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**MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES
MINES AND GEOLOGICAL DEPARTMENT**

GEOLOGY OF THE KORA-KALIMANGILU AREA

DEGREE SHEET 45, NE QUARTER
(with coloured geological map)

by

D.J. JENNINGS, BSc

Geologist

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Map

Geological map of the Kora-Kalimangilu area (Degree Sheet 45, north-east quarter). Scale 1:125,000	at end
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PREFACE

This report is another in a series of quarter degree geological sheet descriptions that, regrettably, have been awaiting publication for several years since field work and publication of the geological map were completed in 1961.

The task of preparing the report for publication has been part of a UK-funded project under which geologists of the British Geological Survey have worked alongside Kenyan counterparts of the Editorial Section of the Mines and Geological Department. A major aim of this project is to reduce publication delays in the future so as to ensure the rapid application of geological data to the search for, and controlled development of, Kenya's mineral, groundwater and energy resources.

A major part of the report is a description of a suite of Precambrian metamorphic rocks typical of the Mozambique Belt, covered, over about half the area, by a thin veneer of unconsolidated sediments of uncertain age.

The remoteness and aridity of the area, away from the Tana river, reduces the economic mineral potential but continued search for base metals in the basic and ultrabasic rock areas might be worthwhile. In addition heavy mineral sands (ilmenite, rutile, monazite and zircon) may be present in the post-Basement sediments, including the Tana river alluvium.

C Y O Owayo
Commissioner of Mines and Geology

J Wachira
Chief Geologist

June 1991

ABSTRACT

The quarter degree sheet described in this report is bounded by the equator and latitude 0°30' S and by longitudes 38°30' E and 30°00' E. It spans the Tana river some 100 km upstream of Garissa.

Rocks mapped include the most easterly outcrops of Precambrian 'Basement System' gneisses at this latitude, and the western feather-edge of the overlying Tertiary and Quaternary sediments. Good exposure along the Tana river valley reveals an unusually mafic and calcareous sequence of gneisses, and farther south a major hypersthene-rich gabbro intrusion is recorded, with minor ultramafic associates. The broad altered periphery of the gabbro, together with the structural pattern displayed by the surrounding gneisses, suggests the intrusion was emplaced and solidified before the culmination of folding and metamorphism of the 'Basement System'.

The gneisses and altered outer zone of the gabbro have been invaded by rare basaltic and lamprophyric dykes of assumed Tertiary age. Poorly-consolidated, unfossiliferous calcareous grits crop out near the Tana to both east and west. The sediments are totally devoid of pebbles of the volcanic suites of Mt. Kenya and the Nyambeni hills, indicating the age of the sediments to be greater than that of the Quaternary extrusive rocks of the present upper catchment area of the Tana.

I. INTRODUCTION

General Fieldwork was carried out in March 1960, and from mid-November 1960 to March 1961 for the reconnaissance geological survey of the quarter degree sheet described in this report. This is the north-eastern quadrant of degree sheet 45, bounded by the equator and latitude $0^{\circ}30'$ S, and by longitudes $38^{\circ}30'$ and $39^{\circ}00'$ E (Fig. 1). The mapped area is approximately $3,100 \text{ km}^2$ in extent and bisected by the Tana river some 100 km^1 upstream of Garissa.

By far the greatest part of the area falls within Tana District of Coast Province. The south-western corner of the area includes about 310 km^2 of Kitui District, Eastern Province, and in the north-western corner, bounded by the Tana to the south and the Ndajeri river to the east, some 145 km^2 of Isiolo District of Eastern Province falls within the area mapped. A small part of the map sheet, comprising an area of about 125 km^2 , lies 4.8 km north of the Tana and west of the Ndajeri river and falls within Garissa District of North-Eastern Province.

Maps At the time of survey the only topographical map available was the 1:500,000 military sheet, Garissa E.A.F. No. 680 (surveyed in 1940 and revised in 1942). Little accurate detail was shown but the spot heights for Kumbulanawa (1,561 ft) [475.8 m] and Kora (1,449 ft) [441.65 m] were used as height control, and with the numerous barometric spot heights taken during the course of the present survey were used in the preparation of the form lines on the accompanying map. Aneroid readings were corrected for diurnal pressure variation.

Complete air-photo cover was available, mainly as Contract 27 photographs at a scale of approximately 1:50,000, taken by Spartan Air Services in 1958. Gaps along the western boundary were filled by Royal Air Force photography of the 82D series.

Geological information was plotted directly onto air-photos in the field and subsequently transferred to Kodatrace strips of the air-photo flight runs and these reduced photographically. Ground control consisted of survey points at Kora and Kumbulanawa, astro-fixes at Giraffe Pool (89/A/91) just off the south-east corner, and Mbalambala (89/A/86) just within the north-east corner of the area.

Communications Access to the area south of the Tana can be gained most readily from Ngomeni, a village reached by turning north from the main Thika-Garissa road

1 Measurements have been metricated (except where original records, such as rainfall, are quoted). Note that most distances in the original script were approximations; therefore conversions should equally not be considered precise.

This map illustrates the geographical context of the Tana River District, which is situated within the Coast Province of Kenya. The district is bordered by the Tana River to the north and east, and by the Mombasa River to the south. To the west, it is adjacent to the Kitui District. The map also shows the Eastern Province to the north and the North Eastern Province to the northeast. Key towns and locations within the district include Kathure, Kora, Kalimangili, Kumbulanawa, and Mugani. The map includes a scale bar indicating distances up to 25 km, and a legend identifying provincial boundaries, district boundaries, and roads. The map is oriented with North at the top, and the coordinates 0°00'S, 38°30'E, and 39°00'E are marked.

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as a locality where several small whalebacks of granitoid migmatite rise a few metres above grass level. Kwanzui is a solitary low whaleback of hornblende migmatite, while Kumbulanawa is a north-south ridge of giant rounded blocks of gabbro commonly attaining a diameter of 6 m, which rises nearly 60 m above the surrounding countryside. Kalimangilu consists of a conical hill of highly variable amphibolite rocks surmounted by a crest of pegmatite, largely composed of milky quartz. From Kalimangilu the track continues in a generally north-north-easterly direction for 32 km until the Tana River is reached.

A second and better track from Ngomeni enters the west of the area 16 km north of the south-west corner, and maintains a north-easterly direction until it meets the Tana about halfway across the area. It deviates widely from the north-easterly direction for a few kilometres only at Mansumbi, a group of tors of granitoid migmatites.

A route can be picked along the southern bank of the Tana over the eastern half. This ill-defined track leaves the area and heading first east and then south ultimately reaches Garissa some 100 km downstream. A track from Mbalambala east of the map area follows the north bank of the Tana river westwards to Garba Tula via Kora Wells on the northern boundary; from Kora Wells a subsidiary track runs south to the Tana river.

None of the tracks receive any regular maintenance. In their normal state they are motorable only to four-wheel-drive vehicles and then with considerable difficulty, many deviations and some discomfort. The 68-km journey from Ngomeni to Kalimangilu took five hours by Landrover, that part crossing the present area being accomplished at an average speed of 7 m.p.h. [11.3 k.p.h.]

The original track cutting to the south of the Tana was built by the army in the early 1940s, since when these routes have been used sporadically by locust and tsetse fly control teams, livestock officers and occasional crocodile hunters.

Rainfall and climate The country lies in zone of arid bushland where the mean annual rainfall is between about 250 mm and 500 mm. No rainfall figures are available from within the area mapped, but records are kept at Mbalambala 35 km east and Ngomeni 71 km south-west of Kora hill. The average annual rainfall at Ngomeni over a period of eight years was 17.98 inches [457 mm] and at Mbalambala over twenty years 9.9 inches [251 mm]. Average annual rainfall of 22.04 inches [560 mm] from Tharaka (85 km west of Kora) and 24.89 inches [632 mm] from Mwingi (121 km south-west) demonstrate a progressive increase in rainfall westwards with increasing altitude. In the map area, therefore, the rainfall probably grades from about 10 inches [254 mm] per annum in the east to about 15 inches [381 mm] per annum in the west.

There is no station within the area maintaining temperature records but both annual and diurnal variations are considerable. During the course of the fieldwork a maximum shade temperature of 110°F [43°C] was registered before the rains in March at a campsite on the bank of the Tana at Kakungu (altitude 305 m). The highest minimum night temperature in the same month was 80°F [27°C].

Vegetation The variation in climate across the area is reflected in the vegetation which along the western boundary consists of a nearly impenetrable thicket of thorn and evergreen scrub rarely exceeding 3.7 m high, above which rise many large acacia thorns. Patches of 'black cotton' soil carry tuft grasses and dwarf scrub rarely exceeding 1.5 m tall. The central part of the area consists of a wide range of taller trees, and a much less dense ground thicket which allows easier access on foot but involves much labour in cutting motor tracks. Tree-cover thins progressively towards the eastern boundary of the sheet until, particularly on the sediments, and soils derived from them, grassy glades among camel-thorn trees are common, and in the intervening bush country a tortuous motor route can often be picked out for several hundred metres without recourse to tree-felling. Isolated baobab and euphorbia trees tower above the lesser bush in the south and west, and doum palms and fever trees form the largest proportion of the fringe of giant trees which borders the Tana and its tributaries in the north.

Population and fauna During the major part of the fieldwork more or less severe drought conditions affected the whole countryside, and consequently the area was almost devoid of human and animal inhabitants. The various nomadic groups who periodically graze their flocks in this locality kept to other pastures.

No inhabitants or signs of habitation were seen in the Isiolo District in the extreme north-west, and the Boran tribesmen from the western half, north of the Tana, were concentrated nearer Garba Tula and were seen in the area only during the short rains.

On the alluvium of the north bank of the Tana, in the east, are a few maize, millet and potato *shambas* marking the extreme upstream fringe of settlement by the Pokomo, one of the riverine tribes who inhabit the plains of the Tana river from Mbalambala to the coast.

Crocodile and hippopotamus abound in the Tana river. Elephant are often seen near the Tana and they congregate near the saline springs at Komunyu. Leopard, lion, rhinoceros and buffalo are occasionally seen while waterbuck are numerous near running water. Herds of a dozen or more gerenuk are common north of the river, and Grant's gazelle, oryx and lesser kudu are all present, but extremely timid. Giraffe and zebra are only rarely seen.

II. HISTORY AND PREVIOUS GEOLOGICAL WORK

In 1889 J.R.W. Pigott followed the north bank of the Tana to Baza, a village situated on an island in the river, near the present Mbalambala. Entering the area covered by this report nearby, he observed that 'the country becomes much more hilly and quartz reefs crop up at frequent intervals. There is also a good deal of gneiss and sandstone' (Pigott 1890, p. 132). Two days later his route along the north bank of the Tana crossed the bed of a broad sand-river carrying a trickle of clear, slightly salty water, which was almost certainly the Bisanadi. Subsequently he crossed to the southern bank of the Tana some 30 km downstream, and traversing west he re-entered the present area, first crossing comparatively open terrain (the sediments) to reach the hilly country covered with dense scrub (the gneisses).

In 1891 Captain F.G. Dundas, R.N., with a party including C.W. Hobley and Bird Thompson, navigated the Tana as far upstream as Hameye in the 75-foot steamer 'Kenia'. From there a foot safari was mounted to explore the country towards Mt. Kenya, some stores being transported farther upstream by canoe. The route ran parallel to the Tana across the present area over 'an undulating barren wilderness intersected by numerous dry water courses, with outcrops of pink gneiss.' The rapids at the mouth of the Chanyigi sand-river, the Hagazo falls (or 'Hoffman's Falls' of Carl Peters), were described as forming 'a cataract rising in three tiers to a height of 20 feet, the tiers being formed of ledges of gneiss'. Two days later the party camped on the north bank opposite Kora, where the distinctive granitoid tors were described as 'peculiar dome-shaped hills of red gneiss'. The canoe was finally abandoned at the rapids which extend upstream of Kakungu where the river 'rushes in a series of falls through a rocky gorge ... in a region of bold outcrops of gneiss with hornblende schists' (Gedge 1892, p. 523).

In a subsequent publication referring to the same journey C.W. Hobley (1894) remarked on the cataract, and the rapid transition from 'the flat steppe lands' which overlie the sediments and border the Tana east of Hameye, to the countryside to the west which 'displays ... a new phase of scenery, that of a great area of metamorphic rocks where the river gradually rises in a series of steps formed by rapids or falls.' The first running tributary to the Tana, the Bisanadi, was referred to as the 'Salt' river and was observed as a narrow, brackish rivulet in a stream bed nearly 100 yards wide.

Much later, Hobley (1920) remarked that the metamorphic rocks of the west disappear from view at the Hagazo falls, but it was suggested by Gedge (1892, p. 520) that under conditions of low water a rocky formation of gneisses could be seen in the river at Hameye. During the present safari the most easterly outcrops of gneiss were seen some 3.2 km north and south of the Tana, 11.3 km downstream of the Hagazo falls.

In 1893 Astor Chanler, an American explorer, travelled up the Tana river as far as the Rojewero tributary, about 16 km west of the Bisanadi, en route to the Lorian swamp.

