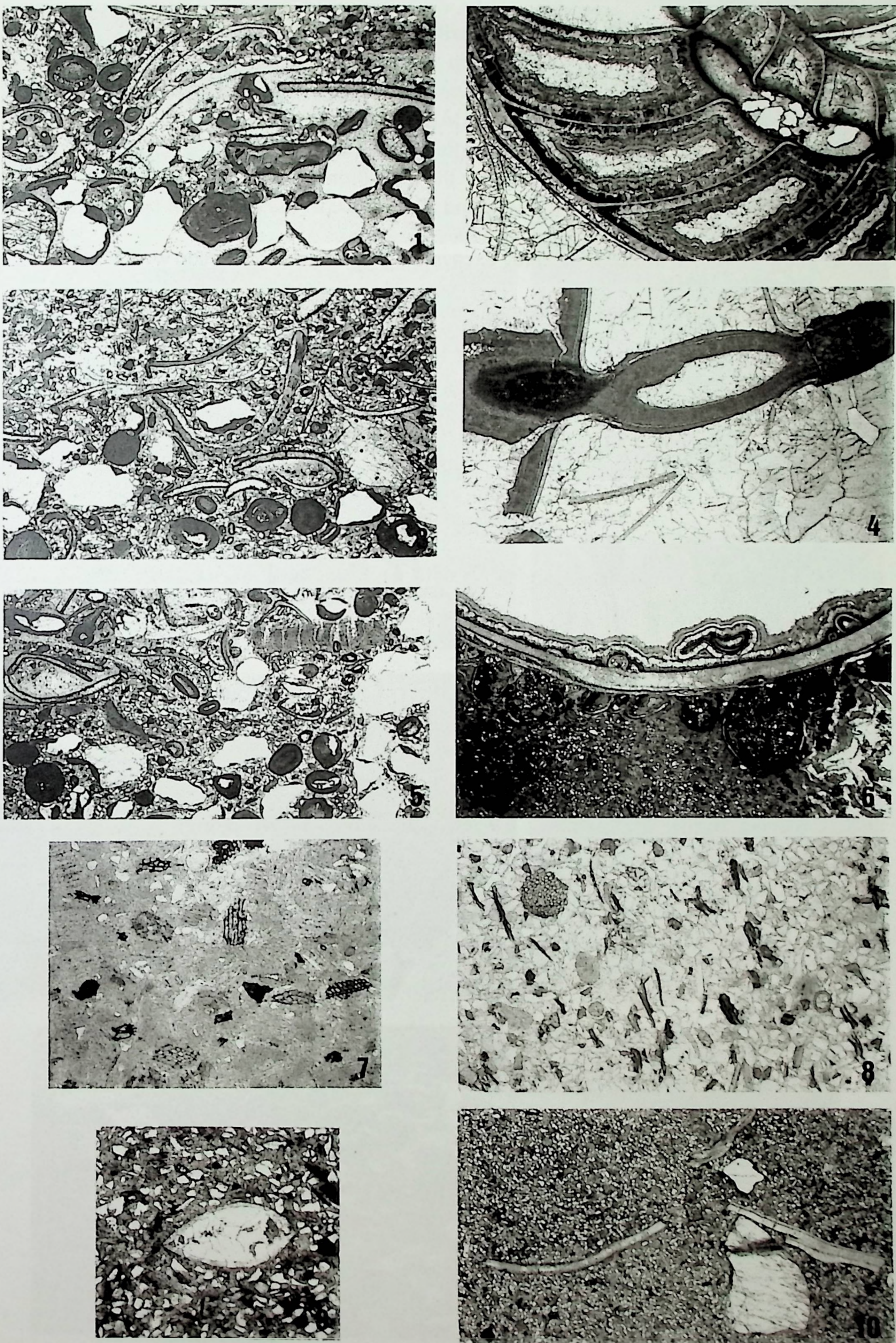
Fig. 7: Enlarged part of Fig. 6: plant remains of the internal sediment of *Perisphinctes* sp. the *Nerinea* Bed from the Tingutinguti and Maimbwi area

