Contributions to the Petrology of British East Africa.

Comparison of volcanic rocks from the Great Rift Valley with rocks from Pantelleria, the Canary Islands, Ascension, St. Helena, Aden, and Abyssinia. (With plate V.)

By G. T. Prior, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read March 25 and November 18, 1902.]

THE following notes on the petrology of British East Africa are the result of an examination of rock-specimens collected by Professor J. W. Gregory on his well-known expedition from Mombasa to Mt. Kenya and Lake Baringo in 1892–3, and of rock-collections from the Uganda Protectorate which have been recently presented to the British Museum by Sir Harry Johnston.

The collections include examples of the Archaean gneisses, schists, and granites which constitute the prevailing basement rocks of Central Africa; of ferruginous schists, coarse sandstones, and quartzites belonging to the Palaeozoic Karagwe series; and of an interesting series of Tertiary volcanic rocks comprising phonolites, phonolitic trachytes, riebeckite-rhyolites, kenytes, and basalts from the volcanoes of the Great Rift Valley, as well as of nephelinites and basaltic rocks containing melilite and perofskite from Mt. Elgon.

GNEISSES, SCHISTS, GRANITES, AND GRANULITES.

These are the basement rocks which occupy such a prominent position in the geology of the African continent. As is well known, the general prevalence of these rocks in Central Africa led Murchison to the hypothesis that this region, like that of southern India, is one of great antiquity which has for the most part never been below the level of the sea.

According to Prof. Gregory[1], in a journey inland from Mombasa to Uganda, after the low-lying coast region with its fringe of coral-rock and Triassic sandstone has been traversed, gneisses and schists become the prevailing rocks until the region of the Great Rift Valley is approached, when they are covered by the enormous outpourings of

[1] The Great Rift Valley. London, 1896, p. 227.

phonolitic lavas from Mt. Kenya and the volcanoes of the Rift Valley. On the western side of the valley, however, the Archaean rocks reappear in the Elgon District and Victoria Nyanza region, where they are in places covered by the ferruginous schists and sandstones of the Karagwe series: thence they extend across Uganda and constitute the main mass of Ruwenzori.

Of these rocks, specimens were collected by Prof. Gregory from the east side of the Rift Valley before the volcanic region was reached. In Sir Harry Johnston's collections from the Uganda Protectorate there are specimens of *gneiss* from the Central Province (Iganga, and the Kadudamu and Kamurujo Hills), Kavirondo (Kisumu), the Elgon District (Tindi, Marama, Ketosh, Kakumega, Nyala, Samia Hills), Unyoro, the Nile Province, and Ruwenzori; of *mica- and hornblende-schists* from the Central Province (Jinga, Nampirika, and the Nabutitisi Hills), Ankole (Egara Hills), Unyoro, Toro, and Ruwenzori; and *granites* from Toro (Katwe), Central Province (Iganga, Kakani Hill), Kavirondo (Awichina near Kisumu), and Samia Hills.

Gneisses and schists from tropical East Africa have been minutely described by Rosiwal [1], and gneisses and granulites from Massailand by Mügge [2] and by Lenk [3], so that only a few points on the microscopic examination of these rocks will be noted here.

Like many of those described by Rosiwal, the *gneisses* in the present collections are characterized for the most part by the large amount of microcline and by their granulitic structure. Some specimens of granite-gneiss from Unyoro, however, present rather the characters of crushed granites. They consist mainly of an aggregate of microcline and quartz with very little ferromagnesian mineral, and show under the microscope very pronounced cataclastic structure. A gneissic-looking rock from Diwona Camp, Ruwenzori [4], has the characters of a crushed and metamorphosed gabbro or coarse dolerite: it consists of large bent and distorted felspars showing microcline-like cross-hatchings, and large crystals of purple augite altered on the margin to hornblende and granular epidote: the interspaces between augites and felspars are occupied by a quartz-felspar-mosaic showing cataclastic structure.

In association with the gneisses and schists occur, both on the east of the Rift Valley and in Uganda, *granulites* similar to the well-known

[1] Beitr. z. geol. Kennt. d. östlichen Africa. Vienna, 1891.
[2] Neues Jahrb. Min., 1886, Beil.-Bd. iv, p. 516.
[3] Baumann, Durch Massailand zur Nilquelle. Berlin, 1894, p. 268.
[4] The specimen is from the Scott Elliot collection in the British Museum.

series in India and Ceylon to which Mr. T. H. Holland has given the name of charnockite[1]. Thus from Unyoro (Chief Matwe) comes a specimen of typical hypersthene-granulite consisting of a granulitic aggregate of quartz and oligoclase, with strings of pleochroic (colourless to rose-red) hypersthene-grains and deep brownish-red biotite in large amounts. A specimen from Kikwen, Iveti Mts., is a kyanite-quartz-granulite in which grains of deep red rutile in large amount are included in both quartz and kyanite.

At Lugard Falls, on the Sabaki River, the granulites, which occur in intimate association with the gneisses, contain, besides biotite, also much pleochroic (brownish-yellow to deep bluish-green) hornblende, and in some cases also a pale bluish-green pyroxene (sahlite). By failure of biotite and increase in the amount of hornblende, these rocks pass into *amphibolites*. In some specimens red garnet is also present, and in this case the hornblende often occurs in peculiar blebs arranged in centric structure, and the garnet contains inclusions of the quartz-felspar-groundmass and also of the green hornblende. A specimen of *granulite* from five days west of Hamaye shows under the microscope (fig. 1, pl. V) pink garnets, in large crystals with very ragged outlines and also in curious vermicular blebs, in a granular base of large plates of oligoclase showing fine twin-striations: besides the garnet, but in smaller amount, occurs the same bluish-green hornblende as in the amphibolites in patches of small blebs, in part isolated in the felspar-base but mainly completely enclosed by the garnet. Plentifully scattered through the slide and enclosed in all the other constituents are minute colourless blebs of a strongly refractive (the refraction is higher than that of the garnet) and doubly refractive mineral which is referable with little doubt to sphene, since it shows a positive biaxial figure with dispersion $\rho > v$ and an optic axial angle equal to that shown by a specimen of sphene. Peculiar centric structures of pyroxene have been recently described by Mr. A. K. Coomáraswámy in garnet-granulites from Ceylon and are attributed by him to corrosion of the garnets by a felspathic magma[2]. In the present case, however, the appearances rather suggest the idea that the garnet has grown at the expense of the hornblende, and they thus tend to favour the views of Mr. T. H. Holland[3], who considers the garnets in many of the granulites of southern India as of secondary origin and derived from pyroxenes which are undergoing amphibolization.

[1] Mem. Geol. Survey India, 1900, vol. xxviii, part 2, pp. 119-249.

[2] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 601.

[3] Records Geol. Surv. India, 1896, vol. xxix, p. 20.

A garnet-hornblende-granulite from Madagascar in the Museum collection presents characters almost identical with those of the present rock. The pink garnet and bluish-green hornblende are precisely similar, but the latter mineral occurs more plentifully in patches of small blebs in the felspar-base than enclosed in the garnets. However, some of the irregular grains of hornblende are enclosed in garnet, and in this case the contour of the latter mineral is seen to follow all the irregularities of the hornblende.

In Uganda the gneissic rocks appear to be traversed in many parts by veins both of acid pegmatites and of basic diabases (often converted into epidiorites). *Pegmatites* were found in Busoga (Iganga) and Bukedi (Kumaga and Kyabala), *diabases* at Kibui in Busoga and at Kabras in the Elgon District, and *epidiorites* on Ruwenzori, in Busoga (Iganga and Jinga), and in Unyoro.

Of crystalline *limestones* associated with the gneisses and schists, there is a specimen from the Bura Mts., Taita, which contains large crystals of a pale green diopside. Specimens in Sir Harry Johnston's collection, of earthy limestone from the Nyando Valley, Kavirondo, collected by Mr. C. W. Hobley from 'concretionary blocks in alluvial deposits overlying granite and gneiss,' are without doubt of recent origin.

FERRUGINOUS SCHISTS, SHALES, AND PHYLLITES; COARSE SANDSTONES AND QUARTZITES.

These rocks belong to the Palaeozoic Karagwe series of Scott Elliot and Gregory[1]. Rocks of this series are stated by them to occur on the Nandi Hills, where their superposition on the gneiss is clearly seen, on the Samia Hills in the Elgon District, and at Berkeley Bay on the east side of Lake Victoria Nyanza; while on the western side of that lake they extend over a distance of 100 miles from Butunguru on the Kagera River to Kiarutanga. The order of succession of the rocks belonging to this Karagwe series is given as follows:—(1) at the base, phyllites and ferruginous shales; followed by (2) red and brown sandstones; (3) coarse schistose sandstones; and (4) white granular quartzites.

In Sir Harry Johnston's collections from Uganda are many examples of these rocks. A remarkable series of ferruginous schists, shales, and phyllites comes from Unyoro (Chiefs Byabaswezi, Tibansamba, Kiza and Basigala), but there are also many specimens in the collections from Ankole, Busoga (Bukonge, Kalanga, and Jinga), and the Buvuma Islands in Lake Victoria Nyanza.

[1] Quart. Journ. Geol. Soc., 1895, vol. li, pp. 677–9.

The ferruginous schists and shales from Unyoro vary in colour from pale brown and purple to deep brick-red. Some are banded from deep-red to nearly colourless. Most of them are hard compact and siliceous rocks passing occasionally into black lydite, while others which are softer and more schistose graduate into ferruginous phyllites.

In these characters the rocks present striking similarities with Dr. F. H. Hatch's Hospital Hill series of the southern Transvaal [1], and also with rocks from the Ingwenyaberg, Swaziland, which have been described by Prof. T. Rupert Jones [2]. With specimens of both these series in the Museum collection the African rocks have been compared. The Hospital Hill series of ferruginous shales occurs in the neighbourhood of Johannesburg as part of the Cape system, with the auriferous Witwatersrand quartz-conglomerate immediately above it. The Swaziland ferruginous shales and argillites, which probably belong to the same series, occur in association with gold-bearing serpentine and talcose schists. Amongst the rocks from Unyoro are specimens of quartz presenting some points of resemblance with that of the auriferous Banket formation of the Transvaal, but no visible gold has been detected on any of the specimens from Uganda.