His companion and cartographer, Lieut. von Höhnel, produced a detailed map relating all points to Hameye, the position of which he fixed by a series of astro-shots (Chanler 1893, p. 533).

A highly ambitious journey was carried out in 1901 by Graf von Wickenburg (1903), who travelled from Djibouti on the coast of Somalia via Addis Ababa, Marsabit and the Tana river to Lamu, and kept a survey log from Djibouti to the Tana. Information gained on this safari and from various other sources is presented on a series of accurate small-scale maps. Von Wickenburg headed almost due south from the Lorian swamp to reach the Tana near the Hagazo falls, before heading east.

J.B. Wright, government Geologist, when mapping the Ndeyini area to the south in 1958, took the Kalimangilu track to the north for several kilometres and encountered the margin of the gabbro and amphibolite of that area, and also located a number of dykes (Wright 1964). The geology of areas adjacent to that referred to in this report is described in previous reports by officers of the Geological Survey: to the west by R.G. Dodson (1955), and to the north and south by J.B. Wright (1964, 1973).

III. PHYSIOGRAPHY

Erosion surface The topography of the region has been formed by Pleistocene and Recent erosion by the Tana river which has completely eroded the sub-Miocene peneplain recognised elsewhere by Pulfrey (1960). Extrapolation of the peneplain shows that it would have been present in the map area as a plain sloping from about 760 m in the west to 460 m in the east; none of the hills in the area attains such altitudes.

Drainage The Tana river crosses the northern part of the area from west to east and at right angles to the general strike-trend of gneisses of the 'Basement System'. The river meanders gently across sediments and alluvium for the first 3.2 km, but where it reaches the gneisses it alters course abruptly to the north and becomes constricted in a narrow gorge. Here it falls in a series of minor rapids, only to resume its first gradient on the approach to the junction with the Bisanadi tributary. Downstream of its junction with the Ndirindera tributary the river descends by 4.8 km of rapids to Kakungu, but thereafter is slow-moving and shallow until the Hagazo falls, at the mouth of the Chanyigi sand-river, cause a fall of many metres as the river tumbles between rocky islands.

The Tana river becomes much wider and often braided as it leaves the gneisses, and a thick swamp and jungle-covered alluvial sediments form a 4.8-km wide flood plain for 8 km downstream. In times of severe flooding the plain is inundated.

Rarely is the rainfall in the area sufficient to contribute appreciably to the flow of the Tana, and many of the sand-rivers carry no water for several years in succession. The rapid rise and fall of water level reflects earlier rainfall in the upper catchment area, which includes the eastern slopes of the Nyambeni range, the eastern and southern slopes of Mt. Kenya, and the eastern slopes of the Aberdare mountains as far south as latitude 1° S.

The tributaries joining the Tana river on either side flow in a north-south direction for 6 or 8 km, thus reflecting the predominant 'grain' of the well-exposed gneisses of the region. The major tributaries are commonly confined to regions of more friable mafic gneisses which they cross and recross, changing course abruptly when reaching more homogeneous, less readily-weathered members intercalated in the sequence, or massive pegmatites which locally dominate the countryside.

The major tributaries incised in the gneisses in the middle of the area follow easterly courses inherited from the slope of the end-Tertiary peneplain. Their courses are tortuous as a result of selective erosion of less resistant bands in the gneisses, the strike of which runs obliquely to the general slope of the countryside.

In the south, with increasing distance from the Tana and increasing thickness of soil cover, the effects of Recent erosion and directional control by underlying banded rocks is much less appreciable and the tributaries display simpler courses and for long distances flow generally easterly, a characteristic indicating their derivation as consequent streams on the end-Tertiary peneplain.

IV. SUMMARY OF GEOLOGY

The Kora-Kalimangilu area is made up mainly of rocks of Precambrian age consisting of schists and gneisses of the 'Basement System' and masses of gabbro apparently intruded before the major metamorphism of the 'Basement System'. The gneisses are intruded by later basalt and lamprophyre dykes.

Impure sandstones and calcareous grits of probable Pliocene or early Pleistocene age overlie the metamorphic rocks in places. The rocks are locally mantled by superficial deposits of derived soils, kunkar limestone and lateritic ironstone. The Tana river and several of its tributaries, especially those running over the sediments, have locally developed broad alluvial fringes.

'Basement System'

Rocks of the 'Basement System' crop out over about half of the area, being best exposed along the line of the Tana river and in the countryside dissected by its tributaries. Soils obliterate outcrops to the south, south-east and north-west, and sediments overlie the metamorphic rocks on both eastern and western boundaries.

The 'Basement System' consists of a succession of schists and gneisses, typically boldly banded, in which members of indubitable sedimentary origin form only a small proportion. The latter consist of leucocratic biotite gneisses, quartz-felspar granulites and calc-silicate rocks representing the metamorphosed derivatives of impure sandstones, arkoses and calcareous grits respectively. Many of the gneisses are mafic and contain much hornblende and/or biotite. Even the darkest rocks commonly contain narrow, pale, quartz-rich feldspathic bands. Metasomatic introduction of quartz and feldspathic material into the gneiss succession in some localities has occurred to such an extent that large tracts have been transformed into coarse granitoid gneisses displaying ill-defined and swirled foliation planes, disrupted 'ghost' banding and other migmatite characteristics. The foliation of gneiss not partly mobilised by metamorphism is invariably parallel to banding and lithological boundaries.

Gabbros

The presence of a large, banded hypersthene-rich gabbro mass is recorded in the south-central part of the area, and smaller intrusions of similar basic composition occur farther west, north-west and north. A wide range of rock types is represented, from anorthositic to pyroxenitic bands, and small ultramafic intrusives composed of serpentinites, pyroxenites and amphibole perknites have been emplaced peripherally.

Minor intrusions

Narrow dykes of basalt and lamprophyre occur locally over the whole area of metamorphic rocks, but none were seen cutting sediments. They are generally parallel or nearly parallel to the strike of the gneiss but a few are conspicuously cross-cutting. Judging from the abundance of basalt float in many parts of the area, it is likely that many more dykes exist than were located during fieldwork. A number of dykes cutting the gabbro and surrounding ortho-amphibolites were found to be composed of fine-grained representatives of petrological composition related to the major gabbro. Barren pink pegmatite veins commonly cut 'Basement System' gneisses, occasionally in such profusion that over wide areas they form more than half of the exposed rock. The pegmatites cutting gabbro and associated ortho-amphibolites are white and quartz-rich and sometimes carry garnet and mica. Carbonate veins, with calcite the predominant mineral, occur rarely.

Sediments

The sediments overlying gneisses both in the east and west are of the same general type, being poorly-consolidated, ill-bedded, pale, impure sandstones and calcareous grits. The superficial layer is invariably friable and bleached or leached white in colour, often with calcrete nodules. Frequently the summits of low mounds and flat-topped ridges in the sediment terrain sport a capping of well-rounded iron-stained quartz pebbles. Locally, more compact, better-cemented samples of grit appear irregularly mottled in shades of buff, pale green, red or khaki. No fossils of any type were seen.

V. DETAILS OF GEOLOGY

1. 'Basement System'

The gneisses of the 'Basement System' form a banded succession with units of widely differing composition. Alternating bands of contrasting type sometimes occur with individual units varying in width from a few millimeters to tens of metres. In field mapping of the gneissic terrain, therefore, the apparent nature of the country rock is largely dependent upon degree of exposure and disposition of the bands. Poorly-exposed interfluvial may display only an occasional rib of blocky quartz-felspar granulite, the least readily-weathered member of the succession. A shallow stream bed incised in the soil cover across the same sequence may expose a few better-foliated members, parts of massive, flaggy bands of biotitic and granular hornblende rocks. A major sand-river, cutting across the strike in the same neighbourhood and exposing the whole succession, may demonstrate that the quartzofelspathic units form a negligible proportion of the succession, and the massive biotite and hornblende rocks form a substantial proportion, but the bulk of the rock is of finely-laminated, easily-weathered mafic banded gneisses which only break the superficial soil cover under conditions of extreme erosion and denudation.

An attempt has been made to divide the banded sequence into three groups during the course of field mapping. Areas mainly composed of banded leucocratic rocks have been designated Xs'. The majority of rocks within this group are leucocratic biotite gneisses and quartz-felspar granulites. Leucocratic hornblende-bearing gneisses are not uncommon and occasional intercalations of rocks rich in ferromagnesian minerals occur. The leucocratic rocks, deficient in ferromagnesian minerals commonly responsible for well-developed foliation planes, typically form massive bands locally attaining widths of several metres.

At the other end of the range, areas composed mainly of hornblende-bearing gneisses are designated Xhh. This group inevitably includes some rocks in which biotite exceeds hornblende, and a small proportion totally devoid of ferromagnesian minerals. These rocks are typically banded in narrow units and quite commonly finely laminated. Xa is the symbol used to cover the intermediate category, where banded leucocratic and mafic rocks occur in approximately equal proportions.

No metamorphic quartzites were recorded anywhere in the succession, and a solitary exposure of a few metres of impure marble near the eastern boundary is the only indication of a true limestone in the pre-metamorphic sedimentary sequence. Calc-silicate rocks are common constituents of the mafic banded sequence. Partly mobilised, hornblende-rich varieties display disrupted banding and have no regional foliation.

The rocks forming the tor-like hill masses of Kora, Yumbandei, Mwetimba, Mansumbi and others, are granitoid migmatites. Foliation planes where preserved undulate markedly, and included bands of only slightly contrasting composition have been broken and swirled, sometimes lensing out and sometimes terminating with highly-crenulated, tassellated ends. Large areas lack well-defined foliation.

For ease of description, gneisses of the 'Basement System' have been classified into the following lithological units:

- (1) Mixed banded gneisses
 - (a) Psammitic gneisses and granulites
 - (i) Granitoid biotite gneisses
 - (ii) Quartz-felspar granulites
 - (b) Semi-pelitic gneisses
 - (i) Biotite gneisses
 - (c) Pelitic gneisses
 - (i) Hornblende-biotite gneisses
 - (ii) Hornblende gneisses
- (2) Quartz-felspar granulites
- (3) Granitoid gneisses
- (4) Impure crystalline limestones
- (5) Calc-silicate gneisses
 - (a) Hornblende-rich calc-silicate gneiss
 - (b) Diopside-rich calc-silicate gneiss
 - (c) Epidote-rich calc-silicate gneiss
- (6) Plagioclase amphibolites.

(1) Mixed banded gneisses

(a) *Psammitic gneisses and granulites*

(i) *Granitoid biotite gneisses* These gneisses are usually medium- or coarse-grained rocks, without marked foliation and with the three main leucocratic constituents, microcline, plagioclase and quartz, occurring in approximately equal proportions, and together forming over 90% of the rock.

Rock bands exposed at the junction of a small sand-river with the Tana, 12.1 km west-north-west of Kora hill, are composed of granitoid biotite gneisses. In hand specimen 45/746,² large crystals of pink microcline, twinned white feldspar and glassy quartz are distinguishable, with irregularly-disposed ferromagnesian clusters. In thin section it is seen that quartz and microcline predominate over slightly sericitised plagioclase, and large plates of brown biotite are accompanied by black iron ore and accessory muscovite and chlorite.

A finer-grained rock, 45/841, crops out on the track south of the Tana, 11.3 km from the eastern boundary, where it forms whalebacks and monolithic blocks without apparent foliation. In hand specimen, pink and white feldspars occur together with less common books of biotite. The microcline of the thin section is fresh, while the plagioclase is often sericitised, with large ragged muscovite plates in their cores. Quartz occurs in 'pools' and medium-grained mosaic patches, and as myrmekite intergrowths with feldspar. Muscovite and black iron ore are accompanied by biotite which is locally altered to chlorite.

A third type of granitoid gneiss as seen in specimen 45/854 crops out in a well-exposed section of leucocratic gneisses in the Chanyigi sand-river 8.9 km east of Komunyu hill. This is a medium-grained, glassy quartz-feldspar rock, with deep red spots of iron-staining from the weathering of magnetite grains, that has a well-developed lineation but no well-defined foliation planes.

(ii) *Quartz-feldspar granulites* The rocks of this group are closely related in composition to the granitoid gneisses, but invariably are much finer grained, usually possessing little or no biotite and a large proportion of iron ore.

A fine-grained grey granulite, specimen 45/771, is a minor constituent of the mafic banded sequence cropping out in the Urukate sand-river 2.4 km from the northern boundary. It is composed largely of microcline, with about one-fifth of the rock plagioclase, of which some is clear and some highly saussuritised. Quartz occurs in equal proportion, and rare irregular or euhedral iron ore is accompanied by accessory muscovite and chlorite.

Similar fine-grained grey granulites, 45/816 from 17.7 km east-south-east of Kora Wells and 45/853 from the section on the Chanyigi sand-river 8.9 km east of Komunyu hill, occur among coarser-grained rocks of the leucocratic sequence. In the former, ragged wisps of biotite, pleochroic in shades of green and khaki, are common among colourless minerals where quartz and microcline preponderate over saussuritised plagioclase, while

2 Nos. 45/746 etc. refer to specimens in the regional collection of the Mines and Geological Department, Nairobi

plagioclase, while in the latter, rare large, irregular black iron ores show alteration products suggesting the conversion of ilmenite to leucoxene.