Fig. 8: Arenitic siltic grainstone (about 60 x) with plant remains from the "belemnite-bearing layers" of *Smeei* Beds from the Tingutinguti and Maimbwi area

Fig. 9: Siltic wackestone with ostracod (about 80x) from the "septaria-bearing layers" of *Smeei* Beds from the Tingutinguti and Maimbwi area

Fig. 10: Same siltic wackestone with bivalve fragments and coarse-grained quartzes from the "septaria-bearing layers" of *Smeei* Beds from the Tingutinguti and Maimbwi area

PLATE 11



Tendaguru Expedition 1909-1913

Plate 12

Excavations

Fig. 1: Working with the shovel in the trench (from Janensch 1914a)

Fig. 2: Working with the shovel in the trench (from Janensch 1914a)

Fig. 3: Partly articulated sauropod skeleton in the ditch (from Janensch 1914a)

Fig. 4: Bamboo bars to ensure a safe work and a protection of the excavated bones (from Janensch 1914a)

Fig. 5: In the trench: in front bones partly excavated; in the back: excavation work (from Janensch 1914a)

Fig. 6: Partly articulated sauropod skeleton (from Janensch 1914a)

PLATE 12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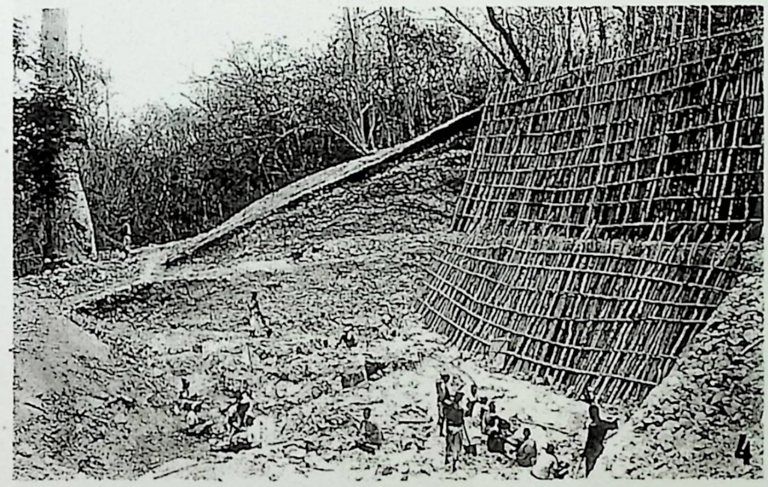
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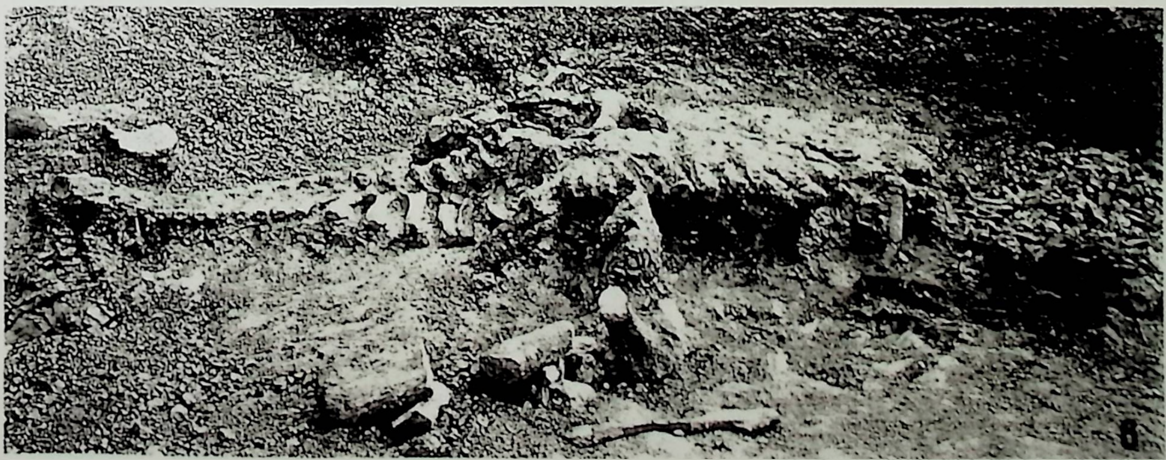
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Tendaguru Expedition 1909-1913

