BULLETIN No. 9



REPUBLIC OF KENYA

Ministry of Natural Resources

GEOLOGICAL SURVEY OF KENYA

THE GEOLOGY AND MINERAL RESOURCES OF KENYA

(Second Revision)

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Five Shillings — 1969

PRINTED BY THE GOVERNMENT PRINTER, NAIROBI

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THE GEOLOGY AND MINERAL RESOURCES OF KENYA

INTRODUCTION

The Republic of Kenya occupies an area of approximately 225,000 square miles, of which lakes account for 5,230 square miles. The country extends between latitudes 4½° N. and 4½° S. and between longitudes 34° E. and 41½° E. It is bounded by Tanzania in the south, by Uganda in the west, by Sudan and Ethiopia in the north and by Somalia and the Indian Ocean in the east.

The total population in 1967 was estimated at almost ten millions. The bulk of the population lives in three areas of the country, near Lake Victoria in the west and south-west, in central Kenya, and in an area of fairly dense population along the coast between Malindi and the Tanzania border. West of the 38th meridian and south of the first north parallel most of the ground lies more than 3,000 feet above sea level, and the climate is equable and pleasant, particularly in the highlands that form the central part of the area.

The chief economic minerals of Kenya in terms of 1968 production and prices, are soda, salt, gold, raw materials for cement manufacture, other limestone products, and carbon dioxide, but numerous other products are worked and the total value produced in 1968 was approximately K£2,500,000 (K£ = Sh. 22/10d Sterling). In addition cement worth over K£3,700,000 was produced from local raw materials. The potential mineral wealth of the country is still not fully known. In 1947 less than one-tenth of its area had been covered by geological survey, even of reconnaissance style, but by the end of 1968 almost three-quarters had been geologically mapped. Prospecting has in the past been sporadic both in locality and time and often carried out by persons of no technical skill, but for the past few years the work of the Geological Survey has been largely confined to mineral prospecting, and in addition much of the western part of the country has been prospected by a joint Kenya Government-United Nations team, and BP-Shell Petroleum Development Company of Kenya Ltd. has been active since 1954 in the search for oil in eastern Kenya.

GEOLOGICAL SURVEY

The first records of geology and mineral resources of Kenya were accumulated towards the end of the 19th century. Early in the present century official geologists were appointed for short periods and, in addition, temporary Colonial Office appointments were made for specific investigations, as in 1914-15 for the examination of a portion of the Northern Frontier District. A permanent Geological Survey, incorporated in the Mines Department, was organized in 1932, and has continued to function. At first for many years staff was limited, but more progress was made between 1940 and 1943 with the aid of a grant from the Colonial Development Fund. At the beginning of 1946 the Geological Survey became a section of a combined Lands, Mines and Surveys Department, but three years later was part of a resuscitated Mines and Geological Department. A grant was obtained from the Colonial Development and Welfare Vote in 1948 to provide for a considerable expansion of staff and activities. Difficulties of recruiting proved to be considerable however, and it was not until 1950 that the full complement of geologists was attained. At the end of 1952 the staff of geologists numbered 16, but on an unbalanced basis, as an adequate number of senior geologists had not been obtained, and specialist posts remained unfilled or uncreated. Assistance was received in 1950-1952 from the United States E.C.A. Organization, when three geologists were seconded for special tasks, and from 1964 when additional staff was provided by the governments of Canada and Britain under technical aid schemes.

PHYSICAL FEATURES

Broadly, the physiographical features of Kenya are as follows:—

(1) A narrow coastal plain in the south-east, which broadens into a wide embayment north of the River Sabaki.

(2) Behind the plain in the south-east lies a narrow shelf averaging about 200 ft. above sea level, underlain principally by Jurassic shales.

(3) A discontinuous chain of hills, made up of Mesozoic sediments, rises to 1,000 ft. or more (Mangea, 1,702 ft.; Shimba in the Kwale Hills, 1,476 ft.) west of the coastal shelf.

(4) The Nyika, an extensive peneplain with scattered hills, ranges and lava plateaux, west of the coastal hills, rises from about 800 to 3,000 ft. Its eastern portion is made up of Palaeozoic and Mesozoic sediments, the larger western part of crystalline Precambrian rocks (the Basement System of Kenya) and recent volcanics. The Yatta Plateau, a narrow irregular-margined lava-capped tableland, stretches from the lower part of the highlands north of Nairobi to the region of Tsavo, a distance of about 180 miles.

(5) The western edge of the Nyika is bounded by extensive hill areas, also composed of Basement System rocks. The summit levels of the hills are the remnants of earlier peneplains.

(6) West of the hills there is a broad belt, stretching from the region of Lake Magadi to Lake Rudolf, of Tertiary to Recent volcanic rocks which, in the south, form the bulk of the Kenya Highlands. The highest points are Mt. Kenya (17,058 ft.) (Plate I*a*) and the flanks of the Rift Valley west of Mt. Kenya (Sattima and Niandarawa in the Aberdare Mountains, 13,214 and 12,816 ft. respectively; the Elgeyo Escarpment, 8,000 to 9,000 ft.; Mau, 9,848 ft.). The western portion includes the Uasin Gishu Plateau, a widespread upland plain of general altitude about 6,000 ft. to 7,500 ft. above sea-level, and the Kericho Highlands (6,000 to 7,500 ft.). On the eastern side a branch extends for many miles to the north-east from the region of Mt. Kenya, and includes the Nyambeni range which rises to an altitude of 7,000 ft.

(7) Roughly in the middle of the volcanic belt lies the Kenya Rift Valley, a more or less meridional depression 30 to 50 miles in width, with its floor often lying thousands of feet below the level of the country on either side. Drainage in the Rift is internal and several fresh and saline lakes lie within it. Magadi is a soda lake, constituted at surface mainly of solid trona with interstitial mother liquor. Lake Naivasha and Lake Baringo are fresh-water lakes.

(8) The country west of the highlands consists mainly of a peneplain (rising to the east from 4,000 to about 5,500 ft.) underlain by Precambrian rocks invaded by granites and other intrusions. On the south-east there are plateau highlands (about 7,000 ft.) made up of the Kisii Series of sediments and lavas. Highlands of roughly equivalent altitude forming the Nandi Hills, which are composed of Basement System rocks and granites, separate the lower country of Nyanza from the Uasin Gishu Plateau. Isolated areas within the western belt are mountainous and centres of Tertiary volcanic activity. The principal areas are Mt. Elgon (14,140 ft.) (Plate I*b*) and the Gwasi (Gembe, 6,237 ft. Ruri-Homa Mountain, 5,741 ft.) group.

(9) The westernmost part of Kenya is a portion of Lake Victoria (3,718 ft.) with a few off-shore islands. The Kavirondo Gulf is a shallow sound extending inland for about 45 miles, though formerly it extended much farther to the east. It lies in a rift valley, transverse to the main Rift.

(10) The North-Eastern Province and the northern part of Eastern Province forms a considerable and lightly populated portion of the country, and consists principally of a peneplain of Precambrian schists and gneisses, sediments of Jurassic to Miocene age, and recent lava plains and volcanoes. There are scattered residual hills and mountains of the older rocks, and in places large volcanic piles are noteworthy, e.g. Marsabit (5,599 ft.) and Kulal (7,522 ft.).

TABLE I—GEOLOGICAL SUCCESSION AND ECONOMIC MINERALS, KENYA—(*Contd.*)

CRETACEOUS	Coastal sediments and sediments of north-east Kenya.	Ijolites and alkaline syenites of Jombo at the coast and east Kitui. Alkaline dykes at the Coast and in east Kitui. Carbonatite at Mrima (Coast).	60–120	Manganese, pyrochlore, rare earth minerals.
JURASSIC	Coastal sediments and sediments of north-east Kenya		120–150	LIMESTONES, SHALES (for cement and ceramics), gypsum, ballast.
TRIASSIC PERMIAN CARBONIFEROUS? } KAROO	Sediments of the coast hinterland. Sediments of north-east Kenya(?).		150–250	Ballast.
PRECAMBRIAN	*Kisii Series* (Bukoban System)—Sediments and volcanics of south-western Kenya.	Dolerites.	600	SOAPSTONE, gold, (cassiterite).
	Embu series—Metamorphosed sediments, central Kenya.		?	
	Ablun Series—Metamorphosed sediments, north-east Kenya.		?	
		Pegmatites in the Basement System.	500–600	Mica, piezo-electric quartz, samarskite, columbite, beryl, felspar, (amblygonite, bismuth, ilmenorutile, amazonite, zinc spinel, fluorspar, rare earth minerals).
		Gabbros of western Kenya; dunites.	?	Chromite, garnierite, magnesite, vermiculite, corundum sapphire, (olivine).

TABLE I—GEOLOGICAL SUCCESSION AND ECONOMIC MINERALS, KENYA—(*Contd.*)

PRECAMBRIAN (*Continued*)	*Basement System*—Gneisses and schists.	Norites and allied rocks, minor peridotites, pyroxenites and granites.	600+	LIMESTONES, MARBLE, WOLLASTONITE, kyanite, asbestos, magnesite, dolomitic limestones, garnet, rutile, ilmenite, sillimanite.
	Kavirondian System—sediments and volcanics of south-western Kenya.	Granites, syenites, dolerites etc.	2,200	GOLD, silver, (molybdenite).
	Nyanzian System—Sediments and volcanics of south-western Kenya.	Granites, epidiorites, etc.	2,200+	GOLD, COPPER, zinc, silver, pyrite, (cobalt, scheelite, arsenic, fluorite).

*Minerals and rocks that are of notable economic importance in Kenya are indicated in capitals, less important minerals (which are not all being worked at present) in lower case letters and minerals known but not yet worked by parentheses.

GEOLOGY

The principal groups of rocks found in Kenya and the economic minerals associated with them are summarized in Table I, and the general distribution of the rocks is shown in the frontispiece. Specific areas are covered by the Geological Survey Report series, all of which are accompanied by coloured geological maps, mostly at a scale of 1 : 125,000.

Precambrian

NYANZIAN AND KAVIRONDIAN SYSTEMS

The presumed oldest Precambrian rocks of Kenya are essentially those of the gold-fields of western Kenya. They are to a considerable extent blanketed by younger rocks, notably in the Kisii and Gembe areas of South Nyanza. Two systems have been distinguished, the older called the Nyanzian, and the younger the Kavirondian System. They are separated by an unconformity, but it is likely that there is little difference in their absolute ages.

The Nyanzian System in north and central Nyanza is made up of a great thickness of lava flows, associated with variable thicknesses of pyroclastic rocks of all grades, and in places with lenses of conglomerate. In south Nyanza the system includes other sediments, among them normal clastic types, and banded ironstones, especially in the Migori gold-belt. Rocks of the system, in a highly altered state, outcrop east of the Kisii Highlands, and also at Kaksingiri, south of Rusinga Island, where there are tremolite schists, amphibolite schists and biotite-quartz schists with bands of knoten-schiefer. Some of the latter rocks may belong to the Kavirondian System. Successions of the system that have been worked out in the parts of Nyanza north and south of the Kavirondo Gulf are given in Table II.

TABLE II—SUCCESSION OF THE NYANZIAN SYSTEM

N. of Kavirondo Gulf	Kisumu district	S.E. of Gwasi	Kisii district	Migori area (Tanzania border)
Basalts.			Andesitic tuffs and sandstones. Andesites.	
Tuffs agglomerates and conglomerates.	Rhyolites, dacites and banded ironstones	Rhyolites, tuffs and banded ironstones.	Rhyolites, tuffs agglomerates, cherts and banded ironstones.	
Andesites.	Major tuffs. Andesites.	Andesites and tuffs.	Andesites etc.	Slaty rocks with andesites and banded ironstones.
Tuffs and agglomerates.		Greywackes and tuffs.		Greywackes, conglomerates and banded ironstones.
Rhyolites.	Basalts and subordinate banded ironstones.	Basalts.	Basalts, subordinate iron stones and mudstones.	Basalts and banded ironstones.
Tuffs and agglomerates.				

It is unlikely that the order of eruption changed from acid to basic north of the Kavirondo Gulf to basic to acid south of it, and more work is required to prove the correct way up of the sequence, or whether the northern succession overlaps the southern and contains upper members that are younger than any of the Nyanzian rocks in south Nyanza.

The Kavirondian System is most typically developed in north and central Nyanza, where its alternating bands of grits or sandstones and mudstones cover wide stretches of country. Intercalated among them are huge lenses of waterlain conglomerates that have proved auriferous in a few localities and at one place have yielded a few small diamonds. In south Nyanza the system is mainly represented by extensive developments of boulder conglomerates, though grits, mudstones and thin flows of hornblende andesites are also present.

Intrusions into the Nyanzian and Kavirondian Rocks

The Precambrian rocks of south-western Kenya are extensively invaded by granites. In the northern part of Nyanza Province the main granites are post-Kavirondian and genetically connected with the gold deposits. In South Nyanza the principal intrusion has, however, been considered of post-Nyanzian—pre-Kavirondian age, and is apparently that associated with gold mineralization in the Migori gold-belt. Owing to the paucity of Kavirondian sediments in south Nyanza it is not possible in most cases to define the age of the granites, except that they are post-Nyanzian or pre-Bukoban.

In addition to the major igneous rocks, the Precambrian of south-western Kenya is invaded by innumerable small masses and dykes ranging from acid to basic in character. Doleritic dykes of pre-granite and post-granite age are known.

Basement System

These rocks were at one time considered to be the oldest exposed in Kenya, but have been proved in the last few years to be younger than the Nyanzian and Kavirondian. The name "Basement" is therefore somewhat of a misnomer, but is retained for the reason that it has been in use for many years, and occurs in numerous publications.