(b) Semi-pelitic gneisses

(i) Biotite gneisses Mafic gneisses with biotite as the sole ferromagnesian mineral are rare in the hornblendic calc-rich sequence displayed in the area. Specimen 45/802 from among banded gneisses exposed in the Gurusumes sand-river 2.4 km from the northern boundary is a medium-grained, dappled black and white rock with pronounced foliation and abundant small garnets. In thin section the garnets, constituting some 5% of the rock, display prominent fractures and contain occasional small inclusions. Some half of the rock is composed of clear, precisely-twinned plagioclase, while quartz and euhedral to subhedral biotite, pleochroic from straw-yellow to deep khaki-brown, occur in approximately equal amounts and form the remainder of the rock. A more granular, biotite-rich rock, 45/842 from the south bank of the Tana west of the junction with the Mwitamisi, is composed of a very fine-grained, regular, clear mosaic of quartz accompanied by less common microcline and plagioclase and abundant small flakes of biotite.

Two rock types exposed in the Mwitamisi river to the east of Kalimangilu, between the hill and the waterholes, are either xenolithic fragments or screens of original country rock in the gabbro margin, now completely metamorphosed. The first, 45/885, is a fine-grained, poorly-foliated dark grey rock, with a sub-granular texture and ferromagnesian minerals locally forming clusters; the appearance suggests an igneous origin. Abundant large and small irregular plates of biotite are pleochroic from straw-yellow to deep brown and are accompanied by accessory green hornblende, numerous irregular granules of sphene often associated with biotite, and a few black iron ores with large subhedral habit or in clusters of small euhedra. The feldspars of the rock are shot with small apatite prisms, and occasional large needles of apatite attain a length of 1 mm. Occasional combined Carlsbad-multiple twins (again suggestive of an igneous origin) are displayed by plagioclase, the majority of which forms an equidimensional mosaic with units of highly variable size. A small amount of quartz is present in rounded interstitial pools.

The second biotite gneiss from this locality is a finely-banded greenish rock. The coloration is caused by chlorite, a common alteration product after biotite, occurring with plagioclase, which is locally sassuritised with the formation of rows of granular inclusions, probably of epidote. Large rounded patches of quartz are present and the rock is cut by a vein of prehnite.

(c) Pelitic gneisses

(i) Hornblende-biotite gneisses Rocks with both hornblende and biotite among the ferromagnesian components are widespread in the mafic banded sequence. One such

rock, 45/741 from exposures on the Tana 9.7 km north-west of Kora hill, contains more hornblende than biotite, and accessory apatite, chlorite and black iron ore. The most common mineral, oligoclase (composition An_{20}) is accompanied by a small amount of quartz.

A darker, medium-grained rock, 45/803 from the Gurusumes sand-river 3.2 km from the northern boundary, contains biotite and hornblende in approximately equal amounts, the former pleochroic from straw-yellow to deep khaki-brown and the latter pleochroic in shades of green. Quartz is present with large amounts of twinned and untwinned feldspar and accessory sphene, apatite and zircon. In a dark, streaky, well-foliated biotite rock, 45/876 from the mouth of the Chanyigi sand-river, hornblende is present in only small amounts. Accessory sphene occurs as large irregular granules and as rims to black iron ore, an association suggesting that the iron ore may be ilmenite. Epidote is occasionally present with the biotite in a quartz-rich leucocratic base with microcline and plagioclase and myrmekite intergrowth.

(ii) *Hornblende gneisses* The name is used here to describe rocks in which quartz is an essential mineral. Quartz-free plagioclase-hornblende rocks are referred to as plagioclase amphibolites. Specimen 45/721 from the mafic banded sequence at the mouth of the Mthongi sand-river 4 km north-west of Kora hill is composed largely of euhedral crystals and interstitial plates of hornblende, pleochroic from pale green to grass- and bottle-green. The plagioclase is less abundant, with ill-defined lamellar twinning suggesting a composition within the oligoclase range, and together with quartz it constitutes the remainder of the rock with accessory epidote, apatite and calcite.

Another dark, medium-grained hornblende gneiss, specimen 45/772 from the Urukate sand-river 4.8 km from the northern boundary, displays the same mineral assemblage in approximately the same proportions while specimen 45/777, from 1.6 km south-east of Kora Wells, has a distinctive appearance. This fine-grained, white granular gneiss, with medium-grained black hornblende partings, displays occasional circular patches of hornblende 5 mm in diameter. The majority of the rock is composed of quartz and untwinned feldspar, the latter locally saussuritised. Highly-coloured green hornblende occurs in circular patches as perforated plates or interstitial patches in optical continuity. It constitutes about half the rock, and includes small crystals of quartz and feldspar.

(2) Quartz-feldspar granulites

Fine-grained, granular quartz-feldspar rocks are prominent among those forming conspicuous ridge features in the centre of the area, north of the Tana. These are represented by a pinkish-grey granulite, 45/785, with many small fractures and distinctive pink microcline-quartz veining, which crops out 6.4 km east-south-east of Kora Wells; specimen 45/768, a light brown glassy granulite flecked with minute black iron ore grains from 1.6 km east of Kora Wells; and 45/790, a medium-grained pink granulite with

larger euhedral magnetite crystals from 9.7 km east-south-east of Kora Wells. The first, 45/785, is conspicuous in containing little or no plagioclase, 70 per cent of the rock being composed of a larger-scale mosaic of microcline with quartz in rounded pools and numerous small euhedral black iron ores.

(3) Granitoid gneisses

Specimens 45/932 and 45/933 were both collected from the tor-like outcrops of Yumbandei. The former is typical of the bulk of the rock, being the felspathic migmatite host rock, while the latter is part of a more mafic, sinuous, lenticular inclusion. In hand specimen, 45/932 is a buff-coloured rock, displaying poor foliation which is demonstrated by the orientation and grouping of flakes of biotite. In thin section microcline is seen to form nearly half of the rock, with quartz and plagioclase occurring in nearly equal proportions and rare myrmekite intergrowths. Large euhedral books of biotite are pleochroic from straw-yellow to deep chocolate-brown and accessory minerals include muscovite, minute zircons, rounded apatite prisms and euhedral sphene. The latter also occurs as irregular grains enclosing or enclosed by black iron ore.

A friable, inhomogeneous pale gneiss (45/933) with common medium-grained black mica flakes and small rusty patches about altered magnetite, forms many of the discontinuous undulating lenses included in the migmatite host.

(4) Impure crystalline limestones

A single small exposure of crystalline limestone (45/1052) was recorded on the track south from the Tana, 14.5 km east-north-east of Kalimangilu. Impurities include small quantities of quartz, feldspar, chlorite after biotite, and pale yellow amphibole in a rock composed of an interlocking granular mass of coarse-grained calcite.

(5) Calc-silicate gneisses

Rocks with varying proportions of hornblende, diopside, epidote and plagioclase are of widespread occurrences among the gneisses of the mafic banded sequence. In only two localities are individual outcrops sufficiently large to warrant delineation upon the map.

(a) *Hornblende-rich calc-silicate gneisses*

These are represented by specimen 45/1023 from an outcrop in the track 4.8 km south-west

of Kathanawa, and 45/850 from the Chanyigi river 8 km east-north-east of Yumbandei. In the former, diopside in perforated subhedral plates and euhedral epidote occur in equal amounts, while fresh medium-grained anhedral hornblende is much more abundant. The remainder of the rock is composed of clear quartz and felspar both as large tattered plates with misty twinning and small untwinned mosaic, with accessory calcite and sphene. The second rock, specimen 45/850, contains yellow-green epidote and less common euhedral and subhedral diopside displaying typical pyroxene sections and cleavages. Intensely-coloured hornblende, pleochroic from deep bottle-green to olive- and grass-green, predominates among the ferromagnesian minerals while among the leucocratic representatives plagioclase is more common than quartz.

(b) Diopside-rich calc-silicate gneisses

These include specimen 45/1022, a minor constituent of the banded gneisses 8 km north of Kathanawa. Large granules of diopside, weakly pleochroic in shades of pale green, are accompanied by less common yellow-green epidote. The remainder of the rock is composed of plagioclase with common accessory scapolite and euhedral crystals of sphene.

Other rocks with diopside as the predominant ferromagnesian mineral include specimen 45/815 from a minor stream east of the Urukate sand-river, 1.6 km north of the Tana, and specimen 45/740 from the crest of a rocky knoll within the elbow-bend of the Tana, 9.7 km north-west of Kora hill. The former, in hand specimen an irregularly-patchy rock with variation in grain-size and colour from dark green-grey to black, includes light segregations of plagioclase. In thin section diopside, with weak pleochroism from neutral to shades of light green, constitutes about half of the rock. Isolated granules and patches of crystals of yellow-green epidote are locally enclosed by diopside, and larger isolated plates of the same mineral are present. The hornblende, segregated into patches, is of an intensely-coloured, strongly-pleochroic variety. A small amount of plagioclase, largely sericitised and locally associated with scapolite, is accompanied by large accessory apatite and small zircons. Nearly half of specimen 45/740 is composed of diopside with subsidiary hornblende and accessory epidote. Scapolite occurs in equal amount with plagioclase, while the commonest light-coloured mineral is quartz, composing about one-third of the rock. Accessory minerals include large sphenes and apatite, together with calcite and zircons.

(c) Epidote-rich calc-silicate rocks

Banded epidiosites occur rarely among the members of the mafic sequence. Epidote-rich segregations are, however, common as 'eyes' in hornblende-rich gneisses and especially in hornblendic migmatites. Local patches of these rocks are monomineralic, but more commonly varying amounts of quartz, plagioclase, diopside or hornblende are present. Specimen 45/773, from a compact green segregation among more friable hornblende gneisses exposed by the Urukate sand-river 4.8 km from the northern boundary, is

inhomogeneous in hand specimen. In the thin section epidote forms mosaic patches and a crude network of rounded grains with interstitial patches of clear quartz and highly saussuritised felspar in which only a hint of twinning remains, marked by a felted mass of alteration products. Small ragged flakes of intensely-coloured amphibole and large irregular patches of sphene are accessory.

A narrow rocky rib forms a prominent north-south ridge to the west of the Mthongi sand-river 4.8-6.4 km south of the Tana. The crest of the ridge is formed of a calc-silicate rock (45/731) which contains epidote, diopside and plagioclase in approximately equal amounts, and subordinate hornblende. An epidosite, specimen 45/767 from exposures in the sand-river 1.6 km east of Kora Wells, is composed of highly sericitised felspar, and abundant epidote, with accessory diopside, scapolite and sphene, and is cut by broad veins of prehnite.

(6) Plagioclase amphibolites

Very dark, hornblende-rich plagioclase amphibolite forms bold outcrops parallel to the general direction of the Chanyigi sand-river. It forms the low rocky hills to the west of the Chanyigi and is well exposed at the islands in the Tana, the locality of specimen 45/877. In hand specimen specks of iron pyrites and chalcopyrite are seen to occur sporadically on the foliation planes. Subordinate twinned and untwinned plagioclase is accompanied by accessory sphene, epidote, muscovite and black iron ore.

A well-foliated, medium-grained black gneiss which forms part of the banded gneiss succession, specimen 45/732 from the Mthongi sand-river 3.2 km west-north-west of Kora hill, is composed mainly of subhedral crystals of hornblende, strongly pleochroic from neutral to bottle-green and displaying marked preferred orientation. The subordinate untwinned felspar forming the remainder of the rock is largely sericitised.

2. Major intrusives

(1) Gabbros and norites

A large rock mass composed of a variety of gabbroic types with related ultrabasic members and their metamorphosed derivatives occupies much of the south-central part of the area west of Kalimangilu. Smaller outcrops of similar basic rocks form the hill groups of Kathanawa and Kathure-Makyala to the west and north-west respectively. South of the Tana, 3.2 km north and 4.8 km north-west of Kora hill, other patches of variable basic rock were located. A calcrete-capped bluff on the north bank of the Tana is probably an extension of the latter. A row of coarse-grained gabbro boulders crossing

a game track on a ridge 8 km north-north-west of Kathure suggest a dyke-like outcrop.

Marginal to the main core of apparently unaffected igneous gabbro is a broad zone of altered and metamorphosed basic rock now predominantly plagioclase amphibolite.

The countryside is undulating with occasional smoothly-conical hillocks littered with copious float of angular fragments. Occasionally the crest of the hill, such as Kalimangilu, is made up of quartz-rich pegmatite. Exposure is best where the Mwitamisiy sand-river and its tributaries have stripped the mantle of soil from the bedrock. Elsewhere, the soil cover obscures the bedrock, especially to the west and south.

At waterholes along the Mwitamisiy downstream of Kalimangilu complex intrusion phenomena are displayed with brecciation and *lit-par-lit* intrusion of a migmatite host rock by more basic material. A small outcrop of gabbro on the western margin of the main intrusive mass, some 6.4 km north of Mwetimba, show occasional fresh spherical cores derived by 'onion-skin' weathering from angular joint blocks.