Altogether the similarity of these schists and shales from Unyoro with those of the Transvaal is sufficiently striking to suggest the correlation of a part at least of the Karagwe with the Hospital Hill series. In their geological position and characters these rocks are also similar to the Cuddapah series of slates and quartzites which occurs above the gneiss in southern India. The ferruginous slaty rocks through which phonolitic rocks have been erupted in the neighbourhood of Adowa and Axum, Abyssinia [3], possibly also belong to the same group.

The rocks of the Karagwe series in all probability belong to the same formations as the schists and sandstones in the neighbourhood of Lake Nyasa described by Bornhardt [4]. Thus the schistose rocks in the Kinga region to the NE. of Lake Nyasa (the Urschiefer (?) formation of Bornhardt) appear to be somewhat similar to the rocks from Unyoro, since they consist of micaceous phyllites and light violet-red and brownish-grey to black shales. That Bornhardt would include some of the Karagwe series in this formation is also clear from the fact that he states that similar

[1] Quart. Journ. Geol. Soc., 1898, vol. liv, pp. 73–99.

[2] Geol. Mag., 1899, vol. vi, p. 105; the particular rocks are marked T. B. in the sections.

[3] This Magazine, 1900, vol. xii, p. 255.

[4] Deutsch-Ost-Afrika. Band vii, Geologie, Berlin, 1900.

schists are mentioned by Reichenbach as occurring in a zone from the south and west of Victoria Nyanza along the east coast of Tanganyika up to the neighbourhood of Nyasa. To the Cape system, however, Bornhardt only doubtfully refers certain conglomerates and coarse sandstones which rest unconformably upon the Urschiefer rocks. In the present collections there are no specimens which can be said with certainty to correspond to the coal-bearing shales to the east and NW. of Lake Nyasa which are described by Bornhardt[1] and correlated by him with the Karoo of South Africa and the Gondwana system of India. Mention, however, is made in Sir Harry Johnston's description of Mt. Elgon[2] of rocks looking like sandstones and of coal-dust thickly strewn over pebbles in the stream-valleys, but no specimens are in the collection.

Of sandstones and quartzites belonging to the Karagwe series in the collections there are specimens from Bukonge on the north shore of Lake Victoria Nyanza (coarse ferruginous sandstone and white quartzite), Nakalanga in Busoga (colourless to pale purple sandstone), the Bugaya Islands, Kisubi and Tagana on the NW. borders of Lake Victoria Nyanza (ferruginous sandstones and quartzites), Ankole, and Unyoro. A white, fine-grained sandstone was also found on the east coast of Lake Naivasha at a height of 6,000 feet.

ERUPTIVE ROCKS.

The eruptive rocks connected with the Great Rift Valley cover an enormous extent of country, and are in this respect, as stated by Prof. Gregory, almost comparable with the Deccan traps of India or the Idaho basalts of North America. They were encountered by Prof. Gregory in his journey from Mombasa to Mt. Kenya soon after passing Mackakos. The immense plain extending westward at the foot of the old gneissic hills consisted of an enormous lava-flow which 'ended abruptly against the flank of the old gneiss ridge on its margin, but ran up the valleys and into the hollows of the mountains, just as the water of a lake follows the irregularities of its shore.'

This lava-region extends to the north, along the Rift Valley with its numerous craters, beyond Mt. Kenya and Lake Baringo, to the south beyond Mt. Kilimandjaro, and to the west across the Rift Valley and beyond the Mau escarpment to within a few miles of the east shore of Lake Victoria Nyanza (to Korando Hill and Kisumu).

The lavas are for the most part of a phonolitic type, rich in alkalies

[1] Loc. cit., p. 461.
[2] Geogr. Journ., 1902, vol. xix, p. 14.

and poor in lime and magnesia, but forming a rock-series varying in basicity from basic kenytes and nepheline-rich phonolites through phonolitic trachytes to acid soda-rhyolites rich in quartz. The first eruptions which gave rise to the phonolitic lavas of the Kapte Plain are stated by Gregory to have taken place in Cretaceous times; in the later eruptions of Kamasia and Laikipia, basalts are associated with the phonolitic rocks; and in the still later eruptions of Kibo (Kilimandjaro) and of the neighbouring still active volcano of Doenyo Ngai, basic kenytes and nepheline-bearing basaltic rocks appear to be the prevailing lavas.

To this later period of eruption also belong the lavas of Mt. Elgon and the Nandi District on the western side of the Rift Valley. These consist mainly of nephelinites with melilite and perofskite, somewhat similar to the 'melilite-basalts' of Doenyo Ngai described by Mügge [1], and of Makinga Hill in German South-East Africa described by Lenk [2].

Further to the west across the Central Province of the Uganda Protectorate no volcanic rocks occur until the second line of weakness marked by the line of lakes from Tanganyika to Albert Nyanza is approached. Here at the foot of Ruwenzori (which itself consists of a block of Archaean gneisses and schists cut by dykes of epidiorite) occur numerous crater-lakes with masses of volcanic tuff, and nephelinites with perofskite are again met with, suggesting that these eruptions belong to the same period as those of Mt. Elgon and Doenyo Ngai.

Further south in NW. Ankole numerous crater-lakes with tuffs occur in the neighbourhood of Lake Albert Edward Nyanza. A specimen of tuff from this district is in the collection, and a scoriaceous olivine-basalt comes from one of the volcanic mountains between that lake and Lake Kivu.

For purposes of description the eruptive rocks will be taken in the following order:—

I. The Phonolitic Series, including:—
  (i) Phonolites, phonolitic trachytes, and phonolitic quartz-trachytes.
  (ii) Riebeckite-rhyolites (comendites) and other soda-rhyolites.
  (iii) (lassy equivalents of phonolites and soda-rhyolites.
  (iv) Kenytes ('trachydolerites').

II. Basalts.

III. Nephelinites containing melilite and perofskite, borolanite, &c., from Mt. Elgon, the Nandi District, and the foot of Ruwenzori.

[1] Neues Jahrb. Min., 1886, Beil.-Band iv, p. 595.

[2] Lenk, Ueber Gesteine aus Deutsch-Ostafrika; in Baumann, Durch Massailand zur Nilquelle, Berlin, 1894, p. 289.

I. The Phonolitic Series.

These rocks are especially characterized by the amount and variety of soda-amphiboles (cossyrite, catophorite, arfvedsonite) as well as of soda-pyroxenes (aegirine and aegirine-augite), and (with the exception of the more ordinary type of phonolite in the Nandi District on the western side of the Rift Valley) by the absence of sphene and nosean, and also of magnetite except as inclusions in the augite-phenocrysts. The prevailing felspar is anorthoclase. They are thus closely related to the 'apachites' of Osann [1]. Almost exactly identical types, as shown later, are also presented by phonolitic rocks from the Canary Islands, the Azores, and the island of Pantelleria. Closely related trachytic rocks from Massailand, German East Africa, have been described by Mügge and by Lenk [2].

The rocks present a very striking example of a *rock-series*, showing the same gradation in character from rocks rich in nepheline at one end of the series to rocks rich in quartz at the other, as, e. g., in Brögger's grorudite-tinguaite series in the Christiania district, and in the similar series from Abyssinia described in a previous paper [3]. Mineralogically the whole group (with the exception of the more glassy rocks) is characterized by the presence of anorthoclase-felspar, and either soda-amphiboles or soda-pyroxenes or both, while in the phonolites at the basic end of the series there occurs, in addition, nepheline, and in the soda-rhyolites at the other end, quartz in large amount. Chemically the series is characterized throughout by the large amount of alkalies (especially of soda) and of iron and by the poverty in lime and magnesia. As seen in the analyses given on p. 247, the percentage of alkalies is fairly constant throughout, so that the individual rocks mainly differ in the relative amounts of the silica, alumina, and oxides of iron.

The following brief description of the more important *mineral-constituents* and their mode of occurrence applies mainly to the phonolites and phonolitic trachytes.

The *felspar*-phenocrysts are not very plentiful in these rocks. They consist mainly of clear glassy sanidines in long Carlsbad-twins showing the characteristic parting, and of anorthoclase recognizable by the minute twin-striations or mottled extinction. The larger crystals have peripheral bands of dark inclusions, and many are much corroded and partially

[1] Tschermak's Min. Mitth., 1896, vol. xv, p. 394.
[2] Loc. cit., p. 229.
[3] This Magazine, 1900, vol. xii, p. 255.

reabsorbed, in which case they often have marginal bands of aegirine-grains. The felspar-laths of the groundmass probably belong to the same species: the larger ones are in Carlsbad-twins, some giving simultaneous straight extinction in the two halves, and others showing mottled extinctions suggestive of anorthoclase.

The *nepheline*-phenocrysts are generally in sharply defined rectangular and hexagonal sections with the cleavage in some cases well marked. They often contain inclusions of augite.

Of the pyroxene group, three members are generally present, viz. a pale green diopside-like augite, aegirine-augite, and aegirine.

The pale green *augite* occurs both as small phenocrysts and as irregular grains in the groundmass. The phenocrysts usually have a margin of grass-green aegirine and often contain inclusions of large magnetite grains and also needles of apatite. They are slightly pleochroic from yellowish-green to pale green, and the extinction is as high as 43°.

The pleochroic (grass-green to yellow) *aegirine*, except as a border round the augite-phenocrysts, only occurs in needles and ragged patches in the groundmass.

The *aegirine-augite* occurs in the same way as the aegirine, from which it is distinguished by its high angle of extinction and less brilliant colour.

Of the soda-amphiboles there are many varieties present in these rocks. They occur for the most part, like the soda-pyroxenes, in ragged patches in the groundmass.

Two varieties may be referred to the *catophorite* of Brögger. One of these (α) shows pleochroism similar to that of the Lougenthal mineral, viz.

$\mathfrak{a}$ = pale brownish-yellow to colourless,
$\mathfrak{b}$ = smoky brownish rose-red,
$\mathfrak{c}$ = reddish-yellow.

Sections with traces of two cleavages inclined at an angle of about 124° showed an optic axis on the edge of the field, while prismatic sections gave extinctions up to 40°: in a prismatic section with extinction of 25° to the cleavage, compensation took place with the quartz-wedge at right-angles to the line of extinction.

The other variety (β) of catophorite showed an approach to ordinary hornblende. The pleochroism was from pale smoky brownish-yellow with a tinge of green to deep purplish-brown nearly opaque. Extinction was as high as 23° and compensation took place at right-angles to it.

The mineral referred to *cossyrite* occurs in ragged ophitic patches and moss-like groups such as are characteristic of riebeckite. The pleochroism was $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$, with

$\mathfrak{a}$ = smoky reddish-brown,
$\mathfrak{b}$ = reddish-brown,
$\mathfrak{c}$ = deep red-brown to opaque.