Plate 13

People and Bones

Fig. 1: Chief overseer Mr. Boheti (from Hennig 1912)

Fig. 2: Janensch and a native chief assistant (from the Berlin Naturkundemuseum)

Fig. 3: Overseer with signs for number and length of uncovered bones (from Hennig 1912)

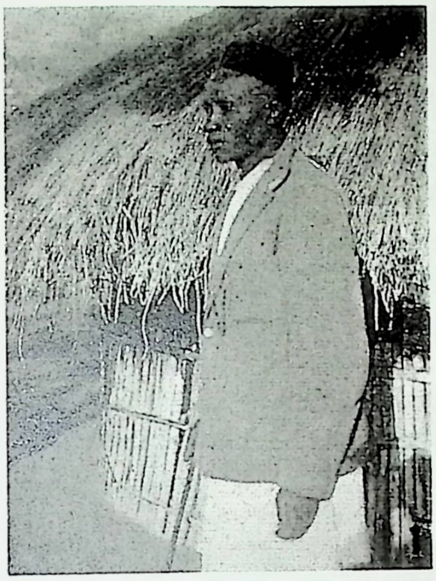
Fig. 4: Shoulder blade of a huge sauropod (from Janensch 1914a)

Fig. 5: Sauropod humerus at the weathered surface (from Janensch 1914a)

Fig. 6: Articulated distal limb bones in a natural position in the sediment (Reck 1912)

Fig. 7: Sauropod humerus broken into several pieces (from Janensch 1914a)

PLATE 13



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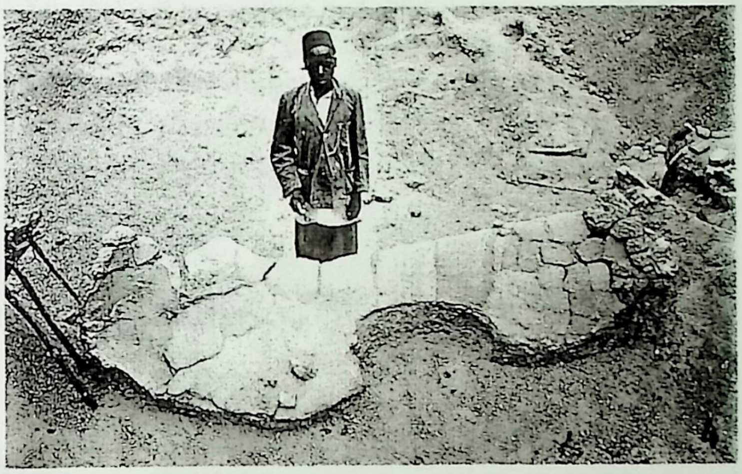

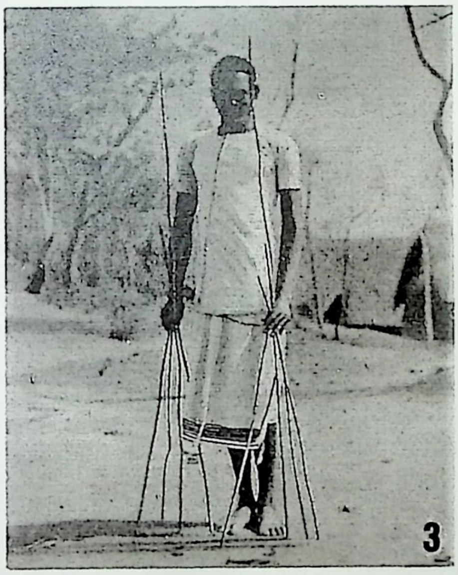

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Tendaguru Expedition 1909-1913