The crystalline rocks of the Basement System cover wide areas of the country, and are particularly extensive in the eastern half. They comprise principally various types of sediments—grits, sandstones, limestones and shales—that have been metamorphosed into gneisses, schists and marbles by heat and pressure or by impregnation by pervading fluids. Other types are derived from lavas and volcanic fragmental rocks.

Igneous rocks are relatively scarce and consist of granite sheets and dykes, and sills of epidiorite and amphibolite derived from originally doleritic or allied rocks, and some ultrabasic rocks. Some are apparently of later date than the metamorphism of the sedimentary hosts, but are probably Precambrian in age.

The variety of rocks in the sedimentary series is extensive and includes, besides widespread mica- and mica-hornblende schists and gneisses, such types as graphite schists, kyanite gneisses, garnet gneisses and schists, sillimanite gneisses, pyroxenite granulites, quartzites and crystalline limestones. Other and rarer kinds include actinolite schists, anthophyllite schists, and epidote schists and gneisses. In some areas there are considerable developments of migmatites, which have arisen by the injection of granitic magma into the gneisses and schists, or by their permeation by granitic fluids. Several granites of northern and north-western Kenya are considered to be the products of granitization of metasediments. Pegmatites of various types are frequently associated with the Basement System rocks, particularly where metasomatic action has been prominent (Plate II*a*).

The crystalline limestones (Plate II*b*) form notable bands and lenses, often of considerable thickness and length, though some are small. A series of outcrops extends

discontinuously through the central part of the country, and others occur in the hills east and north-east of Mt. Elgon and in north-eastern Kenya. The graphitic gneisses also in places form thick and extensive groups of bands.

Intrusions into the Basement System

No major invasions of the Basement System by rocks of granitic types have been located. Extensive outcrops of basic rocks, including pyroxenites, norites and anorthosites have, however, been found piercing it east of Mt. Kenya. Titaniferous magnetite has been found there, and it is possible that other mineral deposits such as are commonly associated with plutonic rocks of that type—nickel, copper and chrome are examples—may eventually be found in association with such rocks.

Ultrabasic sills have been found in the Taita hills and in West Pokot, where they are associated with occurrences of anthophyllite asbestos and sometimes talc and vermiculite. Gabbros of later age are also known in West Pokot, and chromite and nickel minerals have been found in association with some of them. Small intrusions of peridotites and pyroxenites have been mapped at various localities, and a large ultrabasic mass with associated chromite deposits is known at Debel in the northern part of Eastern Province.

Dunites are represented by pipes at a few localities, e.g. near Mtito Andei and at various places in the Kitui District. Deposits of magnesite and subordinate vermiculite, chromite and corundum are associated with these rock masses.

Embu Series

The series is known only in a small area south-east of Embu. It consists of metamorphosed dominantly pelitic rocks, though limestones, sandstones and conglomerates are also represented. The rocks are not granitized and are characterized by minerals indicative of a low grade of metamorphism and by accessory authigenic tourmaline. The age of the rocks is not yet known, but they differ from the Basement System rocks and are provisionally regarded as a younger series.

Ablun Series

The Ablun Series is known in a small area only, in the north-east corner of Kenya. It consists of tightly folded, little metamorphosed rocks, including conglomerates, sandstones, phyllites and limestones. There is evidence of thermal metamorphism, and tourmaline is an abundant accessory in some of the members. No evidence of relative age is available, but the series is considered as younger than the Basement System.

Bukoban System (Kisii Series)

The Kisii Series is restricted to a small area in the south-western part of the country where it forms the Kisii Highlands. The series is three-fold with upper and lower divisions of lavas, and a middle division composed largely of quartzites. Dolerite dykes are known cutting all three divisions. The succession established in the Kisii area is quoted in Table III.

Table III—Bukoban System Succession in the Kisii Area

Upper group	Rhyolites, rhyolitic tuffs, sandstones and conglomerates Andesites and dacites Porphyritic and non-porphyritic felsites
Middle group	Ferruginous siltstones and cherts Quartzites
Lower group	Kisii soapstone Non-porphyritic basalts Porphyritic basalts.

The quartzites in places form prominent escarpments at the edges of the plateau. Frequently on the western side of the highlands there are lenticular masses of non-magnesian soapstone which are metasomatic replacements of the lower lavas.

On the eastern side, where only the two upper groups are represented, the series has a local basal conglomerate, in which gold has been found. Traces of cassiterite are found in heavy residues from some of the quartzites.

The series lies more or less flatly, with only gentle folding, across the upturned edges of the gold-fields formations, and is in fact a thick and impenetrable blanket covering many square miles of what might otherwise have been potential gold-field. There is no evidence of the precise age. It has been considered as possibly Palaeozoic, but is more probably Precambrian, though considerably younger than the gold-fields formations.

Palaeozoic

Coastal Palaeozoic Sediments

Sediments of Palaeozoic age near the coast are grouped as the Duruma Sandstones. The western portion of the sediments south of the Tana River consists of the Taru Grits, a monotonous series of grits, sandstones and shales with traces of coal, and at rare localities a basal tillite-like rock. The grits probably straddle the Upper Carboniferous and the Lower Permian. There appears to be a passage into sediments of Mesozoic age in the southern part of the belt, though recent work in the Sabaki Valley, farther north, points to separation by an unconformity there.

Mesozoic

Coastal Mesozoic Sediments

A continuous strip, about 30 miles in width, of sediments of Mesozoic age is exposed near the coast, stretching from the Tanzania border to the region of the River Sabaki. The sediments range in age from Triassic to Cretaceous, and include part of the Jurassic System. The succession is given in Table IV.

Table IV—Succession of Mesozoic Rocks in Coastal Kenya

System	Stage	Representative	
Cretaceous	Neocomian	Freretown Limestone	
Jurassic	Kimmeridgian	Changamwe shales with lenticular limestones	
	Oxfordian	Rabai Shales	
	Callovian	Miritini Shales	
	Bathonian, Bajocian	Kibiongoni Beds (sandstones and shales); Kambe Limestone	
–unconformity and faulted junctions–			
Trias	Upper	Mazeras Sandstones and Shimba Grits	Duruma Sandstones
		Mariakani Sandstones	
	Lower	Maji ya Chumvi Beds	
Permian, Carboniferous? Palaeozoic		Taru Grits	

The oldest and westernmost Mesozoic sediments consist of shales with subordinate sandstones, but farther east sandstones predominate. Certain beds in the Mazeras Sandstones are prolific in fossil tree remains. The Trias sequence ends with a series of grits, often pebbly, that cap the coastal hill ranges. The lowest beds of the Jurassic are usually marine limestones, in part remarkably pure, which in places have wide outcrops that could be easily worked. The thick predominantly shaly beds that make up the rest of the Jurassic succession contain in places bands of calcareous or ironstone concretions.

Intrusions into the Coastal Sediments

The only intrusions known in the coastal belt are at Jombo and neighbouring hills not far from the Tanzania border, and small masses in the Sabaki Valley at the north end of the belt. The Jombo intrusions include ijolites, melteigites and nepheline syenite, and dykes of camptonite, monchiquite and nephelinite. Recent age determinations prove them to date from the late Cretaceous. It is likely that ouachitites and other alkaline dykes discovered some years ago piercing Basement System rocks in Eastern Kitui and syenites at Endau are of similar age, and consanguineous with the coastal intrusions. A carbonatite intrusion occurs at Mrima, and at Kikonde fenitization of the sediments has occurred.

Mesozoic Sediments of North-East Kenya

The north-eastern corner of the country, over an area of several thousand square miles, is occupied by Mesozoic sediments, which cannot be directly correlated with those of the coastal belt. They are principally Jurassic limestones with shales, clays and gypsum beds, but are overlain by the Cretaceous Marehan Series, and underlain by possible Triassic beds, that may perhaps be correlated with part of the Duruma Sandstones at the coast. The succession is quoted in Table V.

Table V—Succession of Mesozoic Sediments in North-East Kenya

System	Stage	Representative	
Cretaceous	Wealdan	Marehan Series: Marehan Sandstones; Danissa Beds	
	–unconformity–		
Jurassic	Tithonian	Mandera Series; Dakacha Limestones	Daua Limestone Series
	Kimmeridgian	Hereri Shales; Seir Limestones	
	Oxfordian	Rahmu Shales; Muddo Erri Limestones	
	Callovian	Rukesa Shales: Asaharbito Beds	
	Bathonian, Callovian	Murri Limestones	
	Lias	Didimtu Beds	
	–unconformity–		
Trias (?)		Mansa Guda Formation	
	–unconformity–		
Precambrian		Basement System	

Tertiary

Coastal Sediment of Tertiary Age

Sediments referred on the evidence of fossils to the Miocene have been mapped in the Malindi and Hadu areas at the coast, and other Tertiary sediments are sands, sandstones, clays, conglomerates, etc. that lie a short distance inland and frequently form a chain of low hills. They rest on a planed surface of Jurassic rocks, and are ascribed to the Pliocene.

Tertiary Rocks of the Interior

Miocene sediments have been found at numerous inland localities resting on the sub-Miocene peneplain, in gullies cut into it, or on surfaces higher than the peneplain. Deposits occur close to the shores of Lake Victoria, near Koru and Muhoroni, and around Mt. Elgon. Other occurrences have been found in the Rudolf basin, and at several places in the wide area east of that lake and north of Mt. Kenya. Extensive lake deposits, believed to be of late Miocene or early Pliocene age, are found intercalated among lavas near Nairobi; they contain beds of bentonitic clay and are a useful aquifer. In the central part of the Rift Valley in the neighourhood of Lake Baringo are sediments of Miocene and Pliocene age.

The sediments are mainly shallow-water lacustrine deposits, and in some cases fluviatile. Thin limestone beds are not infrequent and usually yield representative faunas. At Muhoroni and Songhor the Miocene limestones are unusually thick, and have been worked for many years for the manufacture of lime.

In addition to the waterlain sediments of Tertiary age there are widespread occurrences of lavas and pyroclastic sediments of Middle or Upper Tertiary age in central, northern and western Kenya. Many of the lavas are of alkaline type including, for example, phonolites (Plate III*a* and III*b*), nephelinites and alkaline rhyolites (Plate IV*a*) and basalts, though calc-alkaline types are not absent and in places predominate. Some of the lavas have given rise to extensive plains or plateaux. Others, with accompanying ash and agglomerate beds, are the result of the action of central volcanoes. More obvious central volcanoes are represented by Mt. Kenya, the Aberdare range, Mt. Elgon, and some of the volcanic masses of the western part of South Nyanza.

Intrusions of Tertiary Age

Few major intrusive rocks of Tertiary age are known. Later members of the coast and Kitui intrusives, mentioned previously, may be of Tertiary age, and alkaline intrusions and carbonatites found on Homa Mountain and nearby in south Nyanza belong to this period. A carbonatite is also known near Muhoroni. The core of Mt. Kenya is an alkaline syenite of Pliocene age (Plate I*a*), and there is evidence of an essexitic mass in the south-western part of the Aberdare range.

Pleistocene

Rocks of Pleistocene age are represented at the coast by raised coral reefs, coral breccias (Plate IV*b*), sandstones and sands. Inland Pleistocene sediments are more extensively developed, particularly in the Rift Valley, where they are represented by thick deposits of lacustrine (Plate V*a*) and fluviatile sediments, among which diatomite beds are commonly found intercalated, and around the Kavirondo Gulf. Considerable progress has been made in the division and dating of such deposits by means of artefacts and vertebrate remains, and a sequence of pluvial and interpluvial periods, perhaps corresponding with the waxing and waning of the glaciations in Europe, has been made out. The sequence shows alternations of wet and dry periods, there being a gradual but constant diminution of the intensity of wet periods since early Pleistocene times. Recent work has shown that variations in Gamblian lake-levels result from

earth movements rather than fluctuations of rainfall. A condensed succession is given in Table VI below.

Age	Stage	Climatic State	Deposits	Prehistoric Cultures
Holocene	Nakuran	Wet phase		Neolithic
	—	Dry phase		—
	Makalian	Wet phase		Mesolithic
U. Pleistocene	—	Dry phase	Deighton's Cliff	Magosian
	Gamblian	Pluvial	Gilgil-Naivasha	Stillbay, developed Levallois
	—	Interpluvial		Early Levallois
M. Pleistocene	Kanjeran	Pluvial	Olorgesailie	Acheulean
	—	Interpluvial	Rawe fish beds (Homa)	
	Kamasian	Pluvial	Kariandusi, Chemeron, Kapthurin	Chellean
L. Pleistocene	—	Interpluvial	Marsabit	
	Kageran	Pluvial	Kanam (Homa), Omo R.	Kafuan

The section in the Kariandusi Valley near Gilgil is quoted in Table VII, and the succession in the Homa-Kisumu area is given in Table VIII.

TABLE VII—PLEISTOCENE SUCCESSION, KARIANDUSI VALLEY

Gamblian ..	Silts and gravels
Kanjeran ..	Gravels, volcanic sands, tuffs and thin diatomites. Main diatomite band
Kamasian ..	Volcanic sands and tuffs.

TABLE VIII—PLEISTOCENE SUCCESSION IN THE HOMA-KISUMU AREA

Upper Pleistocene ..	Loams and sheet limestones of Homa. Mudstones, siltstones and sandstones of south Kisian, Rare and Kanuto	
	Upper Kuwur deposits Upper Bala tuffs and gravels	Homa
Middle Pleistocene ..	Gravels	
	Lower Bala tuffs and limestones, Homa	
	Lower Kuwur tuffs	
	Kanjeran Beds—tuffs, ashes clays and limestones	
	Upper Rawe fish-beds—thin flaggy limestones and silty clays	and contemporaneous agglomerates
Lower Pleistocene ..	R. Miriu gravels	
	Lathiri Sandstones and Orio Tuff	
	Lower Rawe Beds—clays, siltstones, tuffs and thin limestones	
	Kanam Beds—clays, tuffs and gravels.	