The extinction was as high as 43°.

In some specimens, besides the cossyrite and catophorite, occur patches of an *arfvedsonite*-like hornblende with pleochroism from pale smoky brown to pale lavender.

In the Kamasia phonolites occur also large moss-like patches of an amphibole near to *riebeckite* with pleochroism from pale brownish-yellow to a beautiful sky-blue (see fig. 4, pl. V). The riebeckite of the comendites presents the usual pleochroism and optical characters (p. 243).

Mica (*biotite*) occurs in very few specimens and then in only very small amount. It is generally partly reabsorbed and surrounded by an altered zone containing magnetite-grains and either aegirine or catophorite; occasionally it occurs as inclusions in the felspar- and nepheline-phenocrysts.

(i) *Phonolites and Phonolitic Trachytes.*

For purposes of description these rocks may be divided into five groups which graduate into each other:—

(*a*) Phonolites with nepheline in large phenocrysts.
(*b*) Phonolites with nepheline in small crystals surrounded by aegirine.
(*c*) Phonolites with nepheline in small crystals in the groundmass.
(*d*) Phonolitic trachytes with no recognizable nepheline.
(*e*) Phonolitic quartz-trachytes approaching soda-rhyolites.

(*a*) *Phonolites with Nepheline in large phenocrysts.*

In the rocks of this group phenocrysts, in small amount, of anorthoclase, sanidine, and nepheline, together with a little pale green augite, occur in a fine-grained felspar-nepheline groundmass scattered through which are ragged shreds and patches of aegirine, aegirine-augite, pale green augite, and the soda-amphiboles, dark, nearly opaque, reddish-brown cossyrite, and smoky rose-red catophorite. In this group lath-shaped felspar-microliths in the groundmass are not in large amount and flow-structure is not well marked. In the base there is generally some isotropic material (sodalite? or altered nepheline?) interspersed between the felspar-microliths, but nepheline in minute crystals is only rarely recognizable.

Four types will be described, the three first of which differ for the most part only in the mode of aggregation of the soda-amphiboles and pyroxenes, while the fourth differs from the others in containing much sphene and no soda-amphiboles.

In the first type, which may be termed the *Losuguta type*, cossyrite and catophorite are scattered in grains and small patches very uniformly through the groundmass (see fig. 2, pl. V, in which is represented a portion of the groundmass as seen under a $\frac{1}{4}$ in. objective). In most of these rocks the felspar-microliths give some idea of definite flow-structure.

Of this type are specimens from the scarp of Lake Losuguta (291–3, and 301)[1], the summit and base of Doenyo lol Mwaru (421, 424), from north of Guaso Laschau in Laikipia (433), and from south of Lari lol Morjo (429).

In a second type, intermediate between the Losuguta type and the following one, the nepheline-phenocrysts are very large and the coloured constituents occur in more tuft-like feathery forms with intervening clearer spaces. The tufts consist mainly of cossyrite and aegirine or aegirine-augite (fig. 3, pl. V), but catophorite also occurs prominently in some specimens (427), and occasionally pleochroic (pale smoky brown to lavender or sky-blue) arfvedsonite-like hornblendes take the place to a large extent of aegirine. In this type the felspar-microliths have in places a certain directional character, but there is no definite line of flow.

Specimens of this type come from Doenyo lol Mwaru (423), from south of Lari lol Morjo (430), from bottom of ravine between Gopo lol Mwaru and Alngaria (427), from north of Guaso Narok (432), and from Korando Hill and Kisumu in Kavirondo.

In the third type, which may be termed the *Kamasia type*, the tufty patches of grass-green aegirine, deep red to black cossyrite, and sky-blue riebeckite-like amphibole (p. 237) reach their highest development and present a very remarkable appearance in thin sections under the microscope (fig. 4, pl. V). These rounded patches of soda-pyroxenes and amphiboles are scattered porphyritically through the groundmass together with phenocrysts of felspar and nepheline, leaving large spaces free from coloured minerals. They occur almost like a pigment, without crystal-outlines, around groups of minute rectangular nephelines which occasionally are altered to calcite, and also about the phenocrysts of felspar

[1] The numbers in parentheses refer to the specimens in Professor Gregory's collection. Most of the localities of these specimens are given in the maps, illustrating Professor Gregory's journey, in 'The Great Rift Valley.' London, 1896.

and nepheline. In some specimens (385–6) the groundmass in which these patches occur consists mainly of felspar-microliths showing well-marked flow-structure, but in others (358) it is more crypto-crystalline and shows no flow-structure.

To this type belong specimens (385–6) from the foothills of Kamasia, and from gravel below basalt on the Kamnye River (358).

From the Nandi District on the western side of the Rift Valley comes a more ordinary type of phonolite with abundant sphene and no soda-amphiboles. A typical example is a specimen from the Sigowet Hills. This is a dark grey basaltic-looking rock showing to the naked eye large phenocrysts of nepheline with some augite and sphene. Under the microscope are seen large well-defined phenocrysts of nepheline, aegirine-augite, sphene, and a little nosean. The nephelines are generally remarkably free from inclusions, but sometimes contain a little aegirine-augite and sphene; the aegirine-augites show zonal structure with nearly colourless centres having a larger angle of extinction, and have generally a fringe of small grass-green aegirines: the sphene is in large twinned crystals, and the nosean shows inclusions of augite and sphene. The groundmass is to a large extent without action on polarized light, but contains felspar-laths and shreds of aegirine and small crystals of aegirine-augite bordered by aegirine.

Specimens from the bed of the Lower Kedowa River and the bed of the Seget River show almost precisely similar characters.

A dark grey basaltic-looking phonolite from Mt. Manava, Kavirondo, is of a more glassy type. In a glassy base, which is rendered dense with minute tufts of incipient aegirine (?), occur large nepheline-phenocrysts containing zonally arranged inclusions of augite and sphene: there are also small phenocrysts of a pale-green augite (with inclusions of magnetite), and of sphene.

(*b*) *Phonolites with Nepheline in small crystals surrounded by Aegirine* (*Kenya type*).

The type-rock of this group is the phonolite from Mt. Kenya which is figured by Professor Gregory[1]. The mineral constituents are the same as in the preceding group. The phenocrysts, however, consist mainly of felspar, and the groundmass is of coarser grain, the felspar-microliths and altered nephelines being replaced by a trachytic mesh of well-defined felspar-laths showing flow-structure. Scattered through the groundmass are small crystals of nepheline surrounded by ragged aegirine, while

[1] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 210, pl. XI, fig. 5, and pl. XII, fig. 1.

interspersed between the felspar-laths are grains and tufts of aegirine with cossyrite and in smaller amount catophorite. The felspar-phenocrysts are mainly of anorthoclase in Carlsbad-twins showing fine twin-striations; they have generally a narrow, strongly marked band of dark dusty inclusions just within the margin.

The rocks of this group are very similar to some of the phonolites of the Canary Islands which also contain cossyrite and catophorite. They would appear also to be absolutely identical with the 'acmite-trachytes' from Massailand described by Mügge[1], were it not for the fact that they contain nepheline in place of sodalite. In many of the specimens indeed the nepheline is much altered and isotropic and thus simulates sodalite, but in others it is perfectly fresh and doubly refracting, while hexagonal sections show well-defined negative uniaxial figures.

A quantitative analysis of the type-rock from the lava-flow at the base of Mt. Höhnel on Mt. Kenya, gave the following result (I) as compared with that of a somewhat similar phonolitic rock ('tinguaite') from near Axum, Abyssinia[2] (II).

	I. Mt. Kenya.	II. Axum.
SiO_2	58·37	57·81
TiO_2	0·21	—
Al_2O_3	16·65	18·74
Fe_2O_3	4·09	5·76
FeO	3·03	0·42
MnO	0·43	—
CaO	1·66	1·28
MgO	0·37	trace.
Na_2O	7·28	9·35
K_2O	5·46	4·52
P_2O_5	0·08	—
H_2O (below 110°)	0·96	—
H_2O (above 110°)	1·40	1·50
	99·99	99·38

Specimens belonging to this group come from the Athi Plain (166), from a hill below Fort Smith, Kikuyu (158), from the NW. side of the second swamp, Kikuyu (174), from the bed of a stream south of Guaso Laschau (438), and from the east of Losuguta Scarp (281, 284).

[1] Neues Jahrb. Min., 1886, Beil.-Band iv, p. 590.
[2] This Magazine, 1900, vol. xii, p. 269.

(c) *Phonolites with Nepheline in the groundmass.*

In this group the felspar-phenocrysts are in small amount. Nepheline only occurs in the groundmass interspersed between the felspar-laths. Cossyrite and catophorite with aegirine and augite in varying relative amounts occur in ragged shreds and grains interpenetrated by the felspar-laths. The cossyrite is sometimes aggregated in minute tufts round the felspar-laths like iron-filings round a magnet. In some specimens clear isotropic patches (sodalite ?) are present in small amount.

To this group belong specimens from Fort Smith in Kikuyu (160), from the plain at the foot of Doenyo Lersubugo (320), from the lava-capped plateau of Yatta to the east of Lugard's Falls (850), from the plateau above the south end of Lake Losuguta (296), from the Losuguta Scarp (275 and 285), from the Athi Plains (163), from the north end of the ridge west of Lake Kibibi (273), and from the steppes of the Kiroruma and Maranga (552).

(d) *Phonolitic Trachytes.*

These rocks present similar characters to those of the preceding phonolites in containing porphyritic anorthoclases and sanidines in a trachytic groundmass of felspar-laths with interstitial soda-pyroxenes and soda-amphiboles, but no recognizable nepheline is present.

Of these rocks one type is distinguished by the very strongly marked flow-structure of the felspar-laths, and by the scarcity of phenocrysts. A specimen from near Lake Baringo (311) presents a very striking appearance in section under the microscope, as it consists of a trachytic mesh of felspar-laths with a well-marked line of flow, and lenticular patches, almost continuous throughout the slide, of grass-green aegirine, nearly opaque cossyrite, and red ferrite (possibly pseudomorphous after a soda-amphibole).

Of another type nearer to that of ordinary trachytes are two specimens from Kamasia (357 from gravel below the basalt of Kamnye River, and 365 from the Mkuyuni River). They show a trachytic mesh of fairly large felspar-laths (mainly anorthoclase showing fine twin-striations) between which are interspersed irregular grains of pale-green augite, aegirine, and only a little cossyrite.