Plate 14

Live and Work in the Field

Fig. 1: Precise preparation work with the knife (from Janensch 1914a)

Fig. 2: Preparator team at work (from Janensch 1914a)

Fig. 3: Preparation of a dinosaur rib in the trench (from Janensch 1914a)

Fig. 4: Tendaguru Camp with broad tracks and many stores (from Janensch 1914a)

Fig. 5: A tool's store with a man beating the drum as a sign for the end of the days work (from Janensch 1914a)

Fig. 6: Women carrying the water into the "Tendaguru Village" (from Janensch 1914a)

Fig. 7: The bone store with two scribers at the left and porters with bamboo containers at the right (Janensch 1914a)

Fig. 8: Janensch's cabin at Tendaguru Hill (from Hennig 1912)

Fig. 9: Producing the bamboo containers (from Janensch 1914a)

Fig. 10: Loading the bamboo containers with fossil bones (from Janensch 1914a)

PLATE 14

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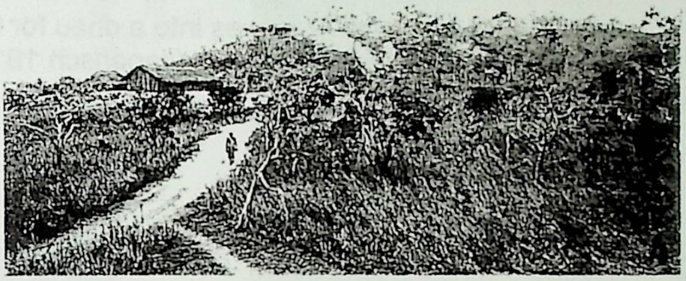

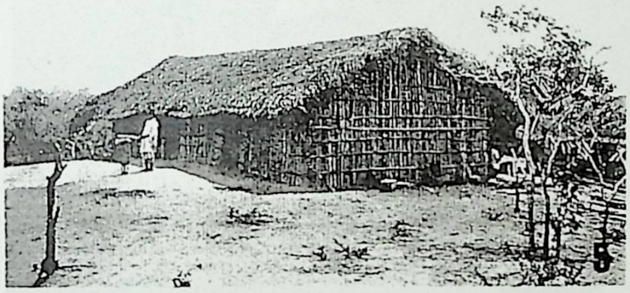

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Tendaguru Expedition 1909-1913

Plate 15

Transport of the Bones

Fig. 1: Caravan of porters ready to carry the bamboo containers to Lindi (from Hennig 1912)

Fig. 2: A heavy bone on its way to Lindi (from Janensch 1914a)

Fig. 3: An other heavy bone being carried to Lindi (from Hennig 1912)

Fig. 4: Caravan of porters crossing the water (from Hennig 1912)

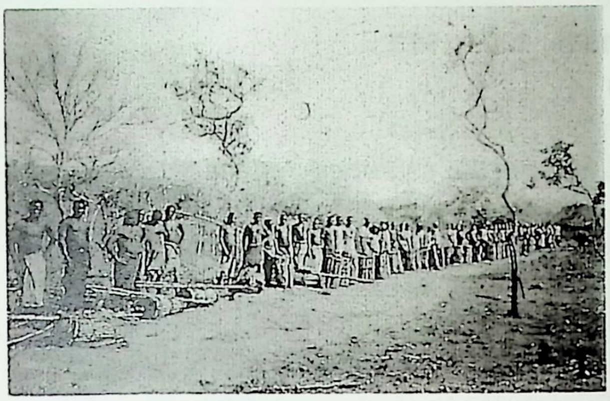
Fig. 5: Caravan of porters crossing the bush (from Hennig 1912)