Other Pleistocene beds have been found at various localities outside the Rift Valley, for example in the Kitui District, where some Pleistocene pond or fluviatile sediments are associated with irregular gypsum deposits and others with beds of lignite. Pleistocene deposits of a more European type are found on the higher mountains where moraines, solifluxion deposits and other glacial phenomena are seen. The glaciers of Mt. Kenya now terminate at between 15,000 and 15,500 feet, but during their maximum extension during the Pleistocene they extended in places to below 8,000 feet.

Volcanic rocks of Pleistocene or presumed Pleistocene age are found in several parts of the Highlands, south-east of Nairobi and in northern Kenya. They are particularly prominent where they built the Nyambeni range north-east of Mt. Kenya, and north of the Chyulu range, half-way between Nairobi and Mombasa. The volcanic cones from which the lavas and tuffs were ejected are often well preserved.

Recent Deposits

The deposits of Recent age are largely soils and alluvial accumulations. The desiccation of lakes has led to the accumulation of salts, particularly at Lake Magadi (Plate VI*b*), which at surface consists of solid trona with interstitial mother liquor, fed and maintained by saline springs. Mineral springs and fumaroles are known in various parts of the country, but do not, so far as is known, give rise to extensive mineral deposits. The principal localities lie within the Rift Valley, though hot springs are also found near the coast and in the western part of Nyanza Province.

There is no modern vulcanicity, though it is within the memory of man that Teleki's Volcano, near the southern end of Lake Rudolf, erupted. The volcanoes that formed the Chyulu range are believed to be of Recent age, and other volcanoes, such as Longonot in the Rift Valley, continued their vulcanicity into recent times.

Tectonic Events

Throughout much of its history Kenya has been unaffected by major tectonic disturbances, though at early and again at late periods extensive movements took place. Insufficient work has been carried out to determine the full sequence of events in Precambrian times, but periods of mountain-building movements are indicated in western Kenya by the upturned remains of the Nyanzian and Kavirondian Systems, and Basement System rocks are everywhere tightly folded. A more gentle orogeny followed in post-Bukoban times. Since then and until Tertiary times movement appears to have been confined mainly to general uplift and periods of long-continued denudation, culminating in the peneplanation of much of Kenya by the late Jurassic and again in Cretaceous times. General uplift followed, again with subsequent denudation, over the early part of the Tertiary era, leading to the formation of the sub-Miocene peneplain. Since the Miocene movement has been mainly confined to geologically moderate vertical or tilting movements of which the effects are most readily seen along the Rift Valley, at the coast, and in western Kenya, in the tilting and warping of the sub-Miocene peneplain, and in the formation of the end-Tertiary peneplain over much of northern and eastern Kenya. All the visible faults connected with the Rift Valley are of Tertiary or later age.

Rift Valley

The Gregory Rift Valley cuts completely across Kenya from the region of Lake Magadi in the south to Lake Rudolf on the northern boundary. It is a complex, almost meridional trough bounded by groups of faults, and frequently with minor troughs and horsts on its floor, which rises from about 2,000 ft. at Magadi to over 7,000 ft. at Longonot north-west of Nairobi, and then sinks again to below 1,300 ft. at Lake Rudolf. In the Rudolf area the continuation of the Rift is for a large part more of a gentle warp, and bears little resemblance to the marked structural trough seen farther

south. Several volcanoes, of which the best-known are perhaps Longonot (9,111 ft.), Suswa (7,732 ft.), and the cauldron at Menengai (7,080 ft.), near Nakuru (Plate V*b*), form prominent mounds rising from the floor. The walls of the Rift are commonly markedly stepped, though in places, notably along the west flank of the Aberdares and the east flank of the Rift in the Elgeyo-Marakwet district, the denuded faces of large single faults are prominent and give rise to magnificent escarpments.

Faulting that can be clearly associated with the Rift does not extend for more than a few miles outside the main walls of the trough. Faulting along the equatorial trough that encloses the Kavirondo Gulf, and extends south-westerly through south Nyanza as the Lambwe trough, is however, of generally similar age to the faulting in central Kenya. Lake Victoria is a gentle depression caused by sag over a wide area, probably as a result of the Rift faulting in Kenya on the east and the Albertine rifting in Uganda.

The Kenya Rift Valley can be traced back to the Miocene, when warping occurred accompanied by extrusion of lava. In the late Miocene or early Pliocene major faulting took place, which was followed by vulcanicity. Two further major episodes of faulting in the late Pliocene and Middle Pleistocene, each again accompanied by volcanic extrusion, and each confined to a narrower area of the Rift floor, formed the Rift Valley as it is seen today.

Movement in Western Kenya

The faulting along the Kavirondo Gulf and the sinking of the Nyanza basin led to tilting and rejuvenation of the sub-Miocene peneplain. Incision as a result of rejuvenation has yielded characteristic V-shaped valleys sunk into the peneplain, through which run relatively swift rivers with bars and rapids at frequent intervals.

Coastal Movement

The effect of Pleistocene and Recent movements at the coast are seen, particularly around Mombasa Island, in the fossil and modern coral reefs and in the estuaries of the few rivers. The raising of Pleistocene coral reefs, in some cases to more than a hundred feet above sea-level, was followed by submergence, when the estuaries of the rivers were drowned and wave-cut benches were eroded in the portions of the reefs still exposed. Subsequent raising of the coast relative to the sea brought these benches once more above sea-level and allowed the growth of the modern coral reefs off-shore.

MINERAL RESOURCES

The localities of the more important minerals in Kenya are shown in the map in the end-pocket of this Bulletin. A comprehensive and detailed account of the minerals known to occur in Kenya will be found in Bulletin No. 8 of the Mines and Geological Department, *Minerals of Kenya* by C. G. B. DuBois.

At the present time three of Kenya's minerals figure prominently as exports, trona (as soda ash), gold and diatomite. In past years copper, kyanite and graphite all played an important part in export earnings. Kenya's main copper producer ceased production in 1966 on exhaustion of ore reserves, the kyanite mine closed down in 1960 in the face of increased competition from synthetic materials and production difficulties, and the last graphite producer closed in 1960, again mainly due to production difficulties. Salt, limestone products, carbon dioxide and kaolin are all produced in important amounts for local consumption, and gypsum, barytes, guano, vermiculite and wollastonite are all becoming increasingly important. Numerous other minerals are worked on a small scale, as can be seen from the Table of Production (Table IX). It should be noted that the list takes no account of the considerable amount of structural materials used each year (building stone, clays, gravel, sand and ballast), other than materials directly used for local manufacture of cement. The latter industry now supplies all of Kenya's needs, and exports close to one million pounds worth of cement annually.

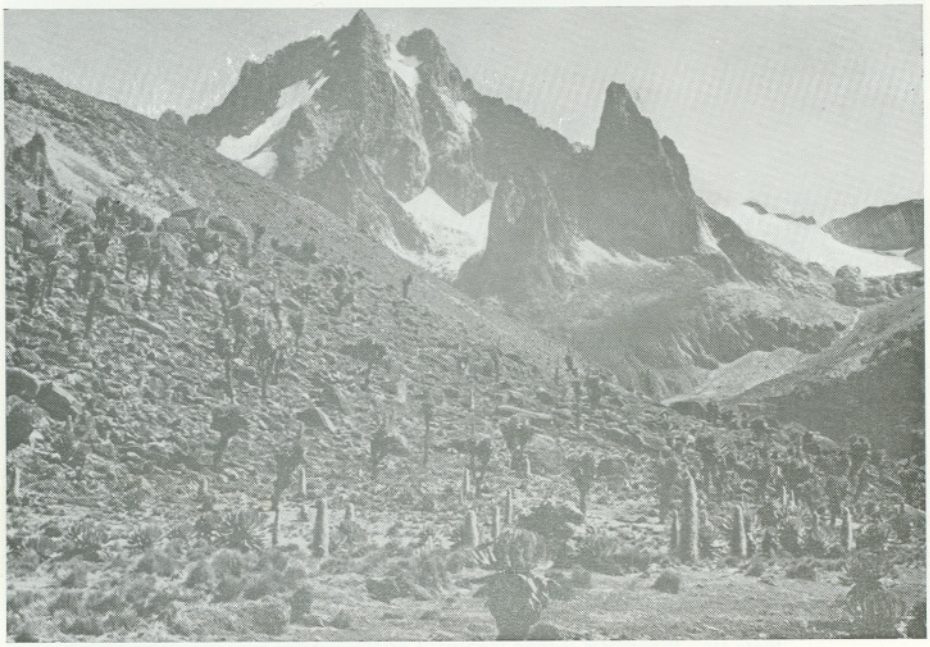


Plate Ia—Mount Kenya (17,058 ft.). The peak is of nepheline syenite, and marks the eroded core of the volcano

[Photo: Kenya Information Service



Plate Ib—Mount Elgon (14,178 ft.), an eroded volcano on the Kenya-Uganda border. The peak shows at right centre

[Photo: Kenya Information Service



Plate IIa—Pegmatites cutting granitized metasediments near Moyale

[*Photo: J. Walsh*



Plate IIb—Workings of Kenya Marble Quarries Ltd. at Turoka, near Kajiado. The marble is a metamorphosed Precambrian limestone

[*Photo: Rowland H. Bound*

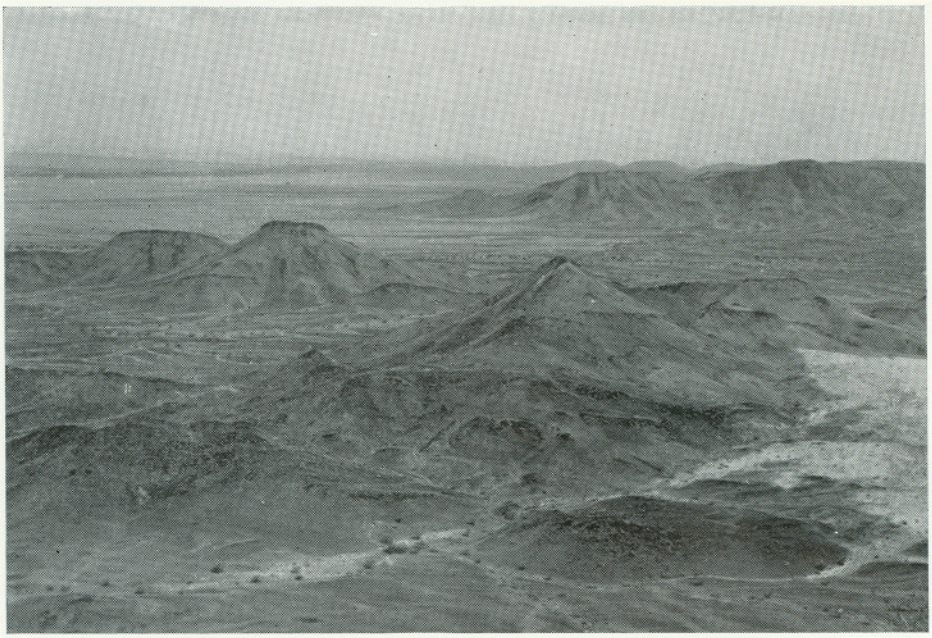


Plate IIIa—Hills of phonolite lava near Lodwar, North Turkana
[Photo: J. Walsh



Plate IIIb—Gorge cut in phonolite lava by the Perkerra River at Marigat, Baringo District
[Photo: J. Walsh

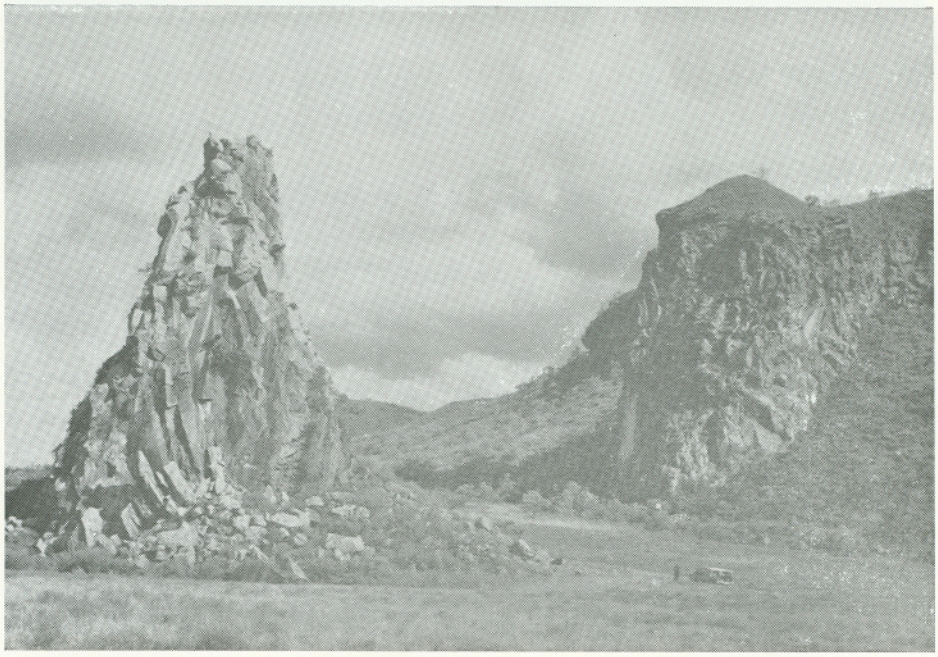


Plate IVa—Alkaline rhyolite lava (comendite)—Fischer's Tower in Njorowa Gorge, Naivasha
[Photo: J. Walsh



Plate IVb—Raised beach of cemented coral sand (coquina), of Pleistocene age, at Watamu, near Malindi
[Photo: Kenya Information Service



Plate Va—Pleistocene to Recent sediments marking an ancient shoreline of Lake Rudolf, Turkwel River, North Turkana