The rocks of this group are very similar to the so-called 'acmite-trachyte' of the Azores and of Kühlsbrunnen, Siebengebirge. They are also closely related to some of the more holocrystalline rocks described later (p. 247) under kenytes.

(e) *Phonolitic Quartz-Trachytes.*

These rocks show fairly large phenocrysts of felspar (mainly anorthoclase in Carlsbad-twins) and, very sparingly, small green augites, in a mesh of felspar-laths micropoecilitic in a paste of quartz which depolarizes in patches. Uniformly distributed through the slide in large amount are ragged shreds of aegirine-augite, a little cossyrite, and much catophorite of the second variety (β). Characteristic of these rocks is the mode of occurrence of the quartz, not in phenocrysts but in micropoecilitic patches, forming a paste for the felspar-laths.

Precisely similar characters are presented by rocks from Punta Pozzolana, Pantelleria.

In this group are included specimens from Kikuyu Scarp (184, 194, 195), Kedong Scarp (182), Longonot (223), Equator Ridge (267), and Kirianduri (257).

(ii) *Riebeckite-Rhyolites* (*Comendites*) *and other Soda-Rhyolites.*

From Gilgil, north of Lake Naivasha, come some remarkable rocks characterized by their large contents of riebeckite and quartz. They appear to represent the volcanic equivalents of hypabyssal paisanites, and to form the most acid differentiation product of the soda-rich magma which has given birth to the flows of phonolitic lavas of the Rift Valley. In these rocks the pyroxenic minerals, green augite and aegirine, so characteristic of the phonolitic rocks, have been almost wholly replaced by the soda-amphibole, riebeckite. Examples of these rocks from Lake Naivasha have already been described by Mügge [1] and are included by Rosenbusch in the group of soda-rhyolites called 'comendites.'

The specimens in the collection made by Professor Gregory show some diversities in structure. A specimen (234) from south of Gilgil exhibits a pronounced flow-structure well marked by dense narrow bands, consisting mainly of riebeckite, alternating with clearer bands in which riebeckite has separated in small tufts and ragged needles, some of which project into cavities. The base consists of a micropoecilitic intergrowth of quartz and felspar, the clear quartz depolarizing in patches and forming a sort of paste in which are distributed clusters of felspar-microliths showing flow-structure. In this respect the base is thus somewhat similar to that of the phonolitic quartz-trachytes just described. The

[1] Neues Jahrb. Min., 1886, Beil.-Band iv, p. 596.

riebeckite-needles show pleochroism from pale yellow for vibrations across their length (c-axis of indicatrix) to deep indigo-blue and almost opaque along the length (a): the extinction is nearly straight and compensation with the quartz-wedge takes place along the length. No porphyritic constituents are present and no definite glass can be seen.

A specimen from the centre of the lava-flow of Doenyo Buru, south of Gilgil, shows a similar quartz-felspar base, but here the riebeckite, instead of forming bands marking flow-structure, is very uniformly distributed in small ragged tufts and moss-like patches, and also in more definite crystalline grains in clearer quartz patches. From such grains, some of which showed the hornblende cleavage of about 124°, the pleochroism could be determined as

$$\mathfrak{a} = \text{deep indigo-blue,}$$
$$\mathfrak{b} = \text{deep blue to opaque,}$$
$$\mathfrak{c} = \text{pale smoky yellow.}$$

Besides the riebeckite, a little cossyrite was also present.

A rock (239) from a lava-flow below pumice, south of Gilgil, has somewhat different characters. It shows a similar quartz-felspar base, but no definite riebeckite occurs in the section, its place being taken, in small amount only, by aegirine and acmite (?) needles. The mineral here doubtfully referred to acmite occurs in small needles and radiating groups and also as an outer zone round aegirine-grains: it is strongly doubly refractive, compensates with the quartz-wedge along the length, and shows pleochroism:—a, along the length, reddish-orange; c, across the length, pale yellow.

A specimen (233) from a flow south of Gilgil is of coarser grain and porphyritic. It shows rounded and corroded phenocrysts of anorthoclase with some rounded crystals of pale green augite and rose-red catophorite, in a felspathic base containing some quartz.

The catophorite showed a hornblende cleavage of about 124° and had pleochroism:—

$$\mathfrak{a} = \text{pinkish-yellow,}$$
$$\mathfrak{b} = \text{rose-red,}$$
$$\mathfrak{c} = \text{pale pinkish-brown.}$$

The extinction was as high as 36° and compensation with the quartz-wedge took place at right-angles to it.

To this group of rocks may also be referred a specimen (225) from Kigate Crags, east of Longonot. It is, however, in parts much more coarse-grained and approaches in structure the paisanite from Mt. Scholoda, Abyssinia, described and figured in a previous paper[1]. Large phenocrysts of clear Carlsbad-twins of sanidine and rounded quartz occur in large amount in a base varying in texture in different parts of the slide, but similar to that of the preceding rocks in consisting of a quartz-paste depolarizing in patches in which are distributed small prismatic felspars. Scattered uniformly through the slide in large amount are irregular grains and patches of riebeckite. A few phenocrysts of an altered brown hornblende with extinction (c-axis of indicatrix) of about 10° also occur and are generally surrounded by a border of projecting grains of riebeckite. Most of the felspar-phenocrysts are bordered by a zone of alteration marked by radiating felspar-laths and ferrite with riebeckite.

(iii) *Glassy equivalents of Phonolites and Soda-Rhyolites.*

The vitreous lavas vary considerably in chemical composition, for whereas some are the glassy equivalents of the phonolites and phonolitic trachytes, others are of a more acid type and have the composition of the soda-rhyolites or pantellerites.

Of phonolitic obsidians there are specimens from the rim of the crater of Longonot (222), the north face of Doenyo Nyuki (203), Losuguta Scarp (298), lake-terrace of Lake Suess (211), and Lake Nakuru. All of these show well-marked flow-structure.

The rock from Losuguta Scarp consists of a glassy base crowded with rounded dirty green patches of incipient aegirine, with here and there more definite aegirine-needles, and scattered felspar-microliths. It has characters somewhat similar to those of the rock from Lewis Col, Mt. Kenya, described by Professor Gregory[2], and also to those of rocks from Pantelleria.

Of more glassy character are the rocks from Longonot and Doenyo Nyuki. These are made up mainly of small deep brown spherulites showing well-marked black crosses between crossed nicols: a few needles of aegirine and one or two porphyritic anorthoclases are present. Phonolitic obsidians (so-called 'rhyolites') in the British Museum collection from the Vallée de Ucanca, Teneriffe, have very similar characters.

The rock from Lake Suess consists partly of spherulitic and partly of red palagonite-looking material. It contains large sanidine-phenocrysts remarkable for their clearness and freedom from inclusions. A few small

[1] This Magazine, 1900, vol. xii, p. 263, fig. 3, pl. 3.
[2] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 212.

crystals of a hornblende near to catophorite are also present: these show pleochroism :—

$\mathfrak{a}$ = pale yellow with a tinge of red,
$\mathfrak{b}$ = smoky rose-red,
$\mathfrak{c}$ = greenish-yellow,

as determined in prismatic sections and in one showing a well-marked hornblende cleavage inclined at an angle of about 124°.

The rock from Lake Nakuru is a glassy black scoria consisting of a streaky intermixture of a nearly colourless glass with a deep brown almost opaque glass. Small phenocrysts of olivine, aegirine, and anorthoclase occur very sparingly. The colourless glass is crowded with skeleton-crystals of very pale green augite, and brown needles, together with minute oval patches differentiated from the clear glass by being less transparent and of a brownish tinge: in many cases these patches are seen to be halos round needle-shaped microliths and skeleton-crystals of felspar.

A chemical analysis of this rock gave the following result :—

SiO_2	... ...	64·00
TiO_2	... ...	0·78
Al_2O_3	... ...	10·43
Fe_2O_3	... ...	6·30
FeO	... ...	3·86
MnO	... ...	0·37
CaO	... ...	1·45
MgO	... ...	0·34
Na_2O	... ...	7·59
K_2O	... ...	4·59
H_2O	... ...	0·17
		99·88

Of clear, compact, colourless (in thin section) obsidians there are specimens from Equator Peak (277) and from Lake Naivasha. These consist almost wholly of glass containing very minute felspar-microliths (visible between crossed nicols) and a few minute needles of aegirine.

An analysis of the rock from Lake Naivasha gave the following result (I), which shows the close relation of the rock to the pantellerites; the analysis[1] of a specimen of which from Cuddia Mida, Pantelleria, is given under II :—

[1] Rosenbusch, Elemente d. Gesteinslehre, 1898, p. 257.

	I.* Lake Naivasha.		II. Pantelleria.
SiO_2 ...	70·61	...	69·02
TiO_2 ...	0·15	...	—
Al_2O_3 ...	8·59	...	10·09
Fe_2O_3 ...	2·52	...	4·42
FeO ...	5·96	...	4·56
MnO ...	0·34	...	—
CaO ...	0·61	...	1·45
MgO ...	0·07	...	0·76
Na_2O ...	6·77	...	6·29
K_2O ...	4·46	...	3·70
H_2O ...	0·10	...	—
	100·18		100·29

(iv) *Kenytes* (*'Trachydolerites'*).

From the Rift Valley come, besides the phonolites and trachytes, also rocks similar to those which occur so extensively on Mt. Kenya, both as lava-flows and as part of the core, and to which Professor Gregory has given the name kenyte.

As previously pointed out by me[1] and also recently by Dr. L. Finckh[2], precisely similar rocks occur on Kilimandjaro. They have been referred by Dr. Finckh to Rosenbusch's somewhat unsatisfactorily named group of 'trachydolerites.' The rocks agree so far with Rosenbusch's definition of this group in having characters in some respects intermediate between phonolites and tephrites. They would form, however, a distinct type (kenyte-type) of the group, especially characterized by the presence of anorthoclase as the prevailing felspar. I am inclined to regard them as members at the basic end of a phonolitic rock-series of which the pantellerites and comendites are the acid equivalents. Chemically at least, although not altogether mineralogically, they stand in fact at the basic end of the phonolitic series just described (p. 235). Some kenytes from Kilimandjaro (e. g. the so-called 'nepheline-basanite' of Hyland) and from the Canary Islands (p. 256) are so far like phonolites that they contain nepheline and leucite. The results of chemical analyses which I have made of two specimens of kenyte from Mt. Kenya are given in the

[1] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 221.
[2] Ueber die Gesteine des Kenya und des Kilimandjaro. Centralblatt Min., 1902, pp. 204–5.

following table, in which are shown the chemical relationships of four members (basic, intermediate, and acid) of the phonolitic rock-series, viz.