It was difficult to distinguish between metamorphosed gabbros and members of the 'Basement System' with similar mineral composition. The minor intrusions in the marginal zone are altered to actinolite-chlorite, and quartz- and biotite-rich members. The massive unfoliated original intruded rock composed of high temperature minerals has resulted in the central core remaining unaffected by subsequent metamorphism. The less homogeneous marginal zones and the bulk of the smaller intrusions have suffered highly irregular retrogressive metamorphism. The percolating fluids utilised the boundaries between different compositional units, including igneous banding and tectonic planes developed during regional metamorphism, thus leaving pods of fresh gabbro within sheaths of altered material.

The status, whether primary or secondary, of actinolite and hornblende is uncertain. Indubitable primary hornblende does not exceed 50 per cent in any rock; therefore none of the rocks can be called a bojite.

a) Anorthosites

Anorthosites crop out as narrow bands and veins forming a negligibly small proportion of the total in the core of the intrusive mass.

Specimen 45/908, from a tributary of the Mwitamisiy, 1.6 km upstream to the north-west of Kalimangilu, was collected from one of a number of lenticular bands and veins of variable width. The hand specimen is a medium-grained granular rock of a light mauve-grey colour devoid of dark minerals, and the thin section shows the rock to consist of an equidimensional granular mosaic of well-twinned plagioclase feldspar of composition An_{56} , locally slightly sericitised. Accessory minerals include muscovite, hornblende and black iron ore. A float pebble of similar material, 45/915 collected a

little farther upstream, is a dark grey, coarse-grained rock, almost black but with a mauve coloration. Plagioclase crystals in the thin section often attain a length of 4 mm and occasionally reach 10 mm. These plagioclase crystals, of composition An_{62} , are well twinned, but in the larger crystals the twins are invariably bent or the crystals fractured and the twins displaced, indicating post-crystallisation deformation. Very small granules and irregularly-shaped crystals of pale green to neutral augite are the common accessory mineral accompanied by rare calcite, epidote and black iron ore.

Specimen 45/943 from a fractured 50-mm vein of light mauve-grey, coarse-grained felspar rock farther upstream has an interlocking texture of large distorted crystals of plagioclase with patchy marginal recrystallisation. Widespread but slight sericitisation is apparent and patches of iron ore blebs locally pattern large plates of felspar. Accessory minerals include chlorite, epidote and calcite.

Sporadic banding in the gabbro 1.6 km north-west of Kalimangilu hill involves units of microgabbro and anorthosite, the latter as infrequent bands varying in width from 10-100 mm. Specimen 45/950 from that locality is also a coarse-grained, grey-black rock which in thin section is seen to consist of large plates of plagioclase often patterned with granules of iron ore. Small patches of regular polygonal mosaic of fresh plagioclase and the crenulated and embayed margins to the original igneous plagioclase crystals illustrate recrystallisation. Twinning is often hazy and indefinite and some crystals show a bold zoned structure towards their margins. Simple anhedral shapes of black iron ore and patches of augite granules are accessory.

(b) Anorthositic olivine-bearing gabbros

All samples of leucocratic olivine-bearing rocks were collected from a small locality south-west of Kalimangilu, including the boulder ridge of Kumbulanawa and the rocky knolls within 1.6 km to east and west of it.

These rocks are coarse-grained, grey-mottled gabbros with granular igneous texture and felspar occasionally attaining a length of over 10 mm. The plagioclase is typically mauvish-grey and sometimes exhibits a pearly lustre due to internal reflection. Granules of yellow-green olivine are readily apparent in hand specimen.

Specimen 45/924, from 400 m east of Kumbulanawa, has olivine, the predominating ferromagnesian mineral, as large, irregularly-embayed crystals, isolated or in clusters, with bold fractures accentuated by tracts of iron ore granules. Reaction rims (coronas) around the olivines are narrow and impersistent, and consist of hypersthene, spinel or an intergrowth of both. Most hypersthene is confined within the ferromagnesian clots as small anhedral flakes, while augite occurs as occasional isolated crystals. Brown hornblende, often including patches of black iron ore grains, is often associated with large, simple-shaped crystals of the same mineral and anhedral deep green spinel. The major rock constituent is plagioclase felspar, invariably multiply twinned, and with many

black rock containing olive-green hornblende and devoid of olivine. Pale green schillerised augite accompanies larger, strongly-pleochroic hypersthene of subhedral prismatic habit and dusted with inclusions. The hornblende displays two distinct habits. The first is as medium-sized anhedral crystals sometimes clear and sometimes patterned or even nearly obliterated with included iron ore grains. Secondly, it occurs as marginal fringes and mosaic patches of small crystals bounding black iron ore and pyroxene and forming patches within the ferromagnesian clots. Development of hornblende at the expense of pyroxene often exploits schiller and cleavage planes and occasional fractures crossing the rock have been utilised by iron-rich percolating fluids which left small green hornblende flakes and chloritic material lining the fractures.

In specimen 45/977, from an exposure in the river bed 2.4 km south-west of Kumbulanawa, anhedral augite and subordinate weakly-pleochroic hypersthene form digital intergrowths with spinel. Pyroxene locally alters into paler actinolitic hornblende.

Specimen 45/949, from 1.6 km north-west of Kalimangilu, is composed of pyroxenes, iron ore and plagioclase with brown hornblende as an accessory mineral.

Rock 45/784, from the north bank of the Tana, is a gabbro composed in part of hypersthene carrying numerous flaky red-brown inclusions on selected crystallographic planes and very pale green augite including rods of black iron ore and altered patchily to khaki-green hornblende. The hornblende forms complete rims as optically-continuous units around cores of altered pyroxene and elsewhere large plates of hornblende are seen to be composed of a regular mosaic of hornblende flakes in similar but not identical optical orientation, again suggesting derivation from a previous mineral. Iron ores are large, anhedral and rounded. The plagioclase which infills the interstices in the ferromagnesian network shows vague progressive zoning, and compositions obtained from a limited number of measurements of extinction angles of multiple twins suggest labradorite with a range from An_{70} in the core to An_{62} at the margins.

Specimen 45/976, from 2.4 km south-west of Kumbulanawa, is a more fine-grained rock composed of pleochroic hypersthene and augite (both of which form intergrowths with spinel), flakes of spinel, irregular shapes of iron ore and quantities of deep khaki to khaki-green hornblende. The latter carries patterns of lines of expelled iron ore granules and marginal concentrations of the same mineral. The felspar is mainly an interlocking mass of precisely-twinned plagioclase but locally small areas are composed of rounded polygons of hazily-twinned recrystallised material.

present as small, rare reaction flakes against olivine, and hornblende is common in small units and surrounding other ferromagnesian minerals as 'hollow-crystal' reaction rims all in optical continuity. Plagioclase, the sole leucocratic mineral, occurs as large and small crystals invariably well twinned and often fractured or bent.

(ii) *Olivine hyperites* This is the most common single rock type and has the most widespread occurrence of all basic intrusive rocks examined. The general appearance both in hand specimen and in thin section shows wide variations. Rock specimen 45/761, collected from the river bed 9.7 km south-east of Monsumbi, is a medium-grained rock so rich in hornblende (apparently primary) that it approaches the composition of bojite. The brown highly-pleochroic hornblende, locally patterned with expelled iron ore, forms large irregular plates enclosing small rounded crystals of plagioclase, pyroxene, iron ore and olivine, the latter usually being screened from the amphibole by a narrow reaction rim of pyroxene dusted with blebs of black iron ore. Crystals of schillerised hypersthene show highly-irregular shapes, while the plagioclase falls in the bytownite range, with a composition of An_{82} .

A rock from Kathanawa, 45/1036, is purplish-black, coarse-grained, and displays a bronzy lustre on some crystal faces. Olivine occurs as large, fractured and embayed cores with alterations to an intensely-coloured olive-green product. These are surrounded by reaction rims of small-scale equigranular mosaic of hypersthene crystals, followed in turn by sub-radial aggregates and sheaves of amphibole laths, intergrown with spinel at their junction with the surrounding plagioclase. Large crystals of augite and hypersthene are highly schillerised, dusty and altered marginally to actinolitic amphibole. In the more altered parts of the slide larger crystals of actinolite are also present. Plagioclase is usually well twinned and fresh but is often fractured, the fractures being laden with blebs of spinel. Patchy sieve plates of scapolite replace plagioclase in places.

(iii) *Olivine norites* Rocks in which augite is markedly subordinate to hypersthene are among the less common of the suite. Specimen 45/1016, collected from a boulder-strewn exposure on the track south-west of Kalimangilu 6.4 km east of Kaithango, is a medium-grained blue-black gabbro. Olivine crystals display no fine-grained reaction rims. Hypersthene forms envelopes of elongate anhedral crystals about olivine cores and intergrowths with spinel. Subordinate augite is of similar habit. In specimen 45/945, an olivine-rich rock from 1.6 km north-west of Kalimangilu, augite occurs as rare flakes in patches of pyroxene, mainly of hypersthene; the latter also forms elongate crystals marginal to olivine and is also the basis of the fine-grained double reaction rim to olivine. Hornblende often completely encloses large iron ores associated with anhedral spinel.

Specimen 45/783, collected from the group of boulders on the Kora Wells-Tana river track, 400 m north of the river, contains olivine in large irregular and resorbed shapes and smaller crystals enveloped with augite and hypersthene in large poikilitic plates of hornblende. Clear elongate shapes of pyroxene lie adjacent to olivine crystals and both are set in mosaic patches which are often dusty and schillerised; some augite is distinctly

zoned. The plagioclase shows misty twinning and carries a high concentration of regularly-disposed green prismatic and rod-like inclusions.

Specimen 45/1028, from Kathanawa, appears coarse-grained and glistening-black in hand specimen. Internal reflection results in a striking bronzy lustre in some crystals. In thin section the olivine appears as a few large crystals, associated with spinel and surrounded by zones first of clear or dusty hypersthene and then of lobes of intergrown pyroxene-spinel, in which some of the pyroxene is augite. Regular rounded subhedral prisms of augite, dusted a more or less rusty colour with inclusions, locally display a border of hypersthene. Plagioclase laths exceed 5 mm length and extinction on Carlsbad-albite twins indicates a composition of An_{70} .

Specimen 45/1044, from the dry river bed near Kathure, is a glistening, medium-grained blue-black gabbro. The olivines attain a length of 2.5 mm and are surrounded by double reaction rims composed mainly of hypersthene but locally of augite. Both pyroxenes display intergrowth structures with spinel. Carlsbad-albite twinned prisms of plagioclase give extinction angles indicating labradorite of composition An_{68} , but locally the felspar occurs as pools of mosaic suggesting local recrystallisation.

A rock (45/890), collected from the track 800 m south-west of Kalimangilu, has glistening black crystal patches in hand specimen which prove to be hornblende. The amphibole is pleochroic from buff to red-brown and occurs in thin section as 3-mm patches of equigranular, irregular polygons of 0.5 mm diameter outlined with tracts of black iron ore granules or patterned by minute blebs and rods of the same mineral, oriented in several directions. Red-brown biotite is also present as an included patch, 1 mm in diameter, of large plates again with margins accentuated in places by concentrations of black iron ore.

Olivine is present as small, irregular, resorbed crystals poikilitically enclosed in plates of hypersthene or surrounded by small crystals of pyroxene and then in turn by brown hornblende. Hypersthene and subordinate augite occur as large schillerised distorted plates giving undulating extinction and also as an equidimensional small-scale pyroxene mosaic.

Well-twinned distorted labradorite (An_{64}) often shows well-defined concentric zones peppered with large spinel granules which are also disposed on occasional twin planes.

(2) Ultrabasic intrusives

The ultrabasic igneous rocks associated with the gabbro suite also cover a wide compositional range, and include perknites, picrites, serpentinites and amphibole rocks

(a) *Pyroxene perknites*

Olivine pyroxenites are present as mafic units in the layered rocks of the gabbro core west of Kalimangilu where they occur as narrow, cm-scale ore-rich bands.

(i) *Olivine-ilmenite pyroxenites* Specimen 45/966 is from outcrops exposed in the stream bed east of the hill of sediment 4 km north-west of Kalimangilu. The gabbro is cut by numerous thin, parallel, lenticular ore-rich bands striking N-S and dipping steeply W. Stream concentrates of dark minerals derived from this area indicate that only a small proportion of the iron ore is magnetic, the majority being ilmenite.

In thin section the most common mineral is augitic pyroxene usually as large subhedral prisms schillerised and carrying black and brown flecks of iron ore. Smaller augite crystals infill gaps, and are sometimes enclosed in anhedral olivine which is only slightly altered along the fractures to a dark brown material. Black iron ore with rare accessory spinel forms some 25 per cent of the rock, displaying irregular shapes and an interstitial habit, sometimes completely including small rounded pyroxenes.

A dense rock from 1.6 km south-west of Kumbulanawa, 45/928, is banded into units 20-30 mm wide in hand specimen, the leucocratic members being of olivine gabbro while the mafic bands are of olivine-ilmenite pyroxenite. Olivine and augite occur in approximately equal proportions while the iron ore again displays a partly interstitial habit.