[Photo: J. Walsh

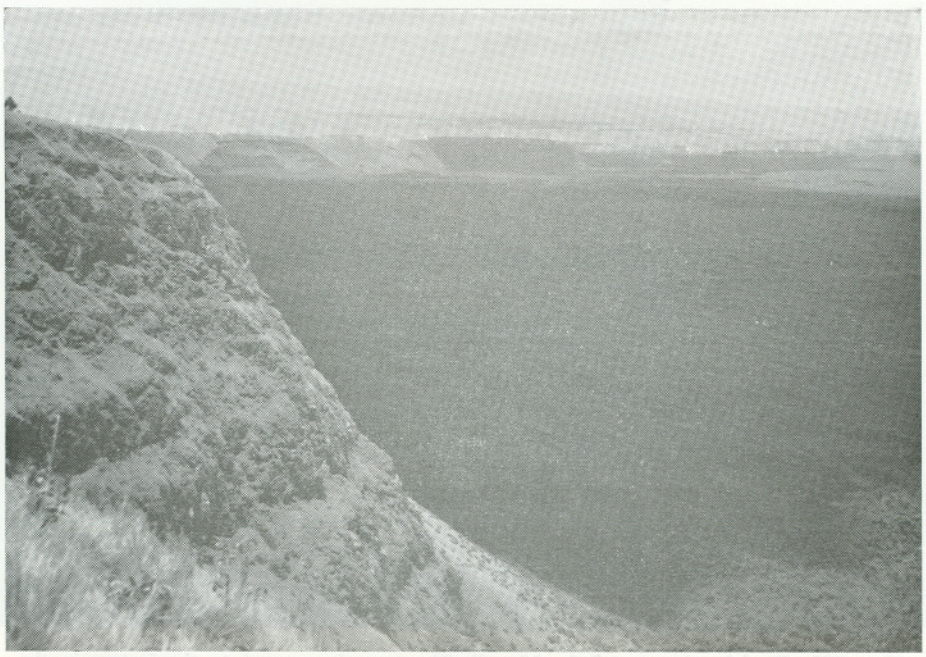


Plate Vb—Menengai Caldera, Nakuru, a collapsed volcanic crater seven miles across

[Photo: J. Walsh

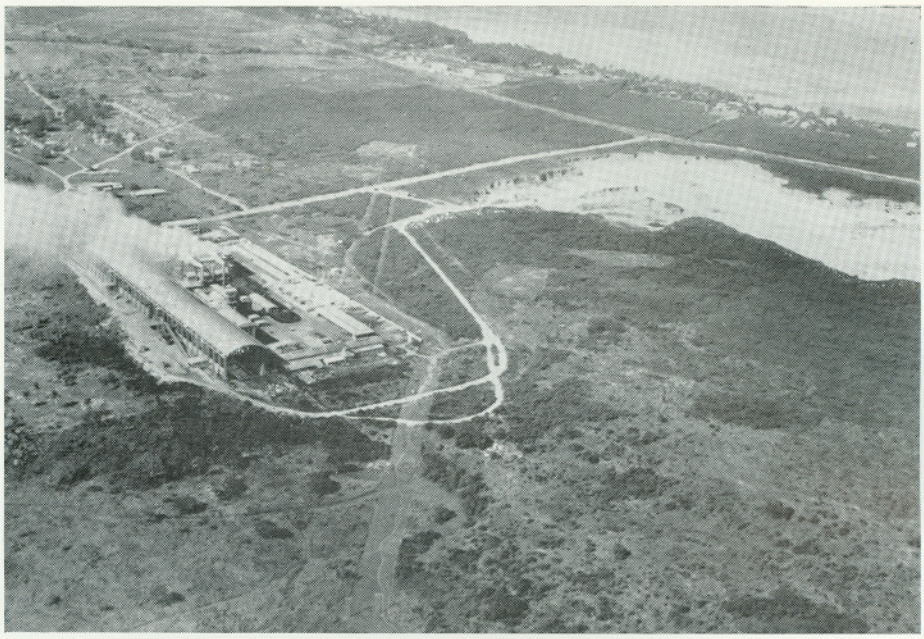


Plate VIa—Bamburi Portland Cement Co. Ltd. factory north of Mombasa. The quarry works Pleistocene coral limestone

[*Photo: Kenya Information Service*

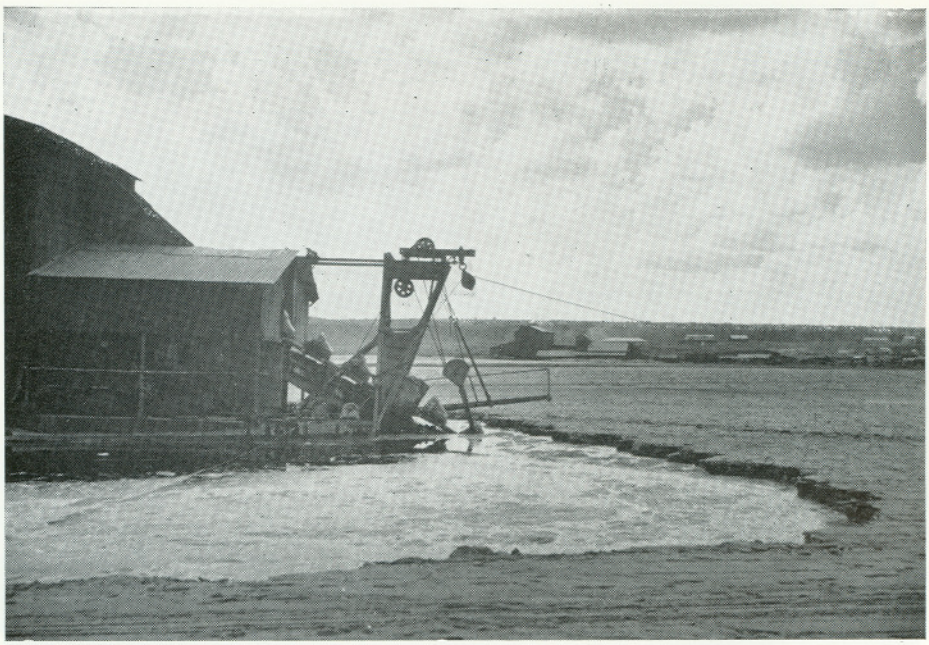


Plate VIb—Dredging trona at Lake Magadi. The trona is pumped to the factory in the middle distance for processing into soda ash

[*Photo: Kenya Information Service*



Plate VIIa—Diatomite mine of African Diatomite Industries Ltd. at Kariandusi, near Gilgil
[Photo: J. Walsh



Plate VIIb—Oil exploration—drilling a shot-hole for seismic prospecting, Coast Province
[Photo: J. S. Buchanan, BP-Shell

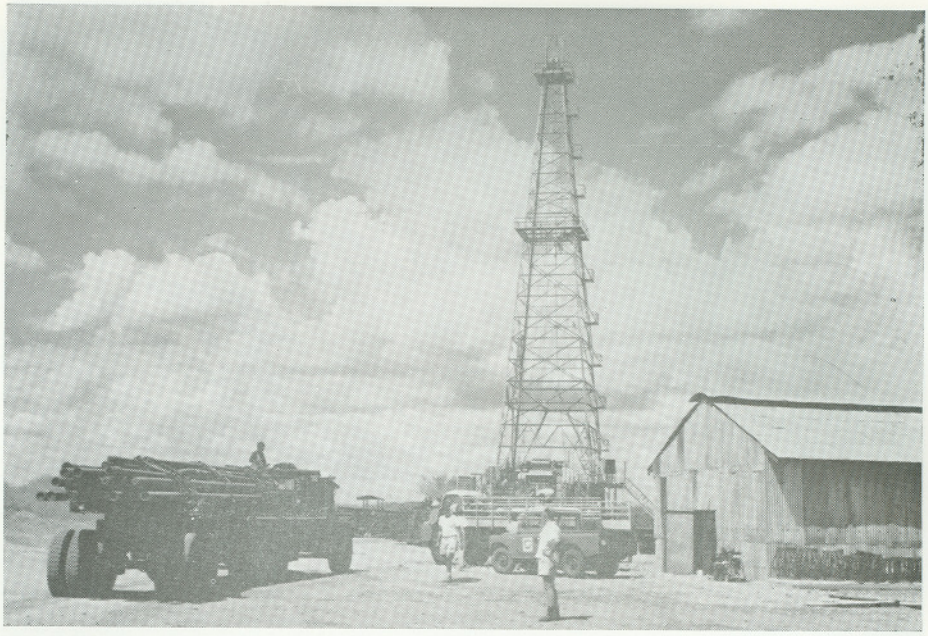


Plate VIIIa—BP-Shell deep test drilling rig at Dodori, north of Lamu. This borehole reached a depth of 14,140 feet

[Photo: Kenya Information Service



Plate VIIIb—Mines and Geological Department diamond drill working on a lead/zinc prospect near Ribe, Coast Province

[Photo: J. Walsh

Kenya is a young country where the emphasis has been largely on agriculture, which is perhaps sufficient to account for the somewhat slow development of mineral resources. As in many other African countries progress has been hampered by lack of local or near markets for many of its minerals. Development is also often hindered by long haulages to sites where minerals can be used, or to the coast for export. The continued search for minerals has opened up wider and wider stretches of the country to development and has been of value to the population in providing work near to their homes and in enabling them to sell farm produce easily, and to improve their standard of living by means of the cash received. This has nowhere been so evident as in the gold-fields.

Portland Cement

Portland cement was produced for many years in Nairobi from imported clinker, the only local material used in the process being gypsum. In 1955 cement made entirely from local materials began to be produced by the British Standard Portland Cement Co. Ltd. (now Bamburi Portland Cement Co. Ltd.) at a factory a few miles north of Mombasa (Plate VI*a*). The cement materials, which consist of Pleistocene coral limestone, Jurassic shale and gypsum, are calcined in vertical and rotary kilns. The factory was originally built for an output of 60,000 tons of cement per year, but various additions to the factory enabled annual production to be raised to around 400,000 tons in 1968.

In 1958 a second factory, owned by the East African Portland Cement Co. Ltd., began production at Athi River, near Nairobi. A rotary oil-fired kiln is used to produce cement from an unusually magnesia-low crystalline limestone quarried near Sultan Hamud, as well as some kunkar limestone from the factory vicinity, decomposed volcanic ash being used for the alumina component. Hitherto all the gypsum used has been carried from near Garissa, close to the Tana River, but in recent months increasing production is being made from gypsum claims within a few miles of the factory. In 1968 production exceeded 105,000 tons, but the plant has been designed for expansion to 400,000 tons a year if necessary.

Soda Products

The trona of Lake Magadi has been worked since 1924 by the present Magadi Soda Company, a subsidiary of I.C.I., and an earlier company with the same name had worked the deposits in the ten previous years. The trona crust is dug by a bucket dredger mounted on a pontoon which floats on a pool of mother liquor (Plate VI*b*). The dredged material is crushed on the pontoon and made into a slurry to be pumped along a floating pipe-line to the factory at the lake side. At the factory the slurry is screened, washed and re-screened to free it from salt and mud. It is then dumped and drained and eventually calcined in large rotary kilns, the calcined material containing between 97 and 98 per cent of sodium carbonate. The average composition of the soda ash is recorded as:—

	Per cent
Sodium carbonate (Na_2CO_3)	97.55
Sodium bicarbonate ($NaHCO_3$)	0.05
Sodium chloride (NaCl)	0.50
Sodium fluoride (NaF)	1.28
Sodium Sulphate (Na_2SO_4)	0.40
Soluble silica (SiO_2)	0.03
Iron oxide (Fe_2O_3)	0.03
Insoluble (sand and clay)	0.50
Water	0.19

TABLE IX—MINERAL PRODUCTION, KENYA, 1958–1967

(From records of the Mines and Geological Department)

	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958
Asbestos (long tons)	50	65	121	182	70	189	135	103	38	107
Barytes (long tons)	209	96	35	—	—	—	—	—	—	—
Beryl (long tons) ..	17	—	—	0·6	—	—	0·5	1·5	2·2	3·5
Carbon dioxide (long tons)	804	804	750	734	509	458	638	826	702	672
Columbite (lb.) ..	—	—	—	—	—	375	—	385	1,399	1,680
Copper (cement) (long tons) ..	11	780	1,938	2,044	2,212	2,191	2,524	1,756	1,982	1,988
Corundum (long tons)	25	—	—	—	—	—	—	—	—	—
Diatomite (long tons)	1,856	1,744	2,183	3,007	3,283	2,863	3,158	3,384	3,608	3,745
Felspar (long tons)	396	161	—	—	—	1	—	—	—	25
Garnet (lb.) ..	349	296	—	—	—	—	—	—	—	—
Gold (fine oz. troy)	33,366	11,898	12,013	12,480	10,193	9,327	12,299	8,645	9,145	7,753
Graphite (long tons)	—	—	—	—	—	—	—	994	566	660
Guano (long tons)	341	318	—	—	—	—	—	—	—	—
*Gypsum (long tons)	242	—	—	—	—	180	71	432	1,199	2,618
Kaolin (long tons)	1,433	879	1,687	1,268	6,558	1,155	729	1,036	1,143	1,185
Kyanite and Mullite (long tons) ..	—	—	—	—	—	—	—	1,265	1,463	536
*Limestone products (long tons)	18,740	16,470	14,180	13,642	16,188	17,995	19,471	24,893	16,733	15,805
Magnesite (long tons)	415	667	66	167	257	—	1,723	30	2,808	492
Meerschaum (lb.)..	315	1,530	4,410	450	13,440	—	2,475	49,280	42,560	68,880
Mica (lb.)	—	—	—	—	1,760	2,293	222	1,244	21,908	15,680
Pumice (long tons)	120	780	1,023	1,415	280	1,110	696	2,420	2,245	733
Raw materials for cement	808,528	795,940	789,192	700,374	581,784	†	†	†	†	†
Salt (long tons) ..	48,032	53,533	50,741	40,056	32,683	18,568	22,650	21,916	19,242	18,721
Sapphire (carats) ..	8,308	3,525	4,212	2,200	800	14,522	1,000	—	—	—

TABLE IX—MINERAL PRODUCTION, KENYA, 1958–1967—(*Contd.*)

	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958
Silver (fine oz. troy)	3,038	19,003	26,785	47,702	52,422	50,160	40,731	35,797	46,420	44,146
Soda Ash (long tons)	106,273	113,048	84,388	82,565	104,175	124,998	144,689	126,981	153,260	111,038
Vermiculite (long tons)	247	75	22	33	91	20	—	253	100	86
Wollastonite (long tons)	12	—	—	—	—	—	—	—	—	—
Value of mineral production (K£)	2,697,619	3,043,270	3,096,394	2,575,388	2,628,298	2,437,612*	2,749,995*	2,464,390*	2,802,714*	2,242,418*
Cement production (long tons) ..	471,398	476,773	497,204	330,983	327,010	340,905	324,717	347,838	308,840	213,992
Value of cement production (K£)	3,190,178	3,774,756	3,793,192	3,243,185	2,542,357	2,653,380	2,559,385	2,635,123	2,516,641	1,895,542

*Excluding material used in cement manufacture.