I. Kenyte from the core of Mt. Kenya (Teleki Valley).
II. Kenyte from the lava-flow at the foot of Mt. Höhnel, Mt. Kenya.
III. Phonolite from the base of Mt. Höhnel, Mt. Kenya.
IV. Phonolitic obsidian from Lake Nakuru.
V. Obsidian (glassy soda-rhyolite) from Lake Naivasha.

	I. Kenyte.	II. Kenyte.	III. Phonolite.	IV. Phonolitic obsidian.	V. Soda-rhyolite.
SiO_2 . . .	53·98	53·80	58·37	64·00	70·61
TiO_2 . . .	0·57	0·31	0·21	0·78	0·15
Al_2O_3 . . .	19·43	18·46	16·65	10·43	8·59
Fe_2O_3 . . .	4·39	6·22	4·09	6·30	2·52
FeO . . .	2·05	0·40	3·03	3·86	5·96
MnO . . .	0·26	0·33	0·43	0·37	0·34
CaO . . .	2·04	2·53	1·66	1·45	0·61
MgO . . .	1·07	1·05	0·37	0·34	0·07
Na_2O . . .	8·81	7·09	7·28	7·59	6·77
K_2O . . .	5·27	5·46	5·46	4·59	4·46
P_2O_5 . . .	0·30	0·53	0·08	—	—
H_2O below 110°	0·13	0·85	0·96	—	—
H_2O above 110°	1·66	3·54	1·40	0·17	0·10
	99·96	100·57	99·99	99·88	100·18

Of the specimens of kenyte from the Rift Valley, rock (408) from Domo Larabwal appears to be a typical example precisely similar to the rock from the core of Mt. Kenya. The large porphyritic anorthoclases with inclusions of the base, and the very pale-green augite and altered olivine, are identical in character. These phenocrysts occur in a dense brown, apparently glassy base, in which a few felspar-microliths can be distinguished.

Other specimens are of a less glassy type, and show an approach to the phonolitic trachytes. These show phenocrysts of anorthoclase (generally not so plentiful nor so large as in the typical kenytes), a few small pale-green augites, and, still more sparingly, olivine in a more or less glassy base of felspar-laths with interstitial opacite (possibly altered soda-amphiboles) and a little augite. Specimens from the descent to Lake Elmenteita (248), crags behind Naivasha Camp (250), east of Mivironi

(265), first swamp, Kikuyu (170), second swamp, Kikuyu (175) have a fine-grained base of felspar-microliths with intermixed streaky patches of more glassy material; but specimens from the ridge just west of Kedong Col, and from the ridge on the floor of the first fault valley in West Kikuyu, are of coarser grain and contain no glass.

II. Basalts.

To judge from the present collections, basalts play in the Rift Valley eruptions a very minor rôle compared with that of the phonolitic lavas.

In Professor Gregory's collection there are specimens from Kamasia and Laikipia, the Tana Steppes, south of Guaso Nyiro, and Kibwezi. In Sir Harry Johnston's collections, besides the basalt-scoria from Ankole, the only specimens of Tertiary felspar-basalts are from Kamasia. Specimens, however, of what are probably much more ancient basalts occur in association with the gneiss at Bedden in the Nile Province and at Ketosh in the Elgon District: an intrusive basalt also occurs in the ferruginous shales of Unyoro.

Of the Laikipia basalts, those of Domo Larabwal are remarkable for the number and large size of the phenocrysts of olivine and purple augite. They are mainly magma-basalts near to limburgite, and consist of a very dense glassy base, containing much magnetite, some purple augite, and only a little felspar, in which are distributed numerous and large phenocrysts of clear olivines and pale-brown to purple zonal augites. The basalts from south of Rangatan Nado (443, 447) are of a different and more ordinary type and consist of a fine-grained mesh of felspar-laths, magnetite, and much purple augite, with only a few small phenocrysts of olivine and augite.

A specimen from Malungu, Tana Steppes (555), is similar to the basalts of Domo Larabwal in containing large phenocrysts of olivine and augite (sometimes intergrown), but is much more felspathic, as it contains phenocrysts of long prismatic plagioclase-felspars, and also felspar-laths in the base together with the augite and magnetite: the latter is in rods, often arranged at right-angles to the principal axis of the olivine.

The ropy basalt-lava of Kibwezi (851) consists of a dense, nearly opaque, glassy base, in which are distributed olivine-phenocrysts in large amount with some shar ly-defined felspar-laths and only a little augite: on the surface, the rock consists of a clear yellow glass containing the same phenocrysts.

Of the specimens from Kamasia some are ordinary felspar-basalts consisting of phenocrysts of plagioclase, yellow augite, and much altered olivine in a base of felspar-laths, augite, and magnetite, but others show characters in some respects intermediate between the phonolitic rocks and basalts, and may thus be referred perhaps to Rosenbusch's 'trachy-dolerites.'

A specimen of this kind from the slope of the basalt-plateau of Kamasia (389) consists of a trachytic mesh of felspar-laths, mostly in Carlsbad-twins with low angles of extinction, interspersed between which are distributed irregular grains of purple augite and some magnetite. With the purple augite is also a little green aegirine and catophorite, and some of the purple augites have green edges.

III. Nephelinites, etc., from Mt. Elgon, the Nandi District, and the Foot of Ruwenzori.

These basic rocks, and also probably the phonolites containing sphene described on p. 239, belong to a later period of eruption than the cossyrite- and catophorite-bearing phonolitic rocks of the Rift Valley. They represent therefore, in all probability, the later differentiation products of the soda-rich magma which gave birth to these earlier phonolitic lavas. Besides differing from the latter in greater basicity and larger contents of lime and magnesia, they appear to be further differentiated from them by the greater amount of titanic acid, which in the more basic rocks is present in the mineral *perofskite*, and in the more acid in *sphene*.

The nephelinites consist mainly of yellow augite, nepheline, and some magnetite, but in some cases the nepheline is partially, and in others almost wholly, replaced by melilite. In the latter case the rocks, to be consistent in rock-nomenclature, may be referred to as *melilitites*, although the name is somewhat cacophonous.

At a height of 8000 feet on Mt. Elgon occurs a *tuff* containing fragments not only of altered nephelinite, but also of the borolanite-like rock and of the jacupirangite-like rock described below.

Nephelinites and melilite-nephelinites.

These are dark basaltic-looking rocks generally showing numerous fairly large phenocrysts of augite.

A specimen from Mt. Elgon (8000 feet) shows under the microscope numerous phenocrysts of yellow augite and a few rectangular sections of an altered mineral (probably melilite) in a dense base consisting of nepheline in square and hexagonal sections with interstitial augite-needles and grains of magnetite. Large grains of magnetite are scattered through the slide, some included in the augite-phenocrysts. These augites are very irregular in outline, are not pleochroic, show well-marked nearly rectangular cleavage, and give extinctions as high as 42°.

Two specimens from a lower elevation on Mt. Elgon (7000 feet) present very similar characters, but approach to augitites, since the nepheline in the base is much less prominent, and in one appears to be wholly replaced by glass: in the latter rock, besides the augite-phenocrysts, there are also a few altered olivines, and some of the augite-needles of the base where they project into cavities filled with analcite (?) have terminations of grass-green aegirine. In neither of these rocks are there any phenocrysts of altered melilite or nepheline.

From the Sigowet Hills and Seget Valley, Nandi, come nephelinites of a less basic character, in which the phenocrysts consist mainly of fairly large nephelines and very little augite: rectangular phenocrysts of altered melilite (?) are also present. The base is similar to that of the nephelinite of Mt. Elgon (8000 feet), and contains much magnetite, but the nepheline, in fairly large rectangular and hexagonal sections, is in greater amount. Scattered through the slide are fairly large grains of purple perofskite.

Similar in many respects to the nephelinites of Mt. Elgon are two rocks from the Nandi District, one from the bed of the upper waters of the Lower Kedowa River, and the other from the Nyando River. They contain precisely similar phenocrysts of yellow augite; but nepheline, both as phenocrysts and in the base, is in the first partially, and in the second almost wholly, replaced by melilite. The augite-phenocrysts are large, but not so numerous as in the Mt. Elgon rocks: in the Nyando rock most of them are surrounded by a fringe of melilite-needles.

The *melilite*-phenocrysts are fairly large and have a slight brown tinge; some show rectangular sections with straight extinction, but most are rounded and partially reabsorbed: the refraction is fairly high, but the double refraction low, and they depolarize in bluish-grey tints. Prismatic sections of the phenocrysts and the needles of the groundmass compensate with the quartz-wedge across the length like the Hochbohl melilite, and one of the phenocrysts, which remained dark between crossed nicols, showed a good negative uniaxial figure. The dense groundmass of these rocks consists of melilite-needles, some rectangular sections of nepheline, much yellow augite in needles, much magnetite, and some glass. Perofskite, the common associate of melilite, is present, but not in large amount, in grains sometimes enclosed in augite and also in the larger grains of magnetite.

In order to isolate the melilite in the Nyando rock for further examination, a mineral separation by means of methylene iodide was made on powdered material which had been passed through a sieve of 100 meshes to the inch. By continued dilution of the methylene iodide with benzol the material was separated into the following portions:—

(1) Sank in methylene iodide.
Under the microscope this portion was seen to consist mainly of magnetite (separable by a magnet) and yellow augite: perofskite was also seen.

(2) Sank with spodumene.
Mainly augite with some magnetite.

(3) Sank with tourmaline.
Augite and magnetite with attached fragments of the base, and grains of melilite in large amount. Many of these melilite grains showed a well-defined central negative uniaxial figure; they gelatinized with hydrochloric acid, and showed the presence of silica, alumina, and lime.

(4) Sank with calcite.
Mainly aggregates of magnetite, augite, and base, with a little melilite, some grains showing good uniaxial figures.

(5) The residue consisted mainly of aggregates of augite, magnetite, and base, with a few colourless grains, probably of nepheline, and alteration products.