In the river bed, 2.4 km south-west of Kumbulanawa, ore-rich bands (45/978) attain a width of 45 cm and are separated by 0.6-2.4 m of gabbro. There the strike is N-E and the dip of the bands is moderate to the NW. Heavily schillerised augite, with red and black iron ore flecks and occasional marginal association with hypersthene and hornblende, occurs in equal proportion with large, irregular, deeply-fractured olivine. A small amount of hornblende as trains of medium-grained mosaic, borders ferromagnesian minerals against pools of plagioclase and is often particularly associated with iron ore.

The basic equivalent of hyperite is a rock containing approximately equal proportions of ortho- and clinopyroxenes only. Specimens 45/1017 and 45/1019 from the lag deposit at a small interfluvium on the track south-west of Kalimangilu, 5.6 km east of Kaithango, are both free of olivine. In the former, augite and strongly-pleochroic hypersthene are accompanied by accessory calcite, hornblende and iron ore.

(ii) *Augitic hypersthene* Specimen 45/996, from the southern flank of the northern hill of the Kalimangilu group, is also composed essentially of pyroxenes with large distorted subhedral prisms of hypersthene, coarsely schillerised and attaining a length of 10 mm, accompanied by subordinate augite and set in a small quantity of finer-grained granular pyroxene mosaic.

(b) *Serpentinites*

Serpentinites, some still carrying numerous fragments of fresh olivine, were found at three different localities. Rock 45/756, from south of the Tana 5.6 km north-west of Kora hill, is in hand specimen a compact black rock with irregular blotches of reddish-brown and buff material, a weakly-developed fabric and patches of fine-grained reticulate patterning. In thin section the rock is seen to be composed mainly of fibrous (optically length-fast) serpentine material locally interleaved with expelled iron ore showing cellular structure, the cells being outlined with further concentrations of black iron ore. A few large, irregular, isotropic olive-green crystals, occasionally associated with simple shapes of original iron ore, are probably spinel.

Specimen 45/1030, from the western flank of the major hill of the Kathanawa group, is a mottled rock with elongated, rounded, dark patches and numerous rusty flecks in a paler base. On weathered surfaces it is finely and deeply pock-marked. In thin section the rock is seen to be composed mainly of chlorite and serpentine minerals, locally rich in grains of iron ore and carrying widely-parted, elongated fragments of olivine still in optical continuity but separated by broad channel-like bands of length-fast cross-fibre serpentine.

The northern peak of the Kalimangilu group has a core of serpentinite. Rock 45/994, from its eastern flank, is light buff-green in colour, patchily dark and light and locally with a fine-scale reticulate pattern of dark veins about pale green cores. The most abundant mineral is fibrous serpentine which forms cross-fibre veinlets and infills sub-polygonal cells sometimes as a series of concentric shells of radially-disposed fibres. Cell margins are often accentuated with black iron ore which locally also shows small-scale wavy, interleaving patterns with serpentine. Rock 45/995 from the peak of the hill is a coarse-grained, dark, dense rock with hackly fracture and occasional large bronze crystals displaying faces up to 6 x 10 mm. Thin section shows the rock to contain serpentine locally intercalated with black iron ore and large, highly-fragmented olivine crystals with serpentine-filled channels carrying median concentrations of expelled iron ore. Isotropic, dark khaki-green crystals, probably of spinel, are present.

Specimen 45/997, from an adjacent exposure at Kalimangilu, can be seen in thin section to be composed mainly of large crystals of olivine with broad fractures infilled with grains of black iron ore and serpentine as cross-fibre veinlets. The serpentine mineral differs from chrysotile in that the fibres are optically length-fast. About a quarter of the rock is composed of pyroxene, predominantly augite, and the remainder of the rock is feldspar, rarely fresh and well-twinned, being usually completely sericitised. Accessory minerals include iron ore and spinel.

(c) *Amphibole perknites*

Ultrabasic rocks composed entirely or largely of amphibole occur within the area with

apparent preference for a zone marginal to the gabbro masses. The amphibole rock intrusions are usually small and locally their exposure suggests a dyke-like form. It is often impossible to assess the mineral composition of the original intrusive rock as it is considered that much of the chlorite and actinolitic hornblende present is derived subsequently by metamorphic alteration.

(i) *Hornblende rocks* A medium-grained glistening amphibole rock (45/999) forms the small calcrete-capped hillock on the eastern bank of the Mwitamisi 9.7 km south of Kumbulanawa. The subhedral hornblende crystals constituting the majority of the rock have cores darkened with alteration products and the interstitial spaces are infilled with scapolite and accessory plagioclase.

(ii) *Actinolite rocks* A specimen collected from the interfluvial outcropping a variety of basic rocks 5.6 km north-west of Kora hill (45/757) appears monomineralic in hand specimen, being composed entirely of medium-grained, lustrous, green-black amphibole crystals. The thin section displays large fresh euhedral and subhedral actinolite with the rare small interstitial quartz patches.

(iii) *Hornblende- and actinolite-chlorite rocks* Rocks of this composition occur at several localities, the proportion of chlorite present varying from a bare 5% to over half of the rock. Anthophyllite is a common accompanying mineral and so also is black iron ore.

Specimen 45/750 from a small dyke-like exposure among the 'Basement System' gneisses 3.2 km north-east of Makyalu is a glistening, dark green, medium-grained friable rock in hand specimen, with an incipient fabric and texture of interlocking laths and mica-like plates of dark minerals. In thin section crystals of hornblende, pleochroic from neutral to pale green and khaki-green and often carrying dense concentrations of grains of black iron ore, attain a length of 2 mm and are accompanied by prismatic laths of colourless anthophyllite frequently 3 mm long, showing occasional perfect rhombic cross-sections. Pools of interstitial low-birefringence material, weakly pleochroic in shades of pale green, are of clinoclase.

A small intrusive mass with diameter on dm-scale crops out among altered basic rocks in a tributary of the Mwitamisi at the southern end of Kalimangilu hill just east of the track crossing.

This greenish-black, medium-grained rock (45/897) shows, in hand specimen, a felted mass of amphibole crystals with 2 mm-long, glistening, needle-like laths in sub-parallel alignment. In thin section actinolite crystals, euhedral and anhedral, large and small, form an interlocking mesh carrying occasional euhedral anthophyllite laths, large interstitial pools of chlorite and accessory rutile. Another rock composed of actinolite, anthophyllite and chlorite, specimen 45/881, is exposed where the eastern flank of Kalimangilu hill meets the Mwitamisi river.

Specimen 45/758, from a small exposure of weathered boulders 9.7 km south of Mansumbi, is composed of large, partly disintegrated prismatic plates of actinolite often smothered with blebs and rods of black iron ore, the actinolite being replaced generally by a felted mass of clinochlore which has developed with a distinct preferential orientation unrelated to the preferred orientation displayed by the actinolite remnants.

In an area of poor exposure to the east of the track south from Mansumbi, an extensive low mound of black boulders 8 km south-south-east of Kathanawa is composed of an actinolite rock. In thin section (45/763) the actinolite crystals are seen to develop locally an external border of colourless tremolite. Subordinate clinochlore is accompanied by accessory black iron ore, haematite and apatite. Specimen 45/1035, from the northern hill of the Kathanawa group, is of interest in that the fine- and coarse-grained ragged actinolite crystals forming an interlocking mesh in equal amount with clinochlore have narrow outer margins of more faintly-coloured amphibole and occasional striated cores suggesting possible derivation from a schillerised pyroxene.

(iv) *Olivine-actinolite-chlorite rocks* Specimen 45/969, from the bluff north of the sand-river 8.9 km north-west of Kalimangilu, is a coarse-grained, dark green ultrabasic rock with hackly fracture and generally rusty, altered appearance on broken surfaces. Most of the amphibole present is actinolite in large sieve-plate remnants and as discontinuous patches in optical continuity with local patchy concentrations of expelled black iron ore. Much of the groundmass is clinochlore while occasional large olivine crystals are marginally changed to iddingsite. Black iron ore and apatite are accessory.

(3) Metamorphosed gabbros

Among the rocks marginal to the main basic intrusion and comprising the smaller intrusive masses, a complete range of types derived by the alteration of gabbro can be demonstrated.

(a) *Metagabbros*

Specimens 45/902 and 45/919 from the relatively unaltered end of the range were previously described under olivine-free gabbros. Hornblende in these rocks forms reaction rims against pyroxene and plagioclases and is associated or clouded with iron ores. It also forms mosaic patches in optical continuity with fragments and cores of pyroxenes.

Specimens 45/722 and 45/723, both from exposures south of the Tana river 5.6 km north-west of Kora hill, are altered gabbros. Obvious recrystallisation characteristics are displayed by 45/722 where large distorted labradorite crystals of composition An_{58} exhibit complex twinning with twin planes bent occasionally through 4° or 5° and displaced by lateral movement. Replacement of original feldspar is common, by irregular polygonal medium-grained mosaic of poorly-twinned plagioclase which occurs in patches, marginally or in tracts across the larger crystals. Sometimes small irregular-shaped fragments of

highly-twinned original labradorite in optical continuity occur as islands in the poorly-twinned feldspar mosaic.

Among the ferromagnesian minerals, cores of pyroxene can be identified as hypersthene, occasionally with numerous oriented inclusions, overgrown and surrounded by patchy concentrations of fine- and coarse-grained amphibole. Fresh-looking interlocking masses of rich brown biotite, irregular crystals of black iron ores and subhedral hornblende prisms occur elsewhere. As with the feldspars, biotite and amphibole crystals are often markedly bent.

Specimen 45/723, from an adjacent exposure, shows wide grain-size and textural variation in different parts of the thin section. Some andesine crystals composition c. An_{50} show progressive variation in extinction angle from core to margin amounting to 10° , equivalent to a 16 per cent variation in anorthite content. Ortho- and clinopyroxene are both present, the hypersthene exhibiting a subhedral prismatic habit and occurring in the coarse-grained, more mafic parts of the slide, associated with large amoeboid and part-interstitial iron ores and accessory apatite. The coarser, pyroxene-rich patches show limited marginal alteration to amphibole but in the finer-grained parts a more equidimensional texture is displayed, with crystals of plagioclase and iron ore predominating, and irregular clusters of hornblende containing rounded cores of pyroxene.

Other types of metagabbros were collected from the Mwitamisi river 400 m from the southern boundary (45/1001); from the same river 4.8 km south of Kumbulanawa (45/1000); and from 800 m north-west of Kalimangilu (45/938).

Specimen 45/1000 was collected from an exposure of mafic hornblende migmatite forming a whaleback in the river and displaying a variety of characteristics common in paramigmatites, including boudinage structures, swirling and contortion of the component bands of contrasting mineral compositions, and lensing out of individual units. Thin section examination shows the band samples to be definitely of gabbroic origin. The rock is composed largely of hornblende exhibiting a variety of habits. It occurs as large plates patterned with granules of iron ore and as dark rims round fine-grained tremolite mosaic also spattered with iron ore granules. Dark rims of hornblende surround large simple anhedral iron ores and form variegated patchy rims about partly-altered cores of augitic pyroxene. The remainder of the rock is composed of plagioclase, locally fresh but usually saussuritised. Rocks collected from Kathure (45/1038, 45/1039 and 45/1040) are all medium-grained, dappled black and white rocks of differing colour index in hand specimen and prove to be metagabbros with cores of pyroxenes preserved amid masses of secondary amphibole. Sometimes the cores retain their schiller structure and, as in 45/1038, some hornblende crystals have patches clouded with inclusions and others have centres spattered with granules and clusters of granules of augite. Feldspars display two habits - one as large irregular plates, well-twinned, bent, fractured, slightly sericitised and shot with needle-like inclusions and another as medium-grained polygonal mosaic patches, clear and untwinned or very simply twinned. Scapolite is a common accessory.

(b) *Ortho-plagioclase amphibolites*

The result of retrogressive metamorphism of gabbros is the production of ortho-plagioclase amphibolites. This rock type is probably the most abundant in the zones surrounding the gabbro core and adjacent to gneisses of the 'Basement System'. In the latter situation it is often impossible to be sure that the rock is of true gabbro parentage as mafic hornblende gneiss bands and hornblende migmatite patches could equally well be derived by retrogressive metamorphism from *lit-par-lit* intrusions of rock of gabbro type, or by regional metamorphism of ferromagnesian-rich sediments or volcanics in the original 'Basement System' succession.

The persistent recurrence of cores patterned with granules of expelled iron ore suggests that in almost every case the present green 'metamorphic' hornblende was derived either from a pre-existing higher-temperature amphibole richer in iron or more likely from an iron-rich pyroxene.