†Figures not recorded.

In 1953 four boreholes were sunk into the lake and subsequent examination of the cores by the Geological Survey revealed that in certain parts sodium bicarbonate (nahcolite) is abundant.

Soda salts also precipitate around others of the Rift Valley lakes, such as Nakuru, Elmenteita and Suguta, and at the hot springs at Kapedo. Some years ago when Lake Nakuru dried up a company was formed to work the salts. Since then, however, the lake has again become covered by water on more than one occasion, and the project has been abandoned.

During the last 35 years there has been a considerable output at Magadi of common salt for household and dairy use, sodium bicarbonate bath salts, and washing soda, and for a few years sodium fluoride (a minor constituent of the lake salts) was extracted. Common salt is also produced from sea-water by solar evaporation at Fundi Isa, north of Malindi.

The export of Magadi products is a considerable item in the economy of the country, as is shown by the figures given in the production tables.

Gold and Silver

Though gold in small amounts has been discovered in various areas, such as West Pokot, Laikipia, north of the Loldaika hills and Machakos, gold and silver mining has been mainly restricted to areas in which the Nyanzian and Kavirondian Systems are found, i.e. in Nyanza Province, in a smaller area east of the Kisii highlands and near Kibigori in Rift Valley Province. It had been carried out in a minor way for several years in a belt near the Tanzania border before the discovery of the Kakamega Goldfield in 1931, which was followed by the more intense examination and exploitation of the deposits of the whole of Nyanza. The discovery was made during a difficult period in the history of the country because of agricultural mishaps and general world trade depression, and a few months saw the rapid influx of hundreds of prospectors and miners. Mining companies soon became interested and within a few years gold mining was on a sound footing. The value of gold produced increased steadily until the early years of the Second World War. Subsequent years until 1948 saw a gradual decline owing to loss of personnel and inability to replace or purchase adequate stores and equipment. The increase of the price of gold in 1948 led to greater production which, however, was not regularly maintained. A further serious drop in production occurred in 1952, with the closing down of the largest mine after a life of about 20 years. Another large producer ceased to work early in 1957. From 1956 to 1966 the main production of gold was from Macalder Mine, as a by-product of copper. On the closing of that mine in 1966 the same company opened a mine in a gold reef, very close to the copper mine, which in 1968 produced 32,000 ounces of gold, but known reserves are likely to be exhausted by 1970.

The production of gold from Nyanza has always been predominantly from quartz veins and a few impregnations, though in earlier years the proportion of alluvial gold won was high. No extensive workable alluvial deposits have been found or are likely to occur, though a small alluvial production will be maintained by individual workers. In recent years alluvial gold has been won in relatively small amounts from the Suam and Marun rivers in West Pokot.

The fineness of gold won from veins has usually been about 850 to 900, but at mines where non-ferrous sulphides are prominent constituents of the primary ore, bullion of much less refined character has been obtained. At one mine the gold is present in the form of electrum. The quartz veins are commonly of lenticular habit, and range in strike length from a few tens of feet to 2,000 feet or more. Extension in depth is not uncommonly greater than the surface strike. The payable gold is restricted to more or less well-defined shoots, and the extent of payable ore is usually considerably less than the maximum extent of the quartz veins. The thickness of the veins varies from the

size of stringers (of which unusually rich examples have been discovered from time to time) to 20 or 30 feet. The average width of veins worked is, however, probably less than two feet. The gangue of the veins is principally quartz, but carbonates, felspar, ilmenite, chlorite, epidote and sericite figure in some. The principal sulphides are pyrite, pyrrhotite, arsenopyrite and chalcopyrite; galena and blende are sometimes present in minor amounts. Tourmaline and scheelite have been found in some veins, and fluorite has been recorded from a vein in South Nyanza. Tellurides are of rare occurrence.

The veins have been found within granite cupolas, a little way inside larger granite masses, or usually within about two miles of the exposed granite contacts. In cases where veins lie farther out from the visible contact there is usually evidence that granite lies at relatively shallow depth.

The ridges of the main gold-field area form part of the sub-Miocene peneplain, and as a whole are characterized by deep weathering. Exposure of many of the gold-bearing quartz veins is poor, and in several cases they have been traced only by the use of loaming methods. Mechanical enrichment of the portions of the veins above the water-table has usually been a marked feature, and in several cases collapsed lode rubble has provided rich reserves. Many massive and extensive veins or dykes of white quartz, some of which extend over several miles, also occur in the gold-fields. Though they usually contain some gold, they have not proved in any case to be of workable tenor.

The figures quoted below (Table X) give a summary of the growth and value of the gold industry.

TABLE X—PRODUCTION OF GOLD IN KENYA

PERIOD	PRODUCTION	VALUE
	Troy oz.	K£
1926–1930	4,669	18,060
1931–1935	73,226	368,183
1936–1940	385,768	2,405,710
1941–1945	252,813	2,150,145
1946–1950	118,298	1,135,459
1951–1955	55,713	701,389
1956–1960	46,773	584,415
1961–1965	56,312	718,174
1966	11,898	149,490
1967	33,366	420,118

Note:—Quantities quoted were measured as unrefined ounces up to 1939, and as refined ounces for later years. Value of gold produced up to end-1939=K£2,143,170; 1940 to end-1967=K£6,507,973; total K£8,651,143.

Silver obtained during the refining of exported gold only reached a significant figure during the mining of copper at Macalder Mine, where gold alloyed with silver was an important by-product.

Diatomite

Extensive deposits of diatomite are known in Pleistocene lake-beds at various points in the Rift Valley. An occurrence at Kariandusi, near Gilgil (Plate VII*a*), has been worked for many years, and deposits on the Koora plains near Magadi were formerly worked by the soda company and have been sporadically worked in recent years. From time to time deposits on the Soysambu Estates, near Elmenteita, are worked in conjunction with those at Kariandusi, and recently exploitation of an occurrence at Gicheru in the Kedong Valley began.

Other deposits are known at mile 62 on the Konza-Magadi branch-line railway, at Nderit and other places near Elmenteita, near Eburru, and in Subukia. That at Kariandusi is noteworthy in containing several bands of diatomite, one of which is more than 100 ft. in thickness where best developed, and of unusual purity. The main band has inclusions and bands of tuff and pumice which, however, can be readily rejected in quarrying. The diatomite of this band is dazzling white and samples tested some years ago by the Mines and Geological Department had block density of about 28 lb./cu. ft. and powder density (after screening through a 120-mesh sieve) of between 7½ and 9 lb./cu. ft. Analyses of channel samples taken down the face of the quarry indicated an average content of 84.19 per cent SiO_2 with 5.51 per cent H_2O. After ignition the diatomite was found to absorb 3 to 3½ times its own volume of water. The principal diatom in the rock is *Melosira*.

For some years the Kariandusi deposit was worked on a small scale to satisfy local demands, largely in connexion with the manufacture of household soaps. Immediately after the war a local company was formed to work the main band with a view to processing the material for export for use as a filter aid and as an insulating medium. Since then production has maintained a reasonable level, a considerable portion being sent overseas. The operating company, with suitable processing, is now able to produce a high-grade filtration medium. Other important uses of the powdered and processed material are in heat and sound insulation, as an absorbent and stabilizer in the chemical industry, as a carrier in insecticides and as a mild abrasive.

Carbon Dioxide

Carbon dioxide under pressure was discovered in 1946 at a depth of 450 ft. and below by a borehole drilled for water at Esageri, east of Eldama Ravine on the western flank of the Rift Valley. In 1949 a mining title over an area surrounding the borehole was advertised for tender and in 1951 a Special Mining Lease with a term of 21 years was granted to Carbacid Manufacturing Co. (now Carbacids (1961) Ltd.).

The pressure of the gas escaping from the borehole when it was first capped was 80 p.s.i. which fell to a little over 60 p.s.i. when the factory went into production. In 1959 a new borehole was sunk as a standby a few hundred feet from the original, and a few years later both were still showing pressure in excess of 60 p.s.i. The average CO_2 content of the gas varies only slightly between 98.5 and 99.1 per cent, the balance consisting of nitrogen 0.8 per cent, hydrocarbons 0.6 per cent, argon 0.02 per cent and helium less than 0.01 per cent.

A borehole sunk in 1967 at Kerita, near Uplands on the eastern flank of the Rift Valley, produced gas at a pressure of 35 p.s.i. The composition of this gas is given as CO_2 97.8 per cent, nitrogen 0.8 per cent, oxygen 0.2 per cent, hydrocarbons 1.1 per cent and argon 0.07 per cent. Helium was not detected.

Emanations of carbon dioxide are also known in natural holes in volcanic rocks in the Kedong Valley, in the area south of Lake Magadi, and at various places in the central part of the Rift Valley north-east of Esageri, as at Arus on the Molo River and in the southern part of the Tugen (Kamasia) Hills.

Copper

Traces of copper minerals have been found at several localities in Basement System terrain in the eastern part of Central Province, in Eastern Province and in West Pokot. At Lugard's Falls, where 5 per cent ore was prospected many years ago, the copper occurs in a pegmatite mineralized with chalcopyrite. Later prospecting revealed chalcopyrite and bornite in a granulite to a depth of 15 ft., values between 0.2 and 1.8 per cent of copper being obtained. It is unlikely that such deposits will become of economic interest. Deposits in the north-west angle of the Tsavo-Athi confluence and in the hills south of Voi have been prospected by the Mines and Geological Department. At the

former locality bornite and copper carbonates occur in a granulite over a considerable strike length. A chip sample assayed 2.49 per cent of copper, a channel sample 2.21 per cent of copper over 10 inches, and other samples as much as 4 per cent of copper. It has been suggested that zones of secondary enrichment might occur at depth. South-east of Embu and north-east of Kapenguria traces of ores rich in bornite have been discovered. The source of the Embu specimens has not been found, but in the southern part of West Pokot the sporadic copper occurrences appear to be relics of a deposit in an ultrabasic rock that was granitized and dispersed, so that the possibility of economic ore-bodies seems unlikely.

An extensive copper deposit was known for some years at Macalder-Nyanza Mine in South Nyanza, though for many years the mine extracted only gold from the oxidized zone. Production of copper and zinc concentrates began in 1951 after a change of ownership, and cement copper was produced from 1956 to 1966, together with gold and silver. The ore-bodies, which are now exhausted, were a branching series of lenticular impregnations extending over more than 1,200 ft. They were often more than 20 ft. in width and consisted of massive disseminated sulphides. The oxidized caps, carrying free gold, were about 120 ft. in depth, and at their bases were thin zones of secondary copper minerals.

The primary ore was a fine-grained streaky, granular aggregate of pyrite, pyrrhotite, chalcopyrite, magnetite, arsenopyrite, zinc blende and galena, with interstitial calcite. Chlorite is often plentiful in vein margins. Gold in the ore was present as electrum, and was closely associated with the galena. A small percentage of cobalt was determined in assays.

Other copper occurrences are also known in the margin of a granite mass near Kitere some miles north-east of Macalder Mine, in the central part of South Nyanza. Up to 5.87 per cent of copper was assayed in grab samples from the veins at outcrop. The main vein was prospected underground, being followed for a distance of 280 ft., swelling and pinching from about 6 in. in width to a maximum of about 10 ft., with an average thickness of the order of 20 in. Mineralization was found to be sporadic, values varying from a trace to 20 per cent of copper. The veins are composed of quartz with chalcopyrite and lesser amounts of bornite, covellite and chalcocite with secondary minerals. In 1968-69 a joint Kenya Government-United Nations team prospected copper showings along the Elgeyo Escarpment and Cherangani Hills in Rift Valley Province.

Graphite

Rocks containing graphite are known in both Basement System rocks and in the gold-fields formations. The latter are, however, mudstones of restricted occurrence and unlikely to be of economic interest. Graphite schists containing up to 25 per cent of graphite were worked many years ago in the Basement System rocks of the Machakos district, and a few years ago a small production was made from the same source. More extensive deposits of graphite gneisses were discovered in 1940, during the survey of the Mtito Andei-Tsavo area. Deposits in southern Kitui were explored and worked on a small scale during the war. The same deposits were more intensively prospected later, and a mine established in 1952 continued production until 1960, 3,670 tons of flake and fine graphite being produced. The percentage recovery of graphite from the ore varied between 6.27 and 10.05.