In connexion with these rocks from Mt. Elgon, it is of interest to note the occurrence in the volcanic region at the foot of Ruwenzori of a perofskite-bearing nephelinite, suggesting the idea that the eruptions in this region on the western side of Lake Victoria Nyanza belong to the same period as those of Mt. Elgon. A specimen of this rock from between Katwe and Chukaronga in the Scott Elliot collection is a fine-grained basaltic-looking rock showing no phenocrysts. Under the microscope it is seen to consist of a fine-grained aggregate of small prismatic pale greenish-yellow augites, magnetite-grains, and numerous small crystals of purple perofskite uniformly distributed in a paste of nepheline and a little isotropic material. The perofskite has precisely the same colour as the mineral from Mt. Elgon: many of the crystals are apparently interpenetration twins formed of four lozenge-shaped individuals fitted together in the form of a cross with the axes at right-angles. Other sections of twin-crystals show only three individuals with axes inclined at 120°. These appearances are much in favour of the view that the cubic character of perofskite is due to mimetic twinning, and that the optical anomalies are therefore not due to secondary causes as advocated by Klein and Ben Saude.

A mineral separation of this rock in order to isolate the nepheline was made in the same way as in the case of the preceding melilite-rock. The following particulars are given to indicate the degree of separation which can be effected by means of heavy liquids in the case of a very fine-grained rock. By continued dilution of the methylene iodide a portion of the rock which was ground down so as to pass through a sieve of 120 meshes to the inch was divided into the following parts:—

(1) Sank in methylene iodide, tourmaline floating.
Magnetite, augite, and perofskite: grains of the latter decomposed by sulphuric acid gave a strong titanic acid coloration with hydrogen peroxide.

(2) Sank with tourmaline, calcite floating.
Mainly augite; a little magnetite.

(3) Further diluted, calcite still floating.
Mainly augite, fine-grained.

(4) Further diluted, but calcite still floating.
Aggregates of augite and nepheline with a little attached magnetite and perofskite: coarse-grained.

(5) Sank with calcite, quartz floating.
Similar aggregates to (4), but a larger proportion of nepheline and little or no magnetite.

(6) Sank with quartz, moonstone floating.
Grains consisting mainly of nepheline and probably a little felspar, but still with a little augite attached.

(7) Sank with moonstone, leucite floating.
Mainly nepheline with a few grains giving oblique extinction (felspar): some grains still with augite attached. A portion of the nepheline was tested chemically: it gelatinized with hydrochloric acid, and showed the presence of silica, much alumina, and soda, with only a little lime.

(8) Sank with leucite.

Brown alteration products and a little nepheline.

(9) A slight residue left floating consisted of similar alteration products.

Phonolite with Melanite, allied to Borolanite.

This rock occurs in fragments in a tuff from Mt. Elgon (8000 feet). Under the microscope (fig. 5, pl. V) are seen phenocrysts of nepheline, sharply defined small aegirine-augites, and large zonal melanites in an altered groundmass probably originally consisting of nepheline and felspar with some cossyrite. The nepheline-phenocrysts are large and plentiful, and give sharply defined rectangular and hexagonal sections: one section shows inclusions of perofskite. The aegirine-augites are pleochroic, from pale yellow to green, and have a border or terminations of grass-green aegirine. The melanites contain inclusions of aegirine-augite and sphene.

Augite-Perofskite-Magnetite rock allied to Jacupirangite.

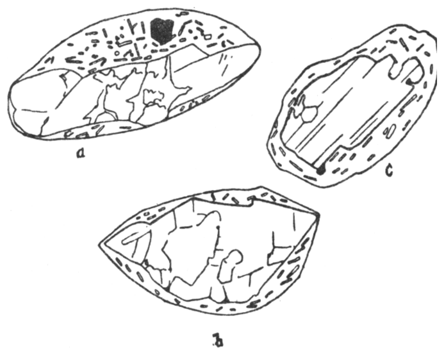
In the same tuff from Mt. Elgon (8000 feet) were dark patches consisting of a coarse-grained aggregate (fig. 6, pl. V) of yellowish brown augites (precisely similar to the augite of the nephelinites), purple perofskites, and magnetite, with some interstitial apatite and a little biotite. The perofskite is doubly refractive, and shows between crossed nicols striae parallel to the cube-faces. This rock suggests analogies with the jacupirangite of Brazil, and with some of the basic differentiation products of the nepheline-syenite of the island of Alnö, Sweden.

Tuff from the foot of Ruwenzori.

The specimen of this tuff in the Scott Elliot collection (No. 96) has been already referred to by me in a paper by Mr. M. Fergusson on the geology of Tanganyika northwards[1]. It is from one of the small volcanic cones which with small crater-lakes are found so extensively on the plain round Ruwenzori. It is of interest from the character of the lapilli which, with fragments of biotite, felspar, and magnetite, constitute the bulk of the rock. These lapilli vary considerably in size, but almost all of the larger ones consist mainly of fragments of gneissic rocks and amphibolites or of mineral fragments (chiefly biotite) from them, enclosed in only a thin film of volcanic material. These fragments have obviously been torn from the walls of the vent during the eruption, and after having been coated with the molten lava have then been ejected as lapilli. In

[1] Geol. Mag., 1901, vol. viii, p. 368.

the adjoining figure three of these lapilli (*a*, *b*, *c*) are represented as seen under the microscope under a magnification of about 16 diameters. In *a* and *b*, fragments consisting of aggregates of felspar and quartz, and in *c*, a piece of biotite, are seen surrounded by a film of glassy volcanic



Lapilli in tuff at the foot of Ruwenzori. They consist of fragments of ancient rocks torn from the walls of the vent and enclosed in a film of lava.

rock containing felspar-needles[1], magnetite, and a little yellow augite. In many of the lapilli the felspar of the enclosed fragment is seen to consist mainly of microcline. One fragment enclosed in lava is an amphibolite, consisting mainly of a pleochroic (yellow to green) hornblende, and pale green diopside with some quartz and felspar.

Comparison of Phonolitic Rocks of British East Africa with those of Pantelleria, the Canary Islands, St. Helena, Ascension, Aden, and Abyssinia.

In the preceding pages attention has been called several times to similarities between phonolitic rocks of the Great Rift Valley and those of Pantelleria and the Canary Islands. In the present section this similarity will be further emphasized by a brief description of particular specimens from these localities, and at the same time somewhat similar rocks from St. Helena, Ascension, and Aden will be discussed.

Pantelleria.

Rosenbusch[2] has described the occurrence in phonolitic trachytes from Pantelleria of the same pleochroic (brown to violet) mineral (catophorite) as was found by Mügge in the 'acmite-trachyte' from the Azores.

A specimen of phonolitic trachyte from Montagna Grande in the British Museum collection shows large phenocrysts of anorthoclase, a

[1] Many of the needles consist of calcite, and possibly represent altered melilite.

[2] Mikr. Phys. Ges., 3rd ed., 1896, vol. ii, p. 812.

few green aegirine-augites, and some olivine (with inclusions of magnetite) in a fine-grained trachytic mesh of felspar-laths with interstitial catophorite, augite, and a little cossyrite. This rock is very similar to the rocks from the Rift Valley, having characters intermediate between kenytes and phonolitic trachytes, described on p. 247.

To the more acid type of phonolitic trachyte belongs a specimen from Punta Pozzolana, in which phenocrysts of anorthoclase occur in a base of felspar-laths and micropoecilitic patches of quartz with interstitial thickly distributed cossyrite, catophorite, and augite. The rock is thus almost precisely similar to the phonolitic quartz-trachytes described on p. 242.

A phonolitic obsidian from Montagna Grande, consisting of a brown glass with small, nearly opaque, spherulitic patches and a few small phenocrysts of rounded deep reddish-brown cossyrite, grass-green aegirine and anorthoclases, resembles (except for the presence of the cossyrite) the spherulitic rocks described on p. 244.

As already pointed out, the glassy pantellerites are in chemical composition very similar to the glassy soda-rhyolites of the Rift Valley.

In Pantelleria, therefore, there appears to be a series of alkali-rich rocks analogous to the series found in the Rift Valley. The range, however, appears to be more limited, with silica percentages varying from about 60 to 74, according to the analyses of Förstner [1], and no rock strictly analogous to the typical glassy kenyte from Mt. Kenya has been found in the British Museum collection from Pantelleria. Its place, however, may possibly be taken by a rock from Punta Pozzolana, which has characters intermediate between those of a basalt and trachyte, and may thus be referred to Rosenbusch's 'trachydolerites.' In this rock very large phenocrysts of anorthoclase, with some small purple augites and a little olivine, occur in a medium-grained ground-mass of felspar-laths (mainly plagioclase), purple augite, and magnetite in skeletal crystals.

Canary Islands.

The occurrence of catophorite and cossyrite accompanying aegirine in phonolitic rocks from Gran Canaria and Teneriffe has already been pointed out in a previous paper [2]. Some of the phonolites are precisely similar to the phonolite from Mt. Kenya with nepheline surrounded by aegirine, and the phonolitic trachytes are similar to those described on p. 241. In some of these, however, the ordinary catophorite is replaced by ragged patches of a soda-amphibole presenting somewhat different pleochroism,

[1] Förstner, Nota preliminare sulla geologia dell' Isola Pantelleria. Boll. Com. Geol. d'Italia, 1881, vol. xii, pp. 523–56.

[2] This Magazine, 1901, vol. xiii, p. 89.

from pale grey with a tinge of green for vibrations along the line of extinction ($a : c = 30°$) in prismatic sections, to pale smoky brown with a tinge of purple at right-angles.

The coarse-grained *theralite*, fragments of which have been ejected as bombs in Gran Canaria, presents some points of resemblance with the crystalline rock from the core of Mt. Kenya [1]. It consists of a coarse-grained aggregate of long prismatic plagioclastic felspars and plates of nepheline, with large pleochroic (pale yellow to pinkish-purple) augites surrounded by a zonal intergrowth of pleochroic (light brown to deep reddish-brown) basaltic hornblende similar to that in the rock from Mt. Kenya: the same hornblende is further plentifully distributed in small prismatic crystals together with sphene and apatite in patches grouped round the augites.

In this connexion may be mentioned a coarse crystalline rock (probably a bomb) from Pena, Fuerteventura, having the characters of an *essexite.* It consists of a coarse-grained aggregate of labradorites (symmetrical extinction of 32°) with large ophitic plates of the same basaltic hornblende as in the preceding rock, together with some biotite, pale purple augite (often enclosed in the hornblende), sphene, and apatite.

Glassy phonolitic rocks from Teneriffe (Vallée de Ucanca), with brown spherulites, and porphyritic anorthoclases and small pale-green augites, are very similar to some of the glassy rocks from the Rift Valley described on p. 244.