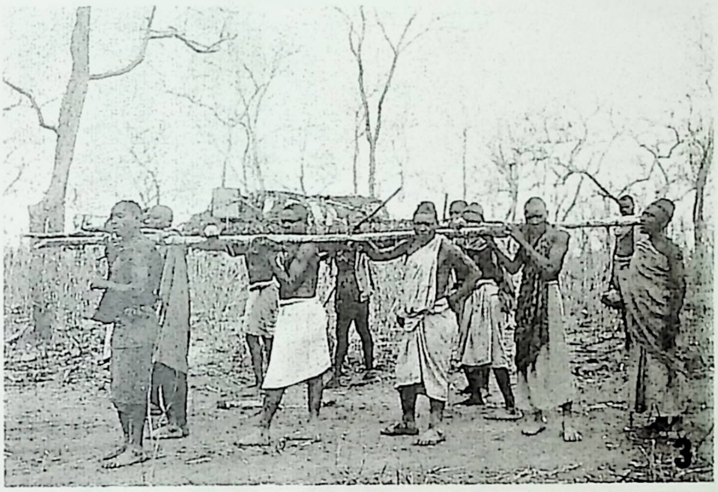
Fig. 6: Caravan of porters carrying the bamboo containers to Lindi (from Janensch 1914a)

Fig. 7: Wooden boxes filled with bamboo containers in the store of the German East African Company ready for shipping overseas (from Hennig 1912)

Fig. 8: Loading the wooden boxes into a dhau for transport to the steamer anchoring off Lindi Bay in the deep waters (Janensch 1914a)

PLATE 15





Tendaguru Expedition 1908, 1909-1913

Plate 16

Dinosaurs

Fig. 1: Distal parts of right hind leg (high about 1,5 m) from the sauropod *Janenschia robusta* (from Fraas 1908)

Fig. 2: Ventral view of a pelvis (width about 1,4 m) of *Barosaurus ?africanus* (Fraas 1908) (from Fraas 1908)

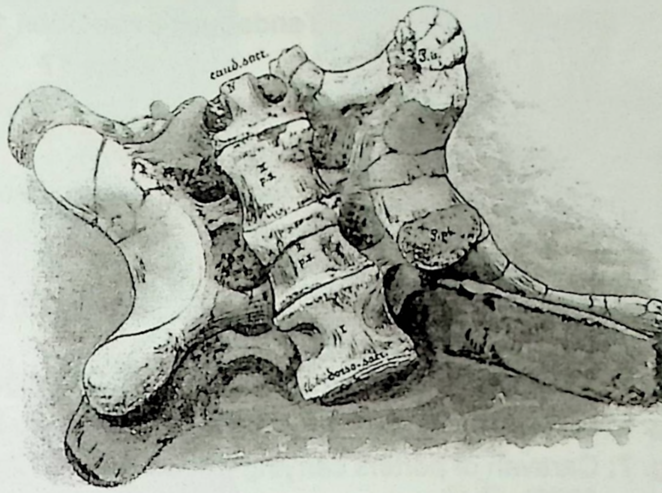
Fig. 3: The foot of *Janenschia robusta* (Fraas 1908) in closer view (from Fraas 1908)

Fig. 4: Femora of *Brachiosaurus brancai* Janensch 1914b exhibited in the Naturkundemuseum in Berlin

Fig. 5: Two humeri and a scapula of *Brachiosaurus brancai* Janensch 1914b exhibited in the Naturkundemuseum in Berlin

PLATE 16

1



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Tendaguru Expedition 1924-1929

Plate 17

British Museum East Africa Expedition

Fig. 1: Preparation of a pelvis (Parkinson 1930)

Fig. 2: Preparation of a pelvis and adjacent vertebrae of a dinosaur (Parkinson 1930)

Fig. 3: W.E. Cutler, leader of the British Museum East Africa Expedition in 1924-1925 (from Leakey 1925)

Fig. 4: F.W.H. Migeod, leader of the British Museum East Africa Expedition in 1925-1929 (from Migeod 1927b)

Fig. 5: Team of workers and a dinosaur scapula (Migeod 1931)

Fig. 6: British Museum Village seen from Tendaguru Hill (Migeod 1927b)

Fig. 7: Caravan of porters carrying wooden boxes filled with bones to Lindi (from Leakey 1925)

Fig. 8: The harbour of Lindi (Migeod 1927b)

Fig. 9: The old fort of Lindi (Migeod 1927b)

PLATE 17