Graphite deposits are also known at several localities in and near the Taita hills. A small mine was opened near Mwatate in 1952 and between 1953 and 1955, when it closed down, produced 400 tons of good-quality flake graphite. Other deposits occur near Tsavo in a favourable situation, being adjacent to the railway and permanent water. The graphite is contained in several, often thick, parallel bands that extend over many miles. Over the portion tested by assay the average carbon content was found to be a little under 6 per cent, though portions of some bands are considerably richer. The

deposits were worked in the area near Tsavo Station during 1944 and 1945, the best production obtained having a carbon content of about 92 per cent with good proportions of large flakes. The Tsavo deposits have the disadvantage that they occur close to large valleys where the removal of weathered material by erosion has left ore that at shallow depths is harder than is desirable in graphite deposits.

Deposits near Namanga were also worked on a small scale in the period 1951 to 1954. Later, extensive deposits were prospected in the area north of the Loldaika Hills and much work has been done on processing the ore to yield suitable products, but commercial production has not yet been started. Extensive sampling has shown that the content of graphite in the ore ranges from 2 to 23 per cent.

Numerous other graphite deposits have been found by prospectors or by the Geological Survey, for example, in the north Kitui area, south of Voi, south-west of Loperot and near the Merti Plateau.

Kyanite and Mullite

Gneisses and schists containing kyanite occur at various localities where Basement System rocks are exposed, particularly in the Machakos district and in the area south-west of Tsavo. A pegmatitic deposit in Machakos has been worked on a small scale, but the kyanite occurs in isolated crystals, and this and the cost of transport render exploitation unprofitable, though a few hundreds of pounds of large fine blue crystals were found and sold as collectors' specimens. Segregations of kyanite rocks so far found in Machakos and adjoining districts are rare and of no great size. Some years ago, however, considerable tonnages of kyanite schists containing 25 to 31 per cent of extractable kyanite that may prove to be workable were discovered by a prospector north-east of Sultan Hamud. Other deposits were discovered by a Government geologist some 28 miles south-west of Sultan Hamud. Original samples collected contained an average of 46 per cent kyanite but subsequent examination of the occurrence by a Government prospector indicated that the overall average is probably considerably less. Low-grade kyanite deposits were later discovered in the area north-east of Isiolo, and kyanite-bearing rocks have been noted in several areas during geological survey, e.g. south of Voi, in the Loita Hills area, etc.

Numerous kyanite-bearing rocks were mapped in 1940-41 in the area between Tsavo and Taveta during an official reconnaissance. At Murka Hill, a few miles north-east of Taveta, unusually fine deposits were noted that were later pegged and worked by a local company. There a band of kyanite schist, lying between biotite gneisses below and quartz schist above, contains scattered lenticles of kyanite rock of greatly varying size and with sillimanite envelopes. Some of the rock contains corundum in addition, providing unusually alumina-rich ore. Some of the segregations are of considerable size and in the course of erosion had given rise to an apron of kyanite-rock boulders, some of tremendous size, on the lower scarp flank of the hill. When mining was begun in 1944 it was possible by blasting and little hand-selection to extract readily large cargoes of kyanite of more than 90 per cent purity. As working continued the boulders were exhausted and it became necessary to quarry the segregations *in situ* under increasing overburden. At the same time attention was turned to the kyanite schists which contain up to 75 per cent of kyanite, though the average content is a little more than half that figure. The kyanite was extracted from the schist and lower-grade kyanite rock by jigging and flotation, and after 1951 the bulk of the production was converted by calcination at the mine to mullite, which is valued at about twice the price of the raw kyanite. The original company sold out to a large mining concern in 1956. Some time was spent on conversion of the extraction and treatment plant, and production and export were re-started in 1958, but the mine was finally closed down in 1960 when working proved unprofitable.

Some of the kyanite was successfully used for local manufacture of mullite bricks and other refractories, but the bulk of the production was exported.

Generally similar but less extensive deposits were found by prospectors at Kevas and Loosoito, north of Murka and on the same strike. Between 1948 and 1952, when the deposits were considered no longer economic to work, 4,537 tons of kyanite rock had been extracted. The total production of kyanite and mullite from all the Taveta deposits was 68,697 tons and 31,321 tons respectively.

Oil

Oil seepages have been reported at various times in eastern Kenya, but none has yet been verified. Other factors, however, suggest the possibility of the occurrence of oil at depth. The Palaeozoic, Mesozoic and Tertiary sediments of the coast and the neighbourhood of the Somalia border contain rocks which might well have been the sources of oil, and structures in these rocks are such that stratigraphic traps may be expected.

BP-Shell Petroleum Development Company of Kenya have held oil-prospecting rights in large areas of eastern Kenya since 1954, and since that date they have spent, and are continuing to spend, approximately one million pounds a year in geological and geophysical surveys (Plate VII*b*) and exploratory drilling. The main focus of drilling has been near the coast inland from Lamu, where several deep holes were sunk, the deepest being 14,140 ft. (Plate VIII*a*), and near Garissa where a depth of 12,000 ft. was exceeded.

An oil refinery, jointly owned by BP-Shell, Esso and Caltex, was opened at Mombasa in 1964 to refine crude oil imported from the Persian Gulf.

Other Minerals of Economic Importance

Notes on minerals and rocks worked or likely to be worked for export or local consumption are given in the following paragraphs.

Arsenic.—Arsenopyrite occurs in some gold-quartz veins, and in certain cases is a prominent constituent. There is no doubt that, with correctly designed plant, a small production of white arsenic could be made concurrently with the operation of some of the veins as gold properties.

Asbestos.—Anthophyllite asbestos has been discovered at several localities, for example, at Kinyiki near Mtito Andei, and in southern Kitui, West Pokot, the Baragoi area and in the Taita Hills. Production of note has so far come only from Kinyiki and West Pokot. For some years the entire output was consumed locally and during the war an asbestos-cement tile and sheet industry was set up in connexion with the production in West Pokot. For some years now the bulk of the output from West Pokot has, however, been exported. Blue asbestos (crocidolite) is known in southern Machakos, near Sultan Hamud, but has not been worked and it is unlikely that deposits of economic size are present.

Ballast.—Large quantities of rock for ballast are available in various parts of the country. Tertiary lavas including phonolite and trachyte are more commonly used in central and western Kenya, and Triassic sandstones at the coast.

Barytes.—A lode of barytes (associated with lead, zinc and feeble copper mineralization) occurs at Vitengeni north-west of Kilifi on the coast. Its maximum width is more than 30 ft. Near the surface the barytes is variably and patchily iron-stained, but clean white mineral can be obtained by hand-picking; at lower levels abundant supplies of white material may be expected. The small present production is all used locally as a paint filler and in glass-making.

Veins of barytes have recently been discovered by the Geological Survey in faults in the Sabaki Valley, 50 miles west of Malindi. They are probably genetically connected with the veins at Vitengeni. Other occurrences of barytes are known in the southern

part of the Coast Province, at Didimtu in North-Eastern Province, in south Kitui, and in the Homa district, Lolgorien and Kahancha, the last three all being in South Nyanza. Most of the occurrences are unlikely to prove workable on any but the smallest scale.

Bentonitic Clays.—Clays with affinities to bentonite occur as intercalations in lake-beds that form part of the generally volcanic sequence east and south-east of Nairobi, in Pleistocene deposits at several localities north of Mt. Kenya, and in Pleistocene or Recent lake beds at Amboseli. The better quality clays of the first two areas are soapy when moist and swell to about three times their original volume when wetted. Research suggests that the clays are composed predominantly of nontronite and illite. Nontronite clays have also been reported from other localities in the Tertiary volcanic areas.

Beryl.—This mineral is found as a minor constituent of mica pegmatites in the Basement System. Some years ago a pegmatite containing a large "blow" of beryl was discovered and mined in the Machakos District, where several pegmatites have yielded small amounts of beryl while being prospected or mined for mica. More recently excellent bluish beryl has been mined at Sebit in the Cherangani Hills, the production again being a few tons. Beryl pegmatites have also been prospected in the Embu area, near Baragoi, at Boji and the Timtu Hills, small parcels of mineral being extracted. Other beryl occurrences are known near Wamba and in the Mukogodo district.

The present small production all comes from the Embu area, where working is stimulated by price increases in recent years and by the presence of small amounts of good quality gem material (aquamarine).

Brick-earths and Clays.—Bricks and tiles have been made for many years at certain localities, though nowhere on a large scale. The main factories are near Mombasa, where for a long time mangalore type tiles have been made, though expansion to include other products has recently been carried out near Muthaiga (Nairobi), where Broseley tiles are made; and in the Gatharaini Valley near Nairobi, where bricks, tiles and other shapes are manufactured. During the war small industries arose at numerous other localities, largely because prisoner-of-war labour was available. The appointment some years ago of a ceramics specialist to the Industrial Research Organization has led to improvements in quality and quantity of the bricks and tiles produced at many localities.

Building-stones.—General purpose building-stones of good quality are not abundant near most of the centres of population, and it is to be anticipated that concrete construction will eventually usurp their place. Coral blocks have been largely used around Mombasa; at Nairobi a thin band of tuff provided stone for most of the buildings until recent years when concrete has been used for large buildings, and similar rocks at Kedowa and Nyeri have provided stone for the area north-west and north of Nairobi. At Kisumu blocks of lateritic iron-stone have been frequently used. Other centres are poorly supplied with building-stones, and usually concrete or brick constructions are necessary. Rocks suitable for concrete ballast are accessible within reasonable distance of most places where extensive building appears likely at present.

Ornamental stones, with the exception of Basement System marble, which has been extracted near Turoka on the Magadi branchline (Plate II*b*), have been little worked, though numerous fine stones among the Basement System rocks and gold-fields granites would be suitable for such use.

Chromite.—Low-grade chromite was discovered some years ago in the southern Embu District, and better material at Debel, south-east of Moyale in Eastern Province. A detailed examination of the Debel occurrences revealed that, although considerable tonnages are available, the chrome content of the ore is somewhat below the figure acceptable to buyers. High-grade chromite has been discovered in the Baragoi area, but during the geological survey of that area little tonnage could be found.

Chromite, of which analysed specimens showed more than 54 per cent Cr_2O_3 and a chrome : iron ratio exceeding 3 : 1, also occurs at Sekerr Mountain in West Pokot. Tonnage of ore appears to exceed 100,000 long tons, and the occurrence of nickel associated with the ore may make the deposit an economic one.

Corundum.—Corundum, usually occurring at the contacts of schists and ultrabasic intrusions, is known at Kinyiki Hill near Mtito Andei, in the Meru District, in the Taita Hills, in Machakos, near Lugoyo east of the Karissia Hills, at Boji Hill north of Chanler's Falls, and in the Loldaika-Baragoi area. It also occurs in some of the kyanite ores of the Taveta District. A small amount was worked in the past in Machakos, but the present production is all from the Meru area. (*See* also Sapphire, on p. 30).

Dolomite.—Basement System marbles with magnesia content approaching that of dolomite were found near Voi during a survey of the Taita Hills. Dolomite is also known in the Jurassic limestones north of Wajir and in the Quaternary lake beds of Amboseli, where it forms the host rock to meerschaum.

Felspar.—This mineral is available in many pegmatites cutting the Basement System. A few of the larger pegmatites, and notably one at Kinyiki, have been worked from time to time, the felspar being used in ceramics factories in Nairobi, and in the manufacture of scouring powders.

Fluorite.—This is a rather rare mineral in Kenya, and for many years was known only in a few gold veins in Nyanza, as thin impersistent veins near Rata in Central Nyanza, and as a rare constituent of the carbonatites of South Nyanza. In 1958 fluorite of a fine, dark-green colour was found in a pegmatite at Kenailmet in Karasuk, and in 1966/1967 several veins of green and (rarely) purple fluorite were discovered in the Baringo and Samburu districts of Rift Valley Province. In 1968 production began on one of the Baringo occurrences, the material being sold to the Bamburi cement works to replace hitherto imported material.

Garnet.—At certain horizons in the Basement System garnet occurs as scattered crystals of varying size or as massive bands. Concentrations of crystals liberated from their matrix are found in some stream-courses, and a few years ago a prospector in Machakos worked such a source and marketed garnet powders and cloths. Eluvial deposits near Tsavo have also been prospected, but no production followed.

Melanite garnets are present in carbonatites and ijolites in Nyanza Province. Gem quality garnets have occasionally been found in Basement System rocks, a small production of pink garnets coming from Meto in Kajiado District.

Glass-sands.—Sands suitable for the manufacture of colourless glass are found along the coast and near to it, e.g. in the Sokoke Forest. In the interior sands are usually too felspathic and too contaminated by iron-bearing minerals to be used for such a purpose without treatment, though some of them can be used in making green and brown glass. In recent years quartz mined from the cores of pegmatites in the Sultan Hamud area has been used in the glass-works at Nairobi. There is a second glass-works at Mombasa.

Guano.—This was first reported from the coast, but to date no significant production has come from that source. In 1966 a prospector discovered bat guano in lava tunnels in the northern part of the Chyulu volcanic field near Makindu, where a steady production is made and sold at a good price, mainly to coffee farmers in Kenya, with a small export to Tanzania. The same prospector also discovered and pegged guano claims in tunnels on Mt. Suswa.

Gypsum.—Gypsum deposits of economic size occur in the northern facies of the Jurassic sediments and as Tertiary and Pleistocene lake and marsh deposits. These include two deposits in the Tula Valley which have been worked for some years, and

occurrences at several localities in the eastern part of North-Eastern Province. Gypsum in crystals up to 18 inches long occurs in argillaceous horizons in the Miocene Turkana Grits flanking the Napedet hills south-east of Lodwar. Thin layers of gypsum are known in Pleistocene sediments near Homa Mountain and in Jurassic shales at Mombasa. The Geological Survey discovered gypsum deposits in recent sediments near Mida Creek, near Malindi; they have since been exploited for use of the mineral at the Bamburi cement factory. Gypsum is also obtained in small amounts from the solar evaporation plant at Gongoni, north of Malindi. In the past few years gypsum has been found in volcanic soils at various places in the Kajiado District, and much of the gypsum used by the East African Portland Cement Co. at Athi River now comes from there.