The striking resemblance of the rocks from the Canary Islands with those of the Rift Valley is further emphasized by the occurrence from the Caldera of Gran Canaria of a typical *leucite-kenyte,* very similar, both macroscopically and microscopically, to the kenyte of Mt. Kenya. The rock is of a deep-brown colour, and shows numerous fairly large phenocrysts of anorthoclase. Under the microscope, phenocrysts of a pale purple augite and large anorthoclases showing minute twin-striations are seen in a glassy base (dense with brown dusty inclusions), through which are scattered a few felspar-laths and fairly numerous bright hexagonal and octagonal sections of leucite showing characteristic zonal bands of dark inclusions.

St. Helena.

In this island, with the basalts are associated phonolitic rocks bearing some relation to the rocks of the Rift Valley. Thus a specimen in the British Museum collection [2] from the rock-mass known as Lot's Wife is

[1] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 208.

[2] The specimens here described belong to a collection presented by Mr. R. L. Antrobus in 1891.

a phonolite somewhat like the rock from Mt. Kenya, showing minute nephelines surrounded by aegirine, which also occurs in feathery patches together with the same pale greyish-brown amphibole as in the phonolitic trachyte of Gran Canaria described above.

Other specimens of phonolitic rocks from the prominent peak Lot are of a somewhat different type, and present many points of similarity, both macroscopic and microscopic, with the rocks from near Axum, Abyssinia, described (and figured) as allied to sölvsbergite in a previous paper[1]. Like the Abyssinian rocks they show a peculiar surface shimmer, due to the platy arrangement of the felspars, and the most prominent constituents are grass-green aegirine in shreds and small grains interspersed between lath-shaped felspars (probably anorthoclase) giving curious undulose extinctions and showing very conspicuous wavy lines of parting (see fig. 4, pl. 3, l. c.); but in the St. Helena rocks, in addition to these constituents, there are present small nephelines and a little cossyrite. The rocks are medium-grained, the felspar-laths being fairly large; in some cases there is an approach to porphyritic structure by larger felspars occurring in a base of smaller laths.

The occurrence in St. Helena of these isolated peaks of phonolite projecting through the overlying basaltic lavas reminds one of the similar association of phonolites and basalts on Fernando Noronha and the Little Island of Trinidad, South Atlantic[2].

Ascension.

In this island the augite-trachytes and obsidians described by Renard[3] appear to play the same rôle in association with the basaltic lavas as the phonolites with the basalts in St. Helena.

Examination of specimens in the British Museum collection shows that most of these trachytes are of a distinctly soda-rich phonolitic type, and that they contain anorthoclase-felspar and the soda-amphiboles, riebeckite and cossyrite. As pointed out by Renard, quartz is present in these trachytic rocks, but there would appear to be no good reason for regarding it in all cases as of secondary origin. In most of the specimens it occurs, in fact, in the base, depolarizing in patches and enclosing felspar-laths, and thus forming a micropoecilitic structure of precisely the same character as that in the phonolitic quartz-trachytes and in the riebeckite-rhyolites of the Rift Valley described on p. 242.

The *riebeckite* occurs in these rocks in characteristic moss-like patches

[1] This Magazine, 1900, vol. xii, p. 265, and fig. 4, pl. 3.

[2] This Magazine, 1900, vol. xii, pp. 317–23.

[3] Challenger Reports, Physics and Chemistry, vol. ii, pt. 4, pp. 39–74.

scattered through the base: it shows the usual pleochroism from yellowish-brown with a tinge of green for vibrations across the length of prismatic sections to deep indigo-blue and opaque along the length, to which the a-axis of the indicatrix is nearly parallel. Accompanying the riebeckite, and in some cases wholly replacing it, is cossyrite: aegirine and also aegirine-augite are generally present, but in comparatively small amount. In a specimen from Green Mt., besides aegirine, which is scattered in small grains uniformly over the slide, and cossyrite, there occurs the hornblende with pleochroism from reddish-brown to deep bluish-brown or opaque described by Renard[1] as also occurring in crystals formed by sublimation in the crevices of the rock. In some of the other specimens this hornblende occurs with a zonal intergrowth of riebeckite. The phenocrysts in these rocks consist of sanidine, and of anorthoclase showing the characteristic minute twin-striations.

Some of these trachytes are strikingly similar to the riebeckite-trachytes from Senafé, Abyssinia, described in a previous paper[2]. That some of them should be referred to the soda-rhyolites is suggested by the results of the chemical analysis of Klement quoted by Renard[3].

In the following table this analysis of trachyte from Ascension is reproduced under I, while for comparison are given under II that of the comendite from Comende, Sardinia; under III that of Klement's analysis of obsidian from Ascension; under IV that of a quartz-keratophyre from the Mühlenthal; under V that of a pantellerite from Mt. S. Elmo, Pantelleria; and under VI that of the glassy soda-rhyolite from the Rift Valley described on p. 245.

	I.	II.	III.	IV.	V.	VI.
SiO_2 ...	70·99	74·76	72·71	70·97	69·02	70·61
TiO_2 ...	—	—	—	—	—	0·15
Al_2O_3 ...	14·84	11·60	12·80	13·84	10·09	8·59
Fe_2O_3 ...	3·76	3·50	2·64	3·21	4·42	2·52
FeO ...	0·35	0·19	1·48	0·78	4·56	5·96
MnO ...	trace	—	trace	0·12	—	0·34
CaO ...	0·60	0·07	0·58	1·26	1·45	0·61
MgO ...	0·14	0·18	0·10	0·20	0·76	0·07
Na_2O ...	5·94	4·35	6·50	6·27	6·29	6·77
K_2O ...	2·40	4·92	3·87	1·57	3·70	4·46
H_2O ...	0·40	0·64	0·48	0·74	—	0·10
	99·42	100·21	101·16	98·96	100·29	100·18

[1] Loc. cit., p. 53. [2] This Magazine, 1900, vol. xii, p. 94. [3] Loc. cit., p. 47.

The obsidians of Ascension, which are seen by the above analysis to be the glassy equivalents of the 'augite-trachytes,' have the chemical composition of soda-rhyolites. One specimen in the British Museum collection shows under the microscope small phenocrysts of anorthoclase in a glassy base crowded with felspar-microliths: one or two small grains of aegirine and aegirine-augite and one of olivine are also present.

The close connexion between these obsidians and comendites and quartz-keratophyres is seen from the above analyses. They differ from pantellerites and the obsidian from the Rift Valley for the most part only in their lower percentage of oxides of iron.

Aden.

Many of the trachytic and phonolitic rocks of Aden show some points of resemblance with the rocks of the Rift Valley. Thus a pale green glassy rock in the British Museum collection showing marked flow-structure has a remarkable similarity with some of the 'kenytes' from Mt. Kenya. Under the microscope it shows small phenocrysts of anorthoclase, with the twin-striations well marked, in a dense glassy base crowded with minute felspar-microliths, and interstitial irregular grains of aegirine-augite and opacite (suggestive of altered cossyrite): amongst the phenocrysts are one or two small crystals of aegirine-augite and, very sparingly, olivine.

Another specimen is a phonolitic quartz-trachyte similar to those from the Rift Valley (p. 242). In this rock small phenocrysts of sanidine and anorthoclase with, very sparingly, aegerine-augite and fairly large olivines occur in a trachytic mesh of felspar-laths with needles of grass-green aegirine, micropoecilitic quartz, and patches of ferrite and opacite very suggestive of altered cossyrite.

Abyssinia.

The general resemblance of phonolitic rocks from the neighbourhood of Axum and of Senafé, Abyssinia, to rocks from the Rift Valley and from St. Helena and Ascension has been sufficiently demonstrated in the preceding pages. In addition, two glassy rocks may be mentioned here as very similar to some of the spherulitic phonolitic obsidians of the Rift Valley. The specimens belong to the Blanford collection[1] and come, one from the Ferra Pass, near Belago, and the other from the

[1] The collection was made by Dr. W. T. Blanford when acting as geologist to the Abyssinian Expedition of 1868 under Sir Robert Napier.

Alagi Pass. They are deep-brown spherulitic glassy rocks showing flow-structure and phenocrysts of anorthoclase with a few pale green augites and, very sparingly, olivine.

General Conclusions and Summary.

Gneisses and schists with granulites form the basement rocks of British East Africa. Above them on the western side of the Great Rift Valley in the Victoria Nyanza region occur the ferruginous schists, shales, and sandstones of the Karagwe series, part of which may probably be referred to the Cape system of South Africa and the Cuddapah series of India. Through these ancient rocks in Tertiary times were erupted the lavas from Mts. Kenya, Kilimandjaro, and Elgon, and from the craters of the Rift Valley and those at the foot of Ruwenzori.

With the exception of basalts from Laikipia and Kamasia and of basic nephelinites and melilite-rocks from the Mt. Elgon district and Ruwenzori, the lavas are mainly of a phonolitic type: all have doubtless been derived from a soda-rich nepheline-syenite- or theralite-magma. They present a remarkable example of a *rock-series* varying in basicity from acid riebeckite-rhyolites to basic phonolites and kenytes, but with all the members characterized, chemically, by the low contents of lime and magnesia and high percentages of alkalies (especially soda) and oxides of iron, and mineralogically, by the presence of anorthoclase and for the most part of both soda-pyroxenes and soda-amphiboles.

In their characters these phonolitic lavas present striking analogies with eruptive rocks from other parts of Africa and the neighbouring islands. This is especially true of the rocks of Pantelleria, the Canary Islands, and Abyssinia; but the phonolitic rocks of St. Helena, Ascension, and Aden also have many features in common with those of British East Africa and Abyssinia. The eruptive rocks of Madagascar are mainly of a phonolitic type [1], and nepheline-syenites occur there, and also in the Transvaal and on the west coast of Africa on the Los Islands, Sierra Leone. Nephelinites and leucitites are also the principal lavas of the Etinde volcano in the Cameroons [2]. Altogether there would seem to be a wonderful uniformity about the eruptive rocks of Africa and the adjacent islands, indicating that they have all been derived from alkali-rich nepheline-syenite- or theralite-magmas.

[1] See Lacroix, Les roches alcalines caractérisant la province pétrographique d'Ampasindava. Nouv. Archives du Muséum d'Histoire Naturelle. Paris, 1902, sér. 4, tom. iv, fasc. 1, 152 pp., 10 pls.; and this Magazine, 1900, vol. xii, p. 272.

[2] E. Esch, Sitz.-Ber. Akad. Wiss. Berlin, 1901, pp. 277, 400.