Rocks providing specimens 45/878 and 45/879 are both composed essentially of plagioclase and amphibole, and occur on the eastern spur of the northern part of Kalimangilu hill where it forms a diminutive cliff at the Mwitamisi river. Both rocks are coarsely segregated into patches predominantly of leucocratic or mafic minerals, and elongation of the dark patches gives the exposure a vague E-W fabric. In 45/879 ferromagnesian clots, consisting of an interlocking mass of randomly-oriented actinolitic hornblende with interstitial infilling of scapolite, form rafts in an anastomosing network of highly saussuritised felspar veins some 10 mm wide. Patterns of expelled iron ore are present in the cores of some actinolite crystals. Cutting the general trend of the coarsely-segregated members are several bands of fine-grained rocks (45/880) with clearly-defined boundaries, striking NW and dipping steeply to the NE. Their disposition suggests that they may be dykes emplaced prior to final regional metamorphism, or perhaps original banding in the gabbro oriented at an angle to the gross, ill-defined fabric developed subsequently in the host rock on metamorphism. Their composition leads to their classification as plagioclase amphibolites. Large and small subhedral iron ores and abundant small prisms of accessory apatite accompany strongly-pleochroic anhedral and subhedral hornblende to form about half of the rock, while the remainder is of rarely-twinning plagioclase mosaic more or less saussuritised with production of epidote and sericite.

Specimen 45/903 from a lens of fine-grained black rock which crops out in the river bed 400 m north-west of Kalimangilu, consists mostly of intensely-coloured, strongly-pleochroic hornblende. Large plates of hornblende carry patterns of oriented rods of expelled iron ore. The appearance of the exposure suggests that the rock may be derived from metamorphism of a dyke or a mafic band in the gabbro.

A fairly normal plagioclase amphibolite from the river south of Kalimangilu (45/898) is of interest in that the pale actinolite with rare iron-speckled cores is accompanied

by plagioclase of which few original well-twinned remnants have survived recrystallisation, which has produced local patches of clear felspar mosaic, large irregular rounded plagioclase crystals with blotchy extinction, and exsolution intergrowths and areas rich in pools of quartz. Rutile and epidote are accessory.

Specimens 45/983 and 45/984, from Kalimangilu waterholes, are from exposures of dark rocks on the north bank of the Mwitamisyi river. Similar in hand specimen, the latter is a fine-grained, olivine-free hyperite while the former is an ortho-plagioclase amphibolite - perhaps the metamorphic derivative of the hyperite. In thin section the plagioclase amphibolite shows different minerals and a different texture in patches. Areas of highly saussuritised felspar carry pseudomorph patches of tremolite-actinolite laths with some chlorite surrounded by a narrow margin of darker hornblende. Contrasting areas are of strongly-coloured subhedral hornblende with occasional inclusions of rounded blebs of iron ore associated with fresh well-twinned plagioclase, suggesting that the latter mineral association may be produced by complete recrystallisation of the former which was produced in turn from the metamorphic breakdown of the hyperite.

Plagioclase amphibolites 45/1010 and 45/1011, from the river-bed 10.5 and 11.3 km west of Kumbulanawa, contain a high proportion of intensely-coloured hornblende with rare patterns of expelled iron ore. Irregular, large iron ores occur in specimen 45/1011 and patterns of oriented crystal units of the fine-grained, granular hornblende mosaic which constitutes the sole ferromagnesian mineral in the rock, are strongly suggestive of derivation from highly-schillerised pyroxene.

(c) *Microgabbros*

Microgabbros, rocks classified as fine-grained gabbros were observed at several localities. Their mineral composition (and sometimes their texture and mineral habit) is strictly comparable with that of the coarse-grained gabbros of the major intrusion of which they are obviously a fine-grained facies. A similar though more restricted range of composition is demonstrated with olivine-rich and olivine-free examples and rocks in which augite preponderates, and others richer in hypersthene. The significant point about this group of rocks is their distribution. In every case they are found invading or associated with rocks of the major gabbro mass or basic rocks demonstrably derived from them. In no cases were doleritic dykes or minor intrusions of microgabbro seen to invade gneisses of the 'Basement System' - a situation to be expected had gneiss and gabbro occupied their present relative positions at the time of dyke emplacement.

If dykes and invaded gabbros were subject to identical metamorphic processes they would be expected to have suffered a comparable degree of alteration and recrystallisation. Specimen 45/880 and 45/903 described elsewhere under 'ortho-plagioclase amphibolites' probably originated as dyke rocks.

Specimen 45/893 is of olivine microgabbro which forms a 1.8-m vertical dyke cutting

the country rock of hornblende-rich hyperite on the track 2.8 km south-south-west of Kumbulanawa. Only rarely have olivines escaped complete obliteration by iron ore granules which now lie developed within the olivines' reaction rim of pyroxene-spinel intergrowth. Alterations of pyroxene to hornblende can be seen and much calcite has been introduced. Most of the biotite in the slide is probably primary, associated with skeletal black iron ores and the feldspar, mainly well-twinned igneous laths, shows pronounced progressive extinction and interstitial growth of crystals with material of contrasting composition. Patches of hazy twinning and shadowy extinction suggest partial alteration. The hornblende-hyperite rock (45/892) carries no olivine and shows little sign of recrystallisation. Rare, rounded blebs of feldspar and quartz pools among the precisely-twinned plagioclase crystals may represent late-stage alteration and introduction.

Although coarse-grained fresh gabbro crops out farther east and west, the rocks exposed adjacent to the outcrop of olivine microgabbro (45/911), 800 m north-west of Kalimangilu, are all dappled black and white plagioclase amphibolites with contorted banding illustrated by contrasting hornblende-rich and granular feldspathic bands. The banded hornblendic sequence has been folded about an axis plunging at 60° to the W and the unaltered igneous material apparently occupies the cores of this minor fold. The microgabbro is apparently clear and unaltered in thin section.

Specimen 45/926 is from one of several small dykes cutting the gabbro of the peak of Kumbulanawa. In hand specimen the fine-grained dyke, some 30 mm in width, shows straight, sharp boundaries with the host rock. The latter is an olivine gabbro with augite predominating over heavily-schillerised hypersthene with hieroglyphic patterns of black iron ore, and both pyroxenes show occasional intergrowth structures with spinel. Hair-line fractures, parallel to the dyke margin, occur frequently in the first 2 mm adjacent to the boundary and are accentuated by minute specks of black iron ore. Only minerals within a marginal width of 1 mm have been affected by the material of the dyke.

Feldspar phenocrysts within the dyke show euhedral prismatic form and are aligned parallel to the gabbro margin. They are dotted with small stumpy rods of spinel, some of which show multiple twinning. At a distance of 8 mm from the boundary, granular augitic pyroxene, black iron ore and subordinate brown hornblende with rare biotite are accompanied by twinned and untwinned feldspar. At the junction brown hornblende predominates among the ferromagnesians almost eliminating iron ore and augite.

A significant feature is the equidimensional granular metamorphic texture of the dyke, apart from the obvious phenocrysts, suggesting the dyke was emplaced carrying ready-formed plagioclase prisms and then crystallised under conditions of temperature and pressure comparable with those required to produce metamorphic granulites.

3. Minor intrusives

Basic dykes are not common in the area, but their distribution is widespread, covering the whole of the area of the 'Basement System' gneisses and the gabbros. Concentrations of angular fragments of igneous origin were observed on the ridges and among float during stream traverses, without any source being located, suggesting that, even if not common, poorly-exposed basic dykes occur rather more frequently than recorded outcrops indicate.

It is apparent that the dykes invading the rocks of the area are of two main groups: basalts, and lamprophyres with camptonitic affinities. Both these groups can be subdivided, the former into basalts with and without evidence of olivine, and the lamprophyres into camptonites and apparently felspar-free rocks, monchiquites.

There is no persistent preferred orientation of dykes in the area except the general tendency, particularly among the basalts invading gneisses, to align themselves with the local strike trend. Well-exposed dykes of camptonite and monchiquite among the gneisses often lie almost at right angles to the local strike trend.

(1) Basalts and dolerites

(a) *Basalts containing olivine*

A narrow dyke crops out in the eastern bank of a stream 6.4 km north-west of Yumbandei, where it strikes 015° and dips 60° to the E. In hand specimen 45/936 the rock appears medium-grained with igneous texture and large prismatic felspar phenocrysts displaying faces sometimes reaching 6 x 4 mm. The rock is cut by occasional greenish veins of chloritic material with specks of iron pyrites. In thin section occasional euhedral and abundant subhedral olivine, deeply fractured and bearing narrow rims of iddingsite and iron ore, are accompanied by complete pseudomorphs after olivine composed of calcite, serpentine and iron ore and less common neutral-buff augite. The large phenocrysts of labradorite, with a composition of An_{66} , show different degrees of alteration, sometimes displaying clear, well-twinned cores with partly sericitised margins and intermediate zones and at other times being more or less completely sericitised. A few large anhedral black iron ore grains are present and calcite appears in large clear plates. The groundmass texture is locally of interlocking subhedral felspar laths and prisms with interstitial infillings of augitic pyroxene, black iron ore and abundant carbonate. Elsewhere large amounts of alteration products from the breakdown of olivine result in patches dominated by red-brown iddingsite, iron staining and carbonate.

In exposure this olivine basalt dyke (45/936) is cut by a second, very much finer-grained dyke which is disposed vertically and strikes nearly N-S. It runs centrally down the

stream bed cutting the earlier dyke to the south and exhibiting distinct sinuous chilled edges. The thin section of the second basalt dyke (45/937a) shows phenocrysts of basic labradorite accompanied by pseudomorphs after phenocrysts of olivine in a very fine-grained, felted groundmass in which minute laths of feldspar, granules of pyroxene and iron ore can be discerned.

Small exposures and a local concentration of angular olivine-bearing basalt fragments occur among the gneisses on the western bank of the Urukate sand-river, 6.4 km north of the Tana. This rock, 45/817, contains well-preserved subhedral olivine and augite crystals, irregular anhedral iron ores and sericitised euhedral feldspar prisms. Associations of calcite and chlorite occur commonly as pseudomorphs after ferromagnesian minerals and elsewhere calcite is associated with zeolite in vesicle fillings. The plagioclase inclusions form clusters with interstitial infilling by pyroxene, iron ore and olivine, together with pseudomorphs of the latter. The groundmass, largely of intensely-coloured augite and highly-sericitised plagioclase, contains crude part-spherules of chlorite, with radial extinction, together with calcite, iron ore and occasional scapolite.

Specimen 45/733, from a dyke cropping out among gneisses in a small stream bed 1.6 km west of Kora hill, is composed of a mesh of completely-twinning plagioclase laths of mid-labradorite composition infilled with pinkish clinopyroxene, pale green chlorite and a liberal spatter of small subhedral black iron ores. Pseudomorphs, probably after olivine phenocrysts, occur in pale green to colourless aggregates of chlorite-serpentine minerals.

Another dyke, aligned along the strike of the gneisses, crops out 3.2 km farther west (45/729). It is of similar composition, with large pseudomorphs probably after olivine and now infilled with calcite and chlorite-serpentine minerals and with vesicles filled with chlorite and zeolite, the latter showing a faint reddish colour due to a fine dusting of minute inclusions. A similar rock (45/1050) forms a dyke crossing the track 7.2 km north-east of Monsumbi.

(b) Basalts without olivine

In the basaltic rocks forming some of the dykes there is no indication of olivine. One such specimen (45/739) is from a line of poor exposures indicating the presence of a dyke some 3.7 m wide crossing the track 4.8 km east of Kiome, 2.4 km south of the Tana. The groundmass is composed of ophitic clinopyroxene and complexly-twinning labradorite laths forming an interlocking mesh with a high proportion of interstitial calcite and crystals of black iron ore.

A slightly finer-grained rock (45/780) forms a substantial dyke 4.8 km south-west of Kora Wells. Rare clusters of euhedral feldspar prisms form the phenocrysts in a groundmass of intensely-coloured brown augite, feldspar laths, iron ore and interstitial calcite. Again the vugs present are infilled with carbonate and zeolite, the latter dusted a pale reddish-

brown with minute inclusions.

Specimens 45/1014 and 45/1015, of a similar basalt type, were collected from a narrow dyke which cuts metamorphosed basic rocks 4 km east of Kaithango. These fine-grained rocks have been severely affected by alteration, particularly of the original pyroxene which now only occurs as rare augite cores surrounded by masses of granular calcite and indeterminate alteration products.

(2) Lamprophyres

The lamprophyric dykes of the area are characterised by the presence of deep brown hornblende. The more basic members of the lamprophyre range are also the under-saturated ones, so where no feldspar is recognised a distinction is possible from camptonites, the unsaturated members being referred to as monchiquites. The classification of this group on the nature of their sometimes doubtfully-crystalline isotropic base and invariably highly-altered feldspar is rather unsatisfactory, but is accepted tentatively. It is stated (Hatch *et al.* 1948, p. 335) that the type-monchiquite has a non-crystalline base which has a composition of nepheline and basic plagioclase, so the presence of an occasional doubtful feldspar cannot be considered critical. It is also stated by these authors that as well as analcime in the base, '... these rocks frequently contain analcite in a more obvious form as small circular areas resembling vesicles, but termed ocelli'. This habit is displayed in several of the monchiquite dyke rocks of the present area.