The two deposits in the Tula Valley are a few miles west and south of Garissa respectively, the latter being near to the River Tana. The first deposit consists of pinkish aggregates of gypsum in clays, and some years ago the gypsum produced was consumed by a local cement clinker grinding factory. The production is now used for cement manufacture, building and agricultural purposes. The second deposit consists of a continuous band of white gypsum in clays. Though white, this gypsum is slightly less pure than that of the other locality. The production was originally consumed locally in the manufacture of plaster of Paris and blackboard chalks. Reserves are considerable, but the cost of the mineral is increased by the great distance it must be transported (mainly by road) to reach centres of population. Export is unlikely unless transport down the River Tana becomes practicable.

Iron Ores.—Deposits of iron ores have been prospected, but appear to be too small to justify working, though some may be of use at a future date. They include haematite-magnetite schists, magnetite segregations (south Machakos), ilmenite sands near Malindi, pyritic lodes and their gossans in Nyanza Province, and some banded ironstones in the northern and southern portions of the same province. A pyritic lode at Bukura is estimated to contain 17,000,000 tons of ore down to a depth of 300 ft. (*see* also Pyrite, p. 29). Clay ironstone nodules occur sporadically in Jurassic shales at the coast, but there is no indication that they might be sufficiently frequent to be of economic importance. Some years ago the Geological Survey discovered a haematite ore-body at Bala near Homa Mountain that is estimated to contain 80,000 tons of ore with an Fe content of 50-60 per cent. Further work around the carbonatite complexes of Nyanza will probably lead to the discovery of similar ores.

In 1965 a deposit of many millions of tons of massive iron ore was discovered near Marimante, 25 miles south-east of Meru township, but the TiO_2 content of the ore, varying between 5 and 15 per cent, makes the deposit of no value under present conditions.

Kaolin.—Several deposits of kaolin have been discovered east of the Rift Valley, notably near Fort Hall, in the southern Machakos District, and the Ndi Hills a few miles north of Voi. All are the result of the weathering and disintegration of gneisses or pegmatites of the Basement System. A deposit in the Rift Valley, near Eburru, is of different type, and has been produced as the result of solfataric action on volcanic rocks. For some years production has been maintained for use in local ceramics factories, both for pottery and for refractories, though at present the bulk is consumed in the manufacture of refractory articles.

Kisii Soapstone.—There are several scattered occurrences of soapstone in south Nyanza, the material available being of varying quality. The rock consists normally of a mixture of sericite and kaolin but grades into more complex types containing in addition epidote, chlorite, quartz, etc. Frequently the stone is closely jointed though at some localitites large blocks can be obtained. The stone has been quarried on a small scale for many years and worked as carvings. During the war, and until 1954, a mining company quarried it more extensively and installed crushing and air separation plant.

The air-floated product was largely consumed by local soap factories. Attempts have been made to use the stone in the worked solid form, for it is readily cut and shaped, and when suitably baked develops a surface frit that renders it much less porous, and potentially useful for electric insulators.

Lead.—For some years a system of galena-barytes veins, containing pockets of zinc blende and traces of copper minerals, has been known in the Mesozoic sandstones at Vitengeni, north-west of Kilifi in Coast Province. The principal vein has a relatively short strike, but at its thickest section is more than 30 feet wide. The galena content over the best part of the vein is apparently about 5 per cent, with silver ranging up to about 8 oz. per ton of galena concentrates. There was a small production many years ago, and during the 1939-45 war a small amount of galena was taken from stacked ore for local use. In 1948 further exploration was carried out by a mining company, when by trenching and drilling a lead content of 5.5 per cent over an average width of 7.6 feet was ascertained. In 1952 another company took up the search, extending its exploration farther from the main opencast. The maximum values obtained during drilling were lead 11 per cent, copper 6 per cent, zinc 9 per cent, gold 0.3 dwt. per short ton, silver 30.2 dwt. per short ton. The work, however, apparently showed that the main vein is not persistent at depth and that away from the opencast the veins are thin and impersistent.

Other traces of galena mineralization are known in the Mazeras District where a deposit was prospected by the British East Africa Company in 1892. Most of the ore material that can be seen thereabouts these days is, however, zinc blende. Recent geochemical work by the Geological Survey showed several anomalous highs in lead and zinc between Mazeras and Vitengeni, and diamond drilling (Plate VIII*b*) shows mineralization to be controlled by faulting.

Galena is found in quartz veins in the Athi Valley east of Katulani, and is also occasionally present in the gold veins of Nyanza Province, and in one near Kaimosi Mission may be an important constituent. In 1967 a small lead deposit was discovered in the Basement System rocks of the Elgeyo Escarpment.

Limestone.—There are three principal lime-burning concerns in the country—at Mombasa, Turoka near Kajiado and at Koru. Production, owing to the limitation of supplies of Portland cement, increased rapidly during the war years and has since been maintained. The limestones worked at the localities named are respectively Pleistocene coral, Basement System crystalline limestones and Miocene lake limestones. Previously Pleistocene lake limestones and carbonatites were worked in the vicinity of Homa Mountain. Pond and spring limestones of Pleistocene and Recent age are worked on a small scale in the Makindu-Kibwezi area. The Basement System limestones usually have a variably high magnesia content, but some are magnesia-poor types.

Resources of limestone in the country are extensive. Basement System marbles are widespread though many are inconveniently placed with respect to transport. Miocene limestones and carbonatites form a large reserve in South Nyanza, and kunkar deposits east of the Rift, Jurassic limestones and coral near the coast and Jurassic and Pleistocene limestones in north-east Kenya are available.

Magnesite.—This mineral occurs as veins in dunite intrusions at Kinyiki Hill, Kapoponi, near Magongo Hill in south Kitui, in the Embu and Baragoi districts, and west of Merti in Eastern Province. The occurrence at Kapoponi has been prospected, and that at Kinyiki worked sporadically. The veins at the latter locality are sometimes two feet or more in thickness and extend over many yards, but more usually they consist of a great number of branching veinlets. The proportion of magnesite to host-rock in more favourable portions of the hill reaches 30 per cent. A small quantity of high-grade magnesite was extracted for export during the early war years, as well as a considerable tonnage of somewhat less rich material.

Manganese.—Deposits of manganese ores were discovered more than 30 years ago at Mrima Hill, south-west of Mombasa, but have not been worked. They are now known to overlie a carbonatite centre, in which large tonnages of pyrochlore, monazite and rare-earth minerals are present. The ores consist largely of psilomelane and hausmannite associated with iron oxides and usually with some barytes. Similar ores are said to have been struck in boreholes for water in other parts of southern Coast Province. Preliminary estimates indicate that the reserves of ore on Mrima Hill amount to over 600,000 tons, and from numerous examples analysed it appears that the average content of manganese will lie between 20 and 30 per cent.

Other deposits of manganese in coastal sediments have been investigated at Kiwara, south-west of Kilifi. The ores resemble those of Mrima, but judging from analyses it is probable that pockets of pyrolusite are also present. Ore reserves indicated by drilling by the Mines and Geological Department in 1964 amount to 443,000 long tons at a grade of 24 per cent MnO_2. Manganese ores are also known in fault veins in the Lali Hills in the Galana Valley.

A small deposit of pyrolusite was discovered some 30 years ago in the Pleistocene lake basin near Gilgil in the Rift Valley. The deposit was small, but consisted of material that could be readily beneficiated by washing and screening. During the war it was largely worked out by officers of the Mines and Geological Department when manganese dioxide was required for use as a drier in locally made paint. A few tons of ore left in the workings were extracted later for use in glass making.

From time to time manganese ores have been reported from areas of Basement System rocks, such as Machakos and West Pokot. In all cases they proved to be oxidation caps on rocks containing large amounts of manganiferous garnets, and to have little extent either laterally or in depth.

Meerschaum.—Good-quality meerschaum was discovered in 1953 in sediments of Pleistocene age in the Amboseli basin. It occurs in small slips and lenses associated with dolomitic limestones and sepiolitic and montmorillonitic clays. The beds are frequently considerably folded, presumably as a result of heaving caused by crystallization in unconsolidated sediments. The manufacture of pipes for smokers using the meerschaum was set up in Nairobi and later moved to Arusha, and research has been carried out into the possibility of using the limestone and clays that occur with the meerschaum.

Mica.—Sheet mica has been worked sporadically in Kenya for many years, but production has never been large. The deposits occur in pegmatites, usually in the Basement System. The principal localities where they have been worked are West Pokot, Sultan Hamud district, Kierra, the Tsavo Valley, and west of the Taita Hills. More recent discoveries have been made in the Baragoi District, where some excellent ruby mica has been found, near the Mathews range, north-east of Isiolo and in the Embu District. The mica extracted has usually been of the ruby or brown muscovite type, though some green muscovite has also been produced. The industry has been hampered generally by lack of capital, and by the inexperience of operators in the cutting and grading of mica.

Mineral Pigments.—During the war paints and washes were difficult to obtain and recourse to local materials was necessary. Reds, yellows and browns were readily obtained from several localities from oxidized clays and other superficial sediments or the material obtained by calcining them. Green pigments were obtained by using green clays in Kitui, and local graphite was used in black paints.

Nickel.—Garnierite, a green nickel silicate, occurs as a patchy impregnation in a body of serpentine at Sekerr Mountain, West Pokot. Locally the serpentine contains

more than 1.0 per cent NiO, which might prove of economic interest should the high-quality chromite deposits at the same locality be put into production.

Pumice.—For some years small quantities of pumice have been dug in Naivasha District of the Rift Valley, particularly from quarries near Longonot. Reserves are large and consumption is likely to increase as light-weight building blocks and pre-fabricated constructions come more into demand. Pumice deposits also occur and could be quarried on the west flank of Menengai, on the Rongai plain, and on the flanks of the Rift Valley between those two localities.

Pozzolana.—Various mineral aggregates among the rocks of the Highlands volcanics have pozzolanic properties, some of a high standard. During the war efforts were made to interest builders in them, but so far little advance has been made in the use of such materials.

Pyrite.—Deposits of pyrite occur in the Nyanza gold-fields. At three places in north Nyanza there are extensive gossans overlying veins and impregnations rich in pyrite or mixtures of pyrite and pyrrhotite. All have been examined in connexion with their small gold content, but none has been worked. A lode at Bukura is estimated to contain 17 million tons of ore down to a depth of 300 feet and it is likely that reserves may exceed this figure as lateral extensions are known to exist. Assays have shown the iron content to vary from 41 to 62 per cent Fe.

Pyritic lodes are also associated with the now-exhausted copper ore-bodies at Macalder-Nyanza Mine in south Nyanza. A small production was made at one time for the manufacture of sulphuric acid at Nairobi, and the dumps at the mine-site contain many thousands of tons of pyrite. Other pyritic bodies in south Nyanza have been prospected but none proved to contain a sufficient overall percentage of pyrite to be of economic interest.

Pyrochlore.—This mineral occurs in the carbonatite complexes of Homa, Ruri, Rangwa, Buru Hill near Muhoroni, and at Mrima. The last has been intensely explored by Government geologists and prospectors, and subsequently by a mining company. The mineral is concentrated in residual and weathered deposits that cap the hill to a considerable depth; it is fine grained and disseminated and the discovery of an economically attractive method of extraction presents a serious problem. Overall reserves exceeding 41 million short tons at a grade of 0.67 per cent Nb_2O_5, and $1\frac{1}{4}$ million short tons at 1.75 per cent Nb_2O_5 in more specific areas indicate that the Mrima deposit must rank as one of the larger potential sources of niobium in the world.

Quartz.—For some years quartz was quarried from a pegmatite at Kinyiki Hill for use in the manufacture of ceramics and recently quartz has been quarried in the Sultan Hamud area for use in glass making. Some 30 years ago one or two large crystals of quartz of excellent piezo-electric quality were found in eluvials at the western foot of Kinyiki Hill. Extensive working in the superficial deposits by a prospector revealed a small number of additional crystals. Subsequently the Mines and Geological Department examined the deposits closely and discovered the source vein, but underground working failed to reveal pockets of crystals. A country-wide search was made for other quartz crystal localities, and several were found where occasional crystals could be recovered. At Tseikuru, in North Kitui, several hundreds of crystals were found in pegmatites or eluvials derived from them. Most were, however, unsuited for piezo-electrical purposes. Rose quartz occurs in a pegmatite vein near Tsavo, and amethyst crystals are found occasionally at various localities.

Quartzites not too distant from Nairobi, that could be crushed for the production of quartz sand, occur in the Bissel area and in Kitui, south-east of Mwingi. Quartzites are also available in the Coast Province, south of Voi.

Rare-earth Minerals.—Prospecting by the Mines and Geological Department at Mrima Hill, Coast Province, indicated the presence of some seven million tons of ore averaging 5 per cent rare-earth oxides, and 35 million tons at 1.1 per cent to a depth of 22 feet over an area of 660 acres. The rare-earth oxides occur mainly in monazite, with lesser amounts in gorceixite and pyrochlore. There is a predominance of either lanthanum or cerium, with neodymium third in abundance, praeseodymium fourth, and either samarium or dysprosium fifth. Gadolinium and europium also occur in significant amounts. Prospecting rights and limited mining rights over the deposit were granted to a commercial concern in 1968, their main target being europium.

Buru Hill near Muhoroni in the Kericho area, which appears to be another carbonatite plug similar to but smaller than Mrima Hill, is also known to contain small amounts of rare-earths, as does the carbonatite of Ruri, near Lake Victoria.

Sand.—Large quantities of sand, mainly from river-beds, are worked each year. The principal sources of supply for Nairobi are the rivers between Athi River and Konza, and the River Voi provides large quantities for Coast Province. In western Kenya rivers in Maragoli and near Kisii provide ample supplies for local requirements.