This may be, however, only a part of a wider generalization, for the association of basalts with alkali-rich phonolitic rocks appears to be common not only to the west African islands, but to the great Atlantic volcanic chain generally. This association, for example, is met with not only in the islands of Ascension and St. Helena, but also in the islands of Fernando Noronha, the Little Island of Trinidad, and the Tristan d'Acunha group. Basalts are the prevailing rocks in the Faroe Islands and in Iceland, and in the latter locality they are associated with obsidians rich in alkalies and poor in lime and magnesia. In the Hebrides also the Tertiary basalts are associated with 'pitchstones,' many of which contain augite and anorthoclase and are thus related to pantellerites. The two European offshoots from the great Atlantic chain are also characterized to a large extent [1] by alkali-rich lavas associated with basalts. This is the case in the volcanic regions of Auvergne, the Eifel, and the Bohemian Mittelgebirge belonging to the northern branch; while in the southern Mediterranean branch the present basaltic eruptions are mainly of a type rich in alkalies, and the trachytic lavas have some points of resemblance (e.g. the Arso trachyte) with the 'acmite-trachyte' of Terceira and the rocks of the kenyte series [2]. To this Mediterranean branch belong also the soda-rich lavas of Pantelleria and the phonolites of Tripoli. The lavas of Santorin, however, appear to be connected with the andesitic eruptions of Asia Minor.

Thus of the four great volcanic chains running north to south, the great Atlantic chain with its European branches, and the minor chain along the east coast of Africa including Madagascar, are characterized by the association of basalts and alkali-rich phonolitic rocks, whereas in the two other great Pacific chains (one from Alaska through Japan and the East Indies to New Zealand, and the other down the western coast of the American continent) andesites are the prevailing lavas.

In this connexion it is of interest to recall the fact which has been noted that the eruptive rocks in the United States become more and more rich in soda as one proceeds from west to east, i.e. from the Pacific towards the Atlantic volcanic chain [3]. Similarly in Europe and Asia the lavas become less rich in alkalies and more andesitic in character (e.g. the Hungarian andesites and the andesitic lavas of Santorin and

[1] With the exception of the Hungarian andesites.

[2] The 'bread-crust' bombs of Lipari (the 'volcanite' of Hobbs, Zeits. Deutsch. geol. Gesellschaft, 1893, vol. xlv, p. 578) are, by their mineral contents at least, more closely connected with the kenyte-series (pantellerites) than with the dacites.

[3] The lavas of the West Indies, however, as we have recently seen, still rather conform to the Pacific than to the Atlantic type.

Asia Minor) as one proceeds from west to east, i. e. from the Atlantic towards the Pacific volcanic chain.

To the basalt-phonolite type appear to belong the eruptive rocks of Kerguelen and of South Victoria Land in the Antarctic Ocean, where basalts are associated in the former locality with phonolites, and in the latter with phonolitic trachytes belonging to the kenyte series [1].

In New Zealand the two types appear to effect a junction, for whereas in the South Island at Dunedin occur basalts with phonolitic rocks similar to those of Cape Adare, in the North Island andesites are the prevailing lavas.

List of Localities.

In conclusion is appended a list of the principal districts in British East Africa from which the specimens described in the preceding pages were collected, with the names of the rocks [2].

Archaean Plateau (Lugard's Falls on the Sabaki River, Iveti Mts., &c.)	*Gneisses, granulites, and amphibolites.*
Athi and Kapte Plains	*Phonolites.*
Kikuyu . . .	*Phonolites, phonolitic trachytes, obsidians, and kenytes.*
Laikipia . . .	*Phonolites, phonolitic trachytes, kenytes, and basalts.*
Baringo District (Kamasia)	*Phonolites, phonolitic trachytes, and basalts.*
Mau District, including Lake Naivasha, Nakuru, &c.	*Phonolites, phonolitic trachytes, riebeckite-rhyolites, and pantellerites.*
Nandi District .	*Phonolites, melilite-nephelinites, granite, and gneiss.*
Mt. Elgon . . .	*Nephelinites, tuffs, and rocks related to borolanite and jacupirangite.*
Elgon District .	*Gneisses, granites, and diabase.*
Busoga	*Ferruginous schists, shales and sandstones, quartzite, granite, diabase, pegmatite, laterite and ironstone.*
Bukedi	*Gneiss and schist, granite, pegmatite, quartzite.*

[1] See Prior, Report on the Rock-specimens, p. 328, in Report on the Collections of Natural History made in the Antarctic Regions during the voyage of the 'Southern Cross.' London, 1902.

[2] A list, with localities, of the specimens in Sir Harry Johnston's collections from Uganda, is given in his book 'The Uganda Protectorate.' London, 1902.

Uganda Province	*Ferruginous shales and sandstones, quartzite, phyllite, diatomaceous earth (8 miles west of Katonga River).*
Ankole	*Phyllites, ferruginous shales and sandstones, and basalt scoria.*
Toro (Ruwenzori)	*Gneiss, schists, epidiorite, nephelinite with perofskite, tuffs.*
Unyoro	*Ferruginous schists, shales, and phyllites; sandstone, quartzite, gneiss, and granulite.*
Nile Province .	*Gneiss and basalt.*

EXPLANATION OF PLATE V.

Microscope-sections of rocks from British East Africa.

Fig. 1.—Garnet-hornblende-granulite from five days west of Hameye (p. 230).
Pink garnet and green hornblende in a groundmass of plagioclastic felspar.
Magnification 10 diam., 2 inch objective.

Fig. 2.—Phonolite from Doenyo lol Mwaru (p. 238).
Portion of the groundmass highly magnified, showing grass-green aegirine, smoky rose-red catophorite, and nearly opaque reddish-brown cossyrite.
Magnification 100 diam., $\frac{1}{4}$ inch objective.

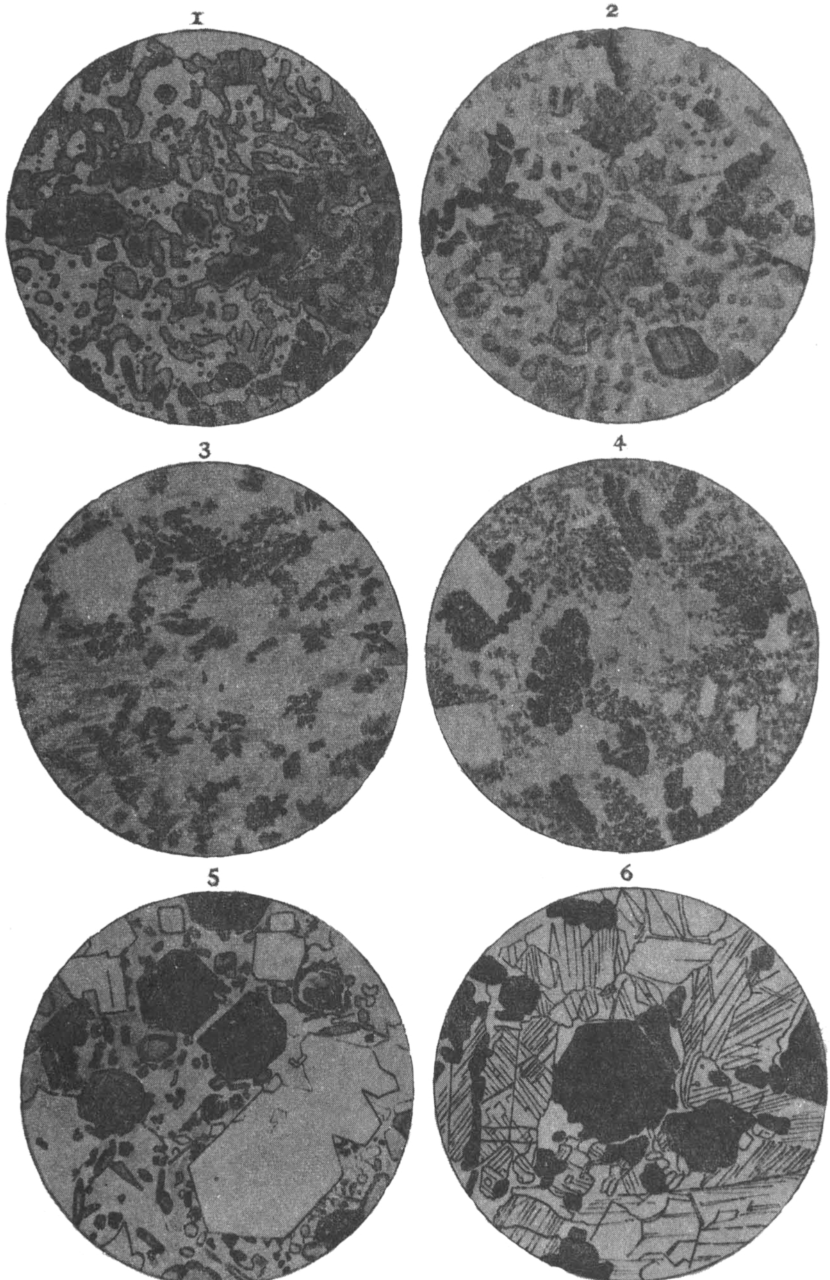
Fig. 3.—Phonolite from south of Lari lol Morjo (p. 238).
Small colourless sanidines, and tufts of green aegirine, deep red-brown cossyrite, and some catophorite in a groundmass of felspar-microliths and altered nepheline.
Magnification 20 diam., 1 inch objective.

Fig. 4.—Phonolite from Kamnye River (p. 238).
Phenocrysts of sanidine and nepheline, and patches of grass-green aegirine, deep brown cossyrite, and sky-blue amphibole near to riebeckite.
Magnification 10 diam., 2 inch objective.

Fig. 5.—Phonolite with melanite, allied to borolanite, from Mt. Elgon (p. 253).
Phenocrysts of nepheline, green aegirine-augites with terminations of aegirine, and deep-brown melanite.
Magnification 10 diam., 2 inch objective.

Fig. 6.—Rock allied to jacupirangite from Mt. Elgon (p. 253).
Yellow augite, purple perofskite, and magnetite.
Magnification 10 diam., 2 inch objective.

The plate has been executed at the Oxford University Press by the three-colour collotype process from a water-colour painted by Miss E. Drake. On the whole the original colours have been fairly well reproduced, although not with absolute truthfulness.



E. Drake, del.

G. T. PRIOR: ROCKS FROM BRITISH EAST AFRICA.

[*Copied from original colour plate.*