(a) Camptonites

A dyke some 1.8 m wide is exposed in the 9-m cliff of highly-deformed mafic gneisses at one of the hairpin bends in the sand-river 8 km east-north-east of Yumbandei. The regional strike of the gneisses is almost N-S with moderate dips to the E, and they have been invaded by coarse pegmatites containing occasional garnets up to 30 mm in diameter. The dyke strikes 100° with a steep northerly dip and cuts both gneisses and pegmatite. A chilled margin, 50 mm wide, is present at both contacts with the gneiss.

In hand specimens (45/847, 45/848 and 45/849) it is a medium-grained, light grey rock with 3-mm circular pink blebs with white cores and 2-mm black ferromagnesian phenocrysts. Both groundmass and leucocratic blebs are rich in carbonate. The thin sections display a few large, irregular, subhedral, embayed black iron ores and rather more common colourless, pink, subhedral and euhedral augite phenocrysts which are occasionally twinned, often zoned, and sometimes show 'hour-glass' structures. The large leucocratic patches, visible in hand specimen, have cores of plates of calcite, crude spherules composed of flakes of penninite, chlorite and rare scapolite, surrounded by concentrations of feldspar prisms. Occasional vesicles are infilled with epidote. The groundmass is speckled with isolated grains and angular clusters of black iron ore, sometimes associated with the abundant anhedral crystals and euhedral prisms of augite and brown strongly-pleochroic barkevikite. Occasional augite crystals show marginal

growths of brown amphibole. In common with most lamprophyres, the leucocratic minerals of the groundmass have suffered severe late-stage alteration. Felspar, invariably shot with fine needles of apatite, either shows a good prismatic habit or occurs as an interstitial infilling. Many of the prisms retain remnants of plagioclase-twinning. Some of the clearer crystals, untwinned or simply twinned, yield optically-biaxial negative figures of small 2V suggestive of sanidine. Refractive indices of felspar, where measured, were invariably lower than that of Canada Balsam, indicating the plagioclase to be an extremely sodic member.

Three light grey vertical dykes with an E-W strike cut Mwitamisyi river 3.2 km south of Kaithango near the southern boundary. The northern dyke is 0.3 m wide. The 3.7-m wide southern dykes display chilled margins.

The northern dyke, specimen 45/1005, a light grey rock, has rounded patches of pink felspar 8 mm in diameter and coal-black 5-mm long ferromagnesian prisms. In thin section, generally rounded and resorbed and uniformly slightly-sericitised felspar phenocrysts appear as clusters. Large anhedral black iron ore clusters are associated with rounded (up to 0.3 mm diameter) apatite. Vesicles are filled with chlorite and calcite. Large phenocrysts of barkevikite hornblende are pleochroic from straw-yellow to deep russet-brown. Barkevikite laths accompany abundant, isolated and clustered iron ores. The groundmass is composed of sheaves of fine laths and interstitial plates of felspathic material and probably some zeolite.

In specimen 45/1007 from the southern dyke, euhedral pink prismatic augite occurs individually or clustered with iron ore which also occurs as abundant, isolated, large and small subhedra. Deep brown, subhedral lamprobolite phenocryst remnants are largely altered to epidote. The medium-grained base is of felspar locally severely saussuritized but preserving remnants of plagioclase twinning. Accessories include sphene, epidote, chlorite and apatite.

A rock type transitional between the camptonites described previously and the succeeding monchiquites is specimen 45/865, from one of two vertical dykes running east-west across the gneisses, 4.8 km east of the Chanyigi river, 2.4 km south of the Tana. In hand specimen it appears as a dark blue-black fine-grained rock with many white flecks. In thin section the light patches are seen to be ill-defined leucocratic material, some felspathic with occasional clear, simply-twinned prisms, but the majority low-birefringent or near-isotropic analcite or zeolite. Some elongate prisms carry herringbone patterns of black iron ore blebs, and the leucocratic base is shot with apatite needles. Interstitial granular calcite is common. In the more mafic parts of the slide abundant prismatic barkevikites and euhedral and subhedral grains of black iron ore accompany less common augite prisms in a base of ill-defined shadowy zeolite and analcite.

(b) *Monchiquites*

The rock type (specimen 45/864) forming the second dyke at the above locality is compact black monchiquite with occasional white carbonate-filled vesicles and more common khaki-green pseudomorph patches. In thin section the pseudomorphs are of calcite and chlorite, lined with brown iddingsite and surrounded by concentric rims of fine-grained granular calcite, and calcite and iron ore mosaic. Rare clusters of a dozen or more radially-disposed euhedral and subhedral zoned augite prisms attain a diameter of over 2 mm but isolated crystals and small clusters are more common. The low refractive index, shadowy, near-isotropic groundmass is crammed with small prisms of augite and barkevikite and much calcite.

A fine-grained grey rock (45/935) with occasional white vesicles from a dyke aligned with the strike of the 'Basement System' gneisses 4.8 km north-west of Yumbandei. Vesicular patches are infilled with coarse-grained calcite, and 'ocelli' of analcite are clouded towards their edges with more fine-grained carbonate and carry a peripheral border of tangentially-disposed amphibole prisms. The predominating ferromagnesian mineral is rich russet-brown, zoned and twinned, elongate prisms of lamprobolite showing pseudo-hexagonal cross-sections. These are closely packed, with a crude flow alignment, and accompany less common elongate prisms of zoned augite. Iron ore occurs isolated or in angular clusters in a groundmass with abundant calcite.

(3) Pegmatites

An exposure among metamorphosed basic rocks in the Mwitamisyi river 1.6 km south-south-east of Kumbulanawa, consists of a pegmatite (45/930) composed mainly of quartz and plagioclase in equal proportions with about a quarter of the rock composed of garnets attaining a diameter of 5 mm, with accessory biotite, black iron ore and iron pyrites. In the exposure fine-grained, dense black schlieren are common in the pegmatite host and irregular parallel trains of garnets cross the quartzofeldspathic material and wrap round the included fragments. Thin section of the fine-grained black rock (45/929) shows it to be composed largely of plagioclase with subordinate hypersthene and iron ore, forming an equidimensional granular mosaic, strictly comparable with that of metagranulites. A vague foliation is indicated by preferred orientation of plagioclase crystals displaying multiple twinning, and leucocratic veins, largely of quartz, across the section.

(4) Carbonate veins

Veins composed predominantly of calcite were observed in three localities exposed in stream beds 9.7 km west of Kora hill, 12.9 km east of Komunyu, and 1.6 km from the

northern boundary 9.7 km west of Mbalambala survey beacon. Associated minerals proved to consist only of quartz, epidote, siderite, chlorite and a few flakes of mica.

4. Tertiary sediments and superficial deposits

A large proportion of the area carries a mantle of unfossiliferous sedimentary rocks of Pliocene or Quaternary age. 'Basement System' gneisses are overlain by sediments to the north-west and in a broad strip along the eastern boundary and a single small outlier of rock mapped as part of the same sediments occurs in the centre of the area, 4 km north of Kumbulanawa.

Although coarse-grained fragments are rare within these rocks, a well-developed lag deposit of pebbles caps much of the sedimentary terrain. Over wide areas where gneisses are now exposed the interfluvial areas also carry a scatter of perfectly-rounded quartz pebbles among more locally-derived float. Collections of these pebbles from sedimentary outcrops and from gneissic interfluvial areas fail to reveal igneous material derived from Mt. Kenya and Nyambeni volcanic rocks, all mafic pebbles being more readily related to the basic igneous suite of Kalimangilu, dykes invading the surrounding countryside and hornblende granulites from the 'Basement System'. Exceptions to this occur where collections of pebbles were taken from the overflow channel of the present-day Tana at the mouth of the Chanyigi river and from a pebble bank 1.6 km north of the Tana near the western boundary. In both these cases the pebble concentrations are considered to have been deposited in Recent times. Basic lava pebbles were also recorded on the interfluvial area overlooking the Tana, 2.4 km west of the mouth of the Bisanadi river at an estimated height of 30 m above the present river level.

Beyond the eastern boundary of the area, away from the Tana and also well to the south, the soil cover developed on the sediments is bright red, but where the soil cover is thinner the coloration is highly variable, being red locally but more commonly pale, sandy and grey or buff. Soils with 'black cotton' characteristics are developed in poorly-drained regions.

The sediments are generally extremely poorly consolidated and cemented. Rarely is any well-defined stratification displayed and where seen there is usually some doubt as to whether it represents true bedding. This is particularly true where horizontal boundaries divide grits of contrasting colour, when the rock is homogeneous in all other respects. Static water tables in the past and colour variation with weathering at depth could produce this effect. Even better-cemented horizons need not be directly related to original bedding; bands of coarse-grained strata and rare pebble horizons give the only undoubted bedding planes.

Where the bulk of the rock is uniformly poorly cemented the absence of well-defined

near-horizontal bedding results in the failure on weathering and erosion to produce 'table-top' and terraced features commonly associated with sedimentary terrains. Features of this type are, however, displayed along the eastern boundary, overlooking the river from the north, but more particularly between the boundary and Mbalambala farther east. The sediments of the north-west are well exposed south of the river where a 'tip-heap' style of topography has developed from the maturing of a 'badlands' terrain. Rounded conical mounds of unconsolidated sedimentary debris carry sparse apical fringes of thorn scrub and concentrations of rounded pebbles, the large ones attaining a diameter of c 13 cm. Rounded pebbles and calcrete blocks accumulate peripherally at the foot of the scree slopes and rapid erosion of the vegetation-free slopes produces deep concavities. Complex dendritic drainage patterns characterise the minor river systems but the major rivers have broad alluvium-filled beds in which the river course is braided or hugs one bank. The alluvium often supports a dense growth of scrub, doum palms and thorn trees.

The proximity of the sediments of the extreme north-west of the area is marked by a 4.8-km wide sprinkling of rounded pebbles within the superficial cover of the gneisses. The general colour of the sediments is off-white or very faint greenish-buff near the surface but variegated in pale shades of red, yellow, purple and green at greater depth. The superficial white coloration of the terrain is largely a result of atmospheric weathering and bleaching of the calcareous grits. Locally, nodules of calcrete strew the ground and are sometimes cemented into large irregular flaggy blocks and elsewhere develop within the sediments assuming arborescent or digitate forms. The fine-grained wash derived from the grits is usually pure white sand which accumulates in local depressions, in stream beds, on banks and as outwash fans from the gullies among the sediment mounds. Concentrations of pebbles, largely composed of iron-stained quartz, occur on near-horizontal surfaces at a variety of levels.

A specimen of calcareous grit, 45/794, collected from a low river cliff in the extreme north-west, proved too friable for sectioning. Included fragments are generally rounded and ill-sorted and are mainly composed of glassy quartz, some fragments attaining a length of 15 mm, with less common feldspar and rock debris including pieces of fine-grained leucocratic granulite. The pale green matrix is highly calcareous with local small patches of pink, rusty-red and purple staining.

River cliffs 6-9 m high show near-horizontal stratification of the poorly-consolidated sediments on the sharp bends in the sand-river 800 m north of the Tana near the western boundary. Contrasts between adjacent bands are mainly in colour and grain-size. Specimen 45/800 from this locality is a fine-grained greenish-white grit with a copious carbonate cement and fragments composed mainly of quartz, the largest attaining a length of 2 mm. A poorly-cemented, boldly-variegated black and buff nodule (45/801) from the same locality proves to be composed mainly of carbonate with concentrations of fine-grained, granular black iron ore forming irregular patches 30-40 mm across. Rare quartz and feldspar fragments are present.

A well-cemented, compact nodule of fine-grained calcareous grit (45/799) of irregular rounded ('Henry Moore-type') shape is from the same locality, 1.6 km north of the Tana, near the western boundary, which provided a concentration of pebbles rich in basic lavas. In thin section it is seen that about half of the rock is composed of fragments oriented with long axes parallel and half of cement. The fragments are sub-angular and occasionally well rounded and sometimes attain a length of 5 mm. The grains are largely of individual minerals in which quartz and well-twinned plagioclase predominate. Other grains were recognised as sphene, in irregular anhedral shapes, bright green fresh hornblende, epidote, microcline, chlorite, biotite, garnet, muscovite, black iron ore and haematite. Small rock fragments proved to be lavas with flow-aligned plagioclase laths.

Sediments are again exposed in the region 1.6 km to the west of Mbalambala survey beacon. To the east a light sandy soil covers the plain and locally carries a near-continuous pebble sheet in which the vast majority of the pebbles are perfectly-rounded quartz, colourless or white within but invariably with exteriors iron-stained red, golden-yellow or liverish-purple. West of the beacon the country becomes broken and dissected after 1.6 km and a series of gullies and minor west-facing scarps mark the thinning of the soil cover and erosion of the western fringe of the sediments. Exposure of bedrock is not common, the slope of the majority of scarp faces falling between 15° and 20° from the horizontal and carrying a complete blanket of sediment debris. Calcrete, bleached grit and deposits of white sand combine to give the area a uniformly white appearance apart from the local concentrations of iron-stained pebbles on horizontal surfaces. A 9-m high conical hill, a residual left behind by the retreating low-angle scarps, carries a thin calcrete capping and has developed mildly-concave scree slopes. The scree is composed of unsorted rotten rock with a preponderance of quartz sand on the upper slope, and large quartz pebbles from the original capping and tumbled blocks of calcrete towards the base.