Sapphire.—A small quantity of gem-quality sapphires is recovered from eluvials at Kinyiki Hill. The stones are derived by the disintegration of large corundum crystals formed at the contact of dunite and hornblende schists. Corundum crystals as much as four feet in length have been found, though the greater part of such crystals is composed of grey or finely cracked material. Small colourless and blue sapphires have also been recovered from intervolcanic gravels in the Chania River at Thika.

Steam (geothermal).—For many years steam escaping from natural vents in the volcanic rocks near Eburru has been used by farmers as a source of water. Numerous steam-jets are known, e.g. in Longonot Crater, south of Lake Naivasha, near Eburru, in Menengai Crater, and near Lake Hannington. Some years ago an engineer suggested that drilling should be undertaken to discover whether large supplies of steam under pressure could be tapped at depth. The idea was taken up by a power company which, after examining the area, began to drill near Orgaria, south of Lake Naivasha, in May 1956. Two boreholes were sunk, drilling continuing until the early months of 1959. The second hole reached a depth of 3,096 feet where, although the temperature was 400° F., no steam was found. The first hole had reached 1,644 feet in difficult ground, a temperature of 210° F. being recorded at 1,610 feet. Again there was no steam.

Talc.—Deposits occur as metamorphic products of ultrabasic intrusions and of magnesian limestones in the Basement System. They vary from pure talc to schists containing actinolite or anthophyllite. Deposits have been worked in Machakos and West Pokot, and sporadic production was maintained from the former locality for some years for local consumption.

Titanium Ores.—Ilmenite is of widespread occurrence throughout Basement System terrain, occurring as sporadic crystals and aggregates in pegmatites. No deposits so far discovered are likely to be of economic interest. Occasional rutile-rich pegmatites have been discovered in the Machakos District, but it is unlikely that sufficient tonnages are available to be of value. Black sands found near the mouths of the few rivers that reach the coast contain much ilmenite together with a small proportion of rutile. Prospecting was carried out on the sands along the coast north of Malindi and in Formosa Bay in 1953. The results showed that, omitting values from black sand streaks, the sands contain less than one per cent of titanium dioxide. The ilmenite contains an average of 0.12 per cent of vanadium pentoxide, but the chromic oxide content is low, only 0.015 per cent.

Vermiculite.—Numerous deposits of vermiculite have been located by prospectors, at Kinyiki Hill, near Sultan Hamud, in the Machakos District, at Kapoponi in south

Kitui, in the Taita Hills, east of the Mathews Range, and in West Pokot. Some are lenticular and intercalated in the Basement System, some occur along fractures cutting it, and others (for example at Kapoponi and Kinyiki) are contact deposits at the margins of schists and dunite. The Kapoponi vermiculite has been stated to be one of the purest available in the world, and small quantities have been in demand in Britain and Australia for use in X-ray work in connexion with soil science and clay mineralogy.

A company was formed some years ago to exploit the Machakos deposits, but failed without production being reached, largely it is believed owing to lack of interest on the part of builders. The 1967 production all came from Ilima Hill, a few miles north of Sultan Hamud.

Wollastonite.—Wollastonite occurs in ijolitic rocks associated with carbonatite limestones in western Kenya, notably Ruri and Usaki, and at several places in crystalline limestones of the Basement System. The largest known deposit lies at Lolkidongai in Kajiado District where inferred reserves amount to 200,000 short tons of ore at a grade of 27 per cent $CaSiO_3$. A local company obtained mining rights over the deposits in 1967 and are actively seeking markets for this mineral.

Zinc blende.—The only notable production of zinc blende was made in 1951 and 1952, when nearly 1,000 tons of concentrates were extracted from the ores at Macalder Mine. Small amounts were obtained in the past from the lead-barytes vein at Vitengeni in Coast Province and from veinlets near Mazeras, north-west of Mombasa. Drilling by the Mines and Geological Department for zinc and lead minerals is now (1969) in progress in the Coast Province.

Minerals of No Present Economic Value

The following notes deal with minerals that occur in Kenya, but have not been worked.

Alum is occasionally found around fumaroles in the Rift Valley, and has been noted as a rock-shelter encrustation at Kigalo Hill near Voi. Small amounts of pickeringite (a magnesia alum) have also been found near Voi. An unidentified mineral aggregate containing large percentages of *aluminium sulphate* was discovered by a prospector, associated with volcanic rocks in the Machakos district. *Amazonite* occurs in pegmatites in the Machakos and south-east Embu areas. *Amblygonite* has been found as a rarity in pegmatites. Small *apatite* deposits were discovered by the Geological Survey in carbonatites at Ruri in South Kavirondo. The maximum apatite content found was about 30 per cent. It is anticipated that further search in the Homa, Ruri and Rangwa areas will reveal other, and probably larger, deposits of apatite-bearing rock. Apatite has also occasionally been found in unusual concentrations in alluvials, e.g. near Songhor.

Bismuth oxide has been found in small amounts in a vein in the Kakamega goldfield. Samples tested contained 0.15 per cent bismuth. Small aggregates of *bismuthinite* (the sulphide) occur in a pegmatite at Boji Hill, east of Archer's Post. *Cassiterite* was reported some years ago in small quantities in gneisses near Broderick Falls, but examination of the area by the Geological Survey failed to substantiate the claim. Disseminated cassiterite occurs within and near the margins of a granodiorite near Soysambu, between Eldoret and Kitale, and has been found in alluvials in rivers draining the granodiorite outcrop. The mineral occurs as traces in the Kisii series quartzites, but examination of serial samples suggests that its distribution is probably markedly localized.

Cinnabar in thin veins associated with the galena-barytes vein at Vitengeni has been known for some years. During the war the area around the locality was closely prospected, and thin veins and impregnations of cinnabar were found over a small area and to a shallow depth. The maximum tenor of samples was about 0.5 per cent.

Coal in very thin layers has been noted in drill-hole cores from the Permo-Trias sediments of the coast hinterland, but so far no evidence has been obtained that workable seams may exist. Recent mapping and palaeogeographical considerations suggest that the occurrence of workable seams of coal is unlikely, unless a concealed coalfield is present at Mackinnon Road, where the coastal sediments are faulted down against the Basement System. Numerous reports have been received of coal in various parts of the country—Machakos, Kitui, Garissa, Lake Stefanie—but in all cases investigated the coal proved to have been transported or to be some other material. The occurrence of coal in the interior is unlikely as no beds of Karroo age are known there, though the possibility of the occurrence of Tertiary lignites, comparable with those of southern Ethiopia, cannot be ruled out so far as the northern part of Eastern Province is concerned. Seams of lignite are known in a thick series of Pleistocene sediments at Mui in Kitui district. A considerable amount of drilling has been carried out on them, but it appears unlikely that they will prove of economic value in view of the relative thinness of the seams, their depth, and their association with clays that become mobile when wet. Lignite was also discovered 48 years ago in a well in the Pleistocene coral near Takaungu on the coast. It is probable that it was derived from a coalified log. Comparable logs have occasionally been found elsewhere, for example in alluvials in the Machakos district.

Cobalt has been recorded in the ores at the Macalder-Nyanza copper mine. *Columbite* (*-tantalite*) is known as a sparse accessory mineral in mica pegmatites, and has been found in the Machakos, Baragoi, Karasuk and West Pokot districts. *Gaylussite* occurs in the black clay soils of Lake Amboseli, where it locally forms more than 10 per cent of the volume of the clays.

Gem-stones (a ruby and, it is reported, some diamonds) were found about 40 years ago in gravels in the Chania River at Thika. The occurrence was later worked by a prospector who after many months failed to find diamonds, though numerous small rubies and sapphires were extracted. An area around Ndarugu was the scene of a "diamond rush" in the early years of the century, but no records are known of what was found. It is rumoured that small pitted diamonds, which were then of no value, were panned, but there is no confirmation of this. A few small diamonds were recovered in the Kakamega area during the washing of gravels for gold, and it is stated that a single diamond was obtained by panning gravels in the River Suam in West Pokot 35 years ago. Moonstones are known in river gravels at the coast, associated with small fragments of gem-quality green and blue kyanite.

Gorceixite (barium aluminium phosphate) has been reported from the weathered cap on the carbonatite centre at Mrima. The amount of phosphate in the hill is considerable, and it has been suggested that much of it is combined in gorceixite. The mineral at Mrima is a strontium-bearing variety. *Ilmenorutile* has been recorded from Kinyiki Hill. *Lithium,* in lepidolite, a lithium mica, has been found in a pegmatite at Sebit in West Pokot. *Mascareignite,* white diatomite-like rocks which, however, consist largely of the siliceous residues of reeds and grasses and contain few diatoms, have been noted in the Kedong Valley, in the Sagana Valley and near Thomson's Falls. The rocks can be distinguished from diatomite by their greater specific gravity. Traces of *molybdenite* were found some years ago in syenite in western Maragoli, and during the survey of the Maralal area, north of Mount Kenya, a pegmatite containing molybdenite was found but considered of no economic interest. Small amounts have been found by the Geological Survey in granite on the south side of the Kavirondo Gulf, and it is also reported in pegmatites in the Taita Hills. There are also traces in pyrochlore ores from Mrima—analyses indicated a content of molybdenum ranging between 33 and 790 parts per million. *Monazite* is a minor constituent of black sands found at the mouths of rivers on the coast. It is also present in some pegmatites and associated schists in the Basement System, and occurs

in considerable proportion in the ores of the Mrima carbonatite in Coast Province. It is also present, but in lesser amounts, in the carbonatite centres of western Kenya.

Nepheline is of widespread occurrence in Tertiary lavas, but is unlikely to become of economic importance except in more coarse-grained plutonics. Urtites and ijolites near Homa Bay might possibly yield supplies. Abundant reserves of *olivine* are available in the dunite at Kinyiki Hill. *Obsidian* suitable for expansion to yield *perlite* has occasionally been found in small quantities, but many of the obsidian occurrences known do not respond to heat treatment. Obsidian deposits are known in the Magadi and Naivasha areas. *Opaline chert* occurs in Tertiary lake beds in the Thomson's Falls area and near Athi River. *Perovskite* containing about 0.5 per cent of niobium pentoxide occurs in an igneous rock at Rangwa. The rock contains on an average 5 per cent perovskite. (*Phosphate—see* apatite, monazite and gorceixite.)

Radio-active minerals, other than monazite and pyrochlore, have been found only in minor amounts. A few years ago a few pounds of samarskite was extracted from a pegmatite near Tura north of the Loldaika Hills (where in fact radio-active minerals were first discovered in 1916) and the same mineral has been found since in Baragoi and West Pokot areas. Other radio-active minerals that have been found in pegmatites include davidite, euxenite, fergusonite, microlite, polycrase and allanite. Slightly radio-active volcanic areas apparently owe their radiation to the potassium in felspar-rich lavas. The carbonatite centres are all radio-active, largely due to the presence of monazite, and can readily be detected and delimited by measuring their radiation. The centre at Buru Hill was discovered by means of its radio-activity. Black sands from the Yala Valley have been found to be weakly radio-active (0.01 per cent eU_3O_8).

Scheelite has been found as an accessory mineral in a few of the gold-bearing veins of Nyanza. It is probably present in many more, but has remained undetermined. Some years ago a vein containing visible crystals and aggregates of scheelite was discovered in the granites at Koyo in the Nandi district. Detailed examination indicated values ranging from 0.07 per cent WO_3 to 5.5 per cent WO_3 in different parts of the vein. *Sillimanite* has been found in several areas, e.g. Kitui, Embu, Machakos, south of Voi, in the Loita Hills area, east of the Merti Plateau, and Maralal but is nowhere sufficiently concentrated to be of present economic value. *Soda nitre* was discovered by the Geological Survey in the Magadi district. It is probably derived from guano, and it is unlikely to prove of commercial interest.

Small supplies of native *sulphur* and sulphur-impregnated tuffs occur around an extinct fumarole near Naivasha in the Rift Valley. The average sulphur content has been estimated at about 12 per cent. Sulphur was also reported from Central Island in Lake Rudolf in 1932 and on Ol Kokwe Island in Lake Baringo in 1967. It also occurs in tuffs of Teleki's Volcano south of Lake Rudolf. *Topaz* occurs in pegmatites near the Thura River in Embu District, and in the kyanite-bearing rocks at Murka. *Vanadium* is present in small amounts in ilmenite in the sands at the coast. *Xenotime* has been identified in pegmatites at Kenailmet (Karasuk) and at Sebit in West Pokot. Fluvial concentrates of *zircon* have been reported in valleys draining the coastal hills, and at Songhor. Tests on samples from the Mombasa area indicate that the content of zircon is too low to be of interest, unless much larger quantities of other minerals could be obtained from the sands at the same time.

WATER SUPPLY

The water-supply establishment in Kenya forms part of the Ministry of Agriculture. Assistance originally given by the Geological Survey was mainly confined to identifications and correlations. More recently extensive surveys have been made in certain areas where water problems arise and it is hoped to continue with such surveys which, while being of a reconnaissance nature so far as geological and mineral

conditions are concerned, should assist and quicken the work of the water geologists. An account of existing and possible water supplies is given in all regional geological reports which are being published as part of the programme of primary mapping of the whole country.

REPORTS AND MAPS

By the end of 1968 approximately 75 per cent of Kenya had been geologically mapped in reconnaissance style, and some 81 Geological Reports published, each accompanied by a coloured map or maps, mainly at a scale of 1:125,000. In addition four Memoirs and eight Bulletins have been published on specific subjects, and an annual report is published on the work of the Mines and Geological Department.

A complete list of publications can be obtained from the Commissioner, Mines and Geological Department, P.O. Box 30009, Nairobi, Kenya.

GPK 1174—2m—4/69