Removal by shallow pitting of the loose scree and weathered zone at intervals up the slope demonstrated a graduation in rock type. A highly-coloured, variegated grit (45/820), basically khaki-grey but with bold patterns of bright rusty-red and with slate-grey clay-rich lenses is found at the lowest levels. Midway up the slope, less highly-coloured clay-rich rocks have local development of calcrete nodules. Towards the top the rock consists mainly of calcrete nodules, poorly cemented with gritty grey clay.

Some 90 m farther south from the track mottled red and greenish-grey, poorly-consolidated grits with occasional pebbles form a steeper slope due to the local development of a better-cemented grit horizon near the surface. A sample of this 0.6 m band, specimen 45/822, appears in hand specimen as a coarse-grained, ill-sorted grit with some well-rounded and some slightly-rounded grains, the largest attaining a length of 14 mm. The majority of the fragments are of quartz, either milky or colourless, and a copious calcite cement is pale greenish-buff in colour except where iron staining causes a pinkish coloration. All fragments recognised in this section were of probable

'Basement System' origin with mineral fragments of quartz, microcline and plagioclase predominating and fine-grained rock particles including quartz-felspar granulites and quartz-felspar-muscovite gneisses.

The sediment-outcrop 4 km north of Kumbulanawa overlies part of the hypersthene gabbro intrusive. It has the form of an 18-m high mound of white calcareous dust cut by a deep erosion gully which shows rare calcrete horizons and occasional rounded fragments of iron-stained quartz, the largest recorded having a length of about 100 mm and a width and breadth of c 50 mm. The acid insoluble residue obtained from a calcrete nodule (45/962) from this site contained mainly ilmenite and magnetite with less common quartz, plagioclase and occasional garnets indicating probable derivation from 'Basement System' gneisses. If this material was of purely local origin it would contain olivine, pyroxene and spinel.

VI. STRUCTURES OF THE 'BASEMENT SYSTEM'

The strike of the gneisses of the northern parts of the area follow the general N-S trend in common with the 'Basement System' throughout most of Kenya. Severe dissection by the Tana river has resulted in excellent exposure across the northern part of the area where there is an abundance of structural data available. In the river section it can be seen that the whole sequence has been thrown into a series of more or less open folds plunging generally northwards. Culminations and depressions of the fold axes illustrated by the form of rock outcrops and confined by lineation measurements result in folds plunging locally to the S.

Broad exposures of leucocratic granitoid migmatite producing a terrain of whalebacks and rounded dome-like hills are often poorly foliated but display dips and strikes locally, which invariably indicate vague inverted boat-like structures, with concordant strikes and dips outward from the centres suggesting the infilling of anticlinal cores or possible bodily introduction of migmatite mobilised at greater depth. Such granitoid migmatite centres on a shallow dome structure to the north of the Tana and near the Gurusumes sand-river to the west, where an anticlinal fold axis plunges shallowly to the S. A similar plunging fold is demonstrated farther east by the mixed mafic hornblendic and leucocratic granulitic sequence 3.2 km east of the Ndajeri sand-river. In the extreme north-east the shallow-dipping, flaggy leucocratic gneisses display persistent shallow southerly lineations, north of the river. This evidence indicates a general disruption of the consistent northerly plunge of the folds approximately along the line of the Tana river. It suggests the possibility of weak cross-folding, insufficient to obliterate existing lineations or develop fresh lineations of its own but sufficient to develop a shallow trough E-W across the area. There is no evidence for repetition of this structure farther south and no confirmatory lineations were recorded.

The major disruption in the general N-S strike pattern occurs in the vicinity of the major gabbro in the south-centre of the area. In the better-exposed parts of the surrounding gneisses to the north of the intrusion, foliation dips have a marked southerly component and this tendency of the marginal gneisses to maintain a sub-radial, inward foliation dip towards the intrusive centre is displayed to north-west, west, south-west and south-east. Lineations recorded from the area immediately surrounding the gabbro have no consistent pattern but invariably contain a major easterly or westerly component and plunge generally towards the intrusive centre.

It is suggested that the basic mass was intruded into the rocks of the 'Basement System' at a time when the latter were sediments proper, or lower-grade metasediments, prior to the major phase of metamorphism and folding involving E-W compression. During the progressive folding the solidified, deep-rooted gabbro intrusion lacked the flexibility of the surrounding metasediments, and the plasticity of the migmatites and was rigidly anchored. The disruption of the uniform E-W compression pattern by this resistant

boss resulted in irregularities in the folding of the rocks immediately surrounding it.

In the last phase of orogenesis, the applied force was greatest from the east and the deforming gneisses were moved sub-horizontally in a westerly direction across the 'tectonic floor'. Any system in the folding in the immediate vicinity of the gabbro mass was disarranged and the result of lateral compression was upward release, with a bodily rise of the folding rock with introduction of radial inwardly-inclined dips about the gabbro boss. Lineations already imprinted on some of the metasediments were retained as the rocks were reoriented and wrapped about the tectonically-unresponsive gabbro.

Tectonic translation of the banded metasediments towards the west involved their compression against the eastern side of the intrusive mass, with resultant isoclinal folding to form a minor synclinorium. The succession, gently folded to occupy some 22.5 km along the Tana river section, is compressed into about 8 km to the east of the gabbro.

VII. METAMORPHISM

In assessing the metamorphic grade of the gneisses and the marginal zone of the gabbro intrusion, mineral assemblages displayed by rocks of the Kora-Kalimangilu area are compared with those of the classification of Turner (in Fyfe *et al.* 1958, pp. 199-239). In many cases complete agreement is shown between the present rocks and the quoted assemblages of the 'staurolite-quartz' subfacies of the 'almandine-amphibolite' facies - a grade produced in regions of intense regional metamorphism.

Specimen 45/802 (previously described under 'pelitic gneisses') and specimen 45/888 from 1.6 km east of Kalimangilu (not previously mentioned in the text), both display mineral assemblages of 'quartz-garnet-biotite-plagioclase-and accessory muscovite', the five essential components of group '3' of the semi-pelitic rocks of the 'quartz-staurolite' subfacies. The majority of the quartzofelspathic rocks of the area with quartz, microcline and plagioclase as major constituents, also contain small quantities of biotite and muscovite and thus fall into Turner's group '7', the 'quartz-muscovite-biotite-microcline-plagioclase' of the semi-pelitic or quartzofelspathic rocks of the same subfacies.

Confirmatory evidence of metamorphic grade comes from mineral assemblages of the calc-silicate rocks which can usually be grouped with Turner's group '11' of the calcareous rocks of the same subfacies. The essential minerals are: 'diopside-hornblende-epidote' with additional plagioclase often associated with scapolite, quartz and microcline, and accessory sphene as complementary minerals (Fyfe *et al.* 1958, p. 229).

Plagioclase amphibolites derived from igneous basic rocks are devoid of the essential epidote (except in rare cases where it occurs as accessory), characteristic of rocks of the 'staurolite-quartz' subfacies, so these rock types are more appropriately classified in group '4' of the sillimanite-almandine subfacies of the almandine-amphibolite facies. It will be noted that neither of the classic type-minerals - sillimanite and staurolite - were recorded from the area.

Group '6' of the staurolite-quartz group of the 'staurolite-quartz' subfacies for magnesian-rich assemblages is quoted as 'cummingtonite-tremolite' with anthophyllite as a possible alternative to the cummingtonite. It is of interest to compare this assemblage with the present composition of some of the small basic intrusions marginal to the gabbro where the minerals present are actinolite, anthophyllite and subsequent chlorite.

VII. ECONOMIC GEOLOGY

1. Minerals

No mineral deposits of economic importance were located during the course of the present survey. Such minor occurrences of economic minerals as were recorded were unpromising and further prospecting was not considered justified in this inaccessible area.

Pegmatites The vast majority of pegmatite veins recorded were barren of ferro-magnesian or ore minerals except for occasional large magnetites. One vein which cuts the gabbro, 400 m east of Kumbulanawa (45/923), included patches with sparse segregations of garnet and muscovite. The muscovite consists of clear unfractured plates sometimes attaining an area of 50 mm² and the rare garnets often have diameters of over 25 mm. The quartz forming the majority of the pegmatite carries rare specks of iron pyrites.

Fragments of a narrow pegmatite vein (45/734, from the interfluvium west of the track 6.4 km west of Kora hill) show quartz, coloured pink and locally green by iron staining. Small grains of magnetite and iron pyrites were recognised.

Carbonate veins Veins composed predominantly of calcite were found in three localities. The associated minerals were quartz, epidote, siderite, chlorite and a few flakes of mica.

Amphibolites Specimen 45/877 from the plagioclase amphibolite outcrop included in the hornblende migmatites near the mouth of the Chanyigi river, locally has foliation planes speckled with sulphide minerals, predominantly chalcopyrite, with subordinate iron pyrites.

Orebands in gabbro Three rocks, 45/928, 45/966 and 45/978, were taken from ore-rich bands in gabbro on Kumbulanawa hill, 800 m to the south-east and 4.8 km to the north and submitted for investigation to Dr. Du Bois, Petrologist of the (then) Geological Survey Department. Spectroscopic examination showed no more than slight traces of chromium although iron and titanium were abundant. Subsequent examination of the crushed rocks indicated that ilmenite was the chief ore mineral, with subordinate magnetite.

Stream concentrates Two heavy mineral concentrates from a river south of Kumbulanawa and 3.2 km north-east of Makyala, together with a surface concentrate from the Ngomeni track at the Mwitamisi 5.6 km from the southern boundary, were also submitted. Spectrographic examination again showed only trace quantities of

chromium, from assemblages composed predominantly of ilmenite, magnetite and a little garnet. Since these concentrates had been obtained from an area containing much gabbro several kilograms were treated in order to produce a substantial non-magnetic fraction, which was then examined for signs of sulphides and platinum-group minerals. No economically-interesting quantities of minerals containing copper, chromium, lead, molybdenum, gold, tin or platinum were identified - the main minerals present being zircon, rutile and monazite, indicating a contribution from rocks of the 'Basement System'.

Several panned stream concentrates from other parts of the area were examined after removal of a large magnetic fraction. In each case the majority of material remaining was composed of zircon, monazite and rutile in varying proportions.

2. Water supply

Drinking water The only permanent supply of unpolluted water available in the area is from the Tana river which, however, frequently contains a high proportion of clay and sand material washed down by heavy rains higher in the Tana drainage area.

Samples of water were collected for analysis (see Table) from three sites north of the Tana: Kora Wells; a well in the Rahole sand-river; and a pool in the tributary to the Tana halfway between the previous two. South of the river samples were collected from a trickle of water in the diminutive gorge near Komuyu and the putrid wells in the Mwitamisiyi east of Kalimangilu. In every case the total salt concentration must vary widely with seasonal precipitation, and during the dry seasons the area is uninhabited partly due to lack of grazing but largely due to too high a salt concentration in the available water supplies.

Water for irrigation Various plans have been suggested for the wide-scale use of Tana river water for irrigation purposes. The terrain is largely unsuited for such ventures in the parts of the present area where 'Basement System' gneisses crop out - the Tana Valley invariably being too deeply incised and the soil cover insufficient. Pokomo tribesmen maintain small *shambas* on patches of alluvial soil on the banks of the Tana for about 10 km in the east of the area, and small-scale irrigation schemes would only seem feasible on alluvium-covered sedimentary terrain at the eastern and western margins where inundation by flood waters is a recurring hazard.

Analyses of water from the Kora-Kalimangilu area
(Parts per million-milligram per litre)

Localities	1	2	3	4	5
Free and saline ammonia as Nitrogen	-	-	-	Nil	0.14
Albuminoid ammonia as Nitrogen	-	-	-	0.71	0.01
Oxygen absorbed 4 hrs at 27°C	-	-	-	7.15	10.95
Nitrates as Nitrogen	Nil	0.05	Nil	Nil	1.17
Nitrites as Nitrogen	Nil	0.06	Nil	Nil	Nil
Total solid residue dried at 180°C	845	160	450	9135	3350
Chlorides	204	20	12	3900	770
Sulphates	72	8	6	965	319
Carbonate hardness as CaCO_3	125	90	380	570	210
Non-carbonate hardness as CaCO_3	Nil	Nil	Nil	Nil	Nil
Total hardness as CaCO_3	125	90	380	570	210
Excess alkalinity as Na_2CO_3	210	15	35	370	1355
Fluorides	1.5	0.2	0.5	3.8	0.8
Heavy metals (Pb, Cu, Zn etc.)	Nil	Nil	Nil	Nil	Nil
Silica (SiO_2)	25	25	25	25	35
Calcium (Ca)	31	23	106	27	40
Magnesium (Mg)	12	8	28	121	26
Iron (Fe)	<0.1	<0.1	<0.1	Nil	Nil
pH	8.5	8.1	7.5	8.9	8.5

Analysis: N. Kirby, Government Chemist, Nairobi

1. Kora Wells
3. Rahole
5. Kalimangilu

2. Five miles west of Malambala survey point
4. Komunyu

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