PARC NATIONAL ALBERT
VIII. — MISSION
D'ÉTUDES VULCANOLOGIQUES.
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NATIONAAL ALBERT PARK
VIII. — ZENDING
VOOR VULKANOLOGISCHE STUDIËN.
Aflevering 2

STUDY
OF
THE VOLCANO NYIRAGONGO

A PROGRESS REPORT

BY

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INTRODUCTION

The active volcano Nyiragongo is located in the « Parc National Albert » on the eastern border of the Belgian Congo, by 29°15′ E and 1°31′ S. Older literature refers to it under the misspelled names « Niligongo », « Ninagongo » or « Tshaninagongo ».

The mountain is part of the Virunga (Birunga) volcanic region and was discovered in 1894 by the German explorer Count G. A. VON GÖTZEN [10]. The volcano has been studied only in a cursory fashion. Scattered observations by occasional visitors and descriptions of rocks with chemical analyses have been published, without any geological setting or mutual relations of the specimens investigated [6, 7, 9, 10, 12, 23, 26, 44, 45].

Even the authoritative review by HANTKE [11] errs seriously in the description of the main physiographical characters. Published information shows the mountain to be the type locality of the nepheline- and leucite-bearing rocks of the « niligongite » family of A. LACROIX [23].

The authors have explored the greater part of the massif mainly in 1954 and 1956, as part of their respective work on feldspathoidal lavas (TH. G. S.) and general mapping of the Virunga volcanics (A. M.). One of us (A. M.) has mapped in detail the terminal crater of Nyiragongo. The study of the collected material will require considerable time and results of special investigations will be published separately. Some of these studies have already appeared [30, 31, 32, 34, 35, 37, 39].

The present paper is a progress report, providing a general view of the volcano and of its geological setting. No interpretation of the results is attempted. The authors consider that they do not yet possess sufficient facts to warrant a petrogenetical discussion. After completion of the study, the authors intend to publish a monograph on the subject in the « Exploration du Parc National Albert », series of the « Institut des Parcs Nationaux du Congo Belge ».

The authors are indebted to the « Institut des Parcs Nationaux du Congo Belge et du Ruanda-Urundi », and to their respective governments, through the agencies of the « Service Géologique du Congo Belge et du Ruanda-Urundi » and the Government Scientific Council of Finland (Valtion Luonnontieteellinen Toimikunta) for the means put at their disposition. Of the many persons who gave direct or indirect assistance, only Mr. KAI HYTÖNEN, who contributed substantially to the field and laboratory work, will be mentioned at the present time.

GEOLOGICAL SETTING.

South of the Ruwenzori massif, the Lake Edward - Lake Kivu section of the Western Rift Valley opens in the Kivu-Ruanda-Toro plateau a trench directed N 20° E, roughly 300 km long and 30-50 km wide. The rifting is of the block faulting type with secondary blocks disposed at an angle to the direction of the main scarps, providing a saw-tooth pattern for the outer, western edge. The main rifting was completed during the Tertiary time. No important post-Pliocene faulting has been traced in this section. Except in the region immediately SW of Ruwenzori [13], this part of the Rift has not been adequately studied and in the maze of structures, the proponent of any tectonic theory may find local evidence for his pet ideas.

Between Lake Tanganyika and the Ruwenzori massif, the country rocks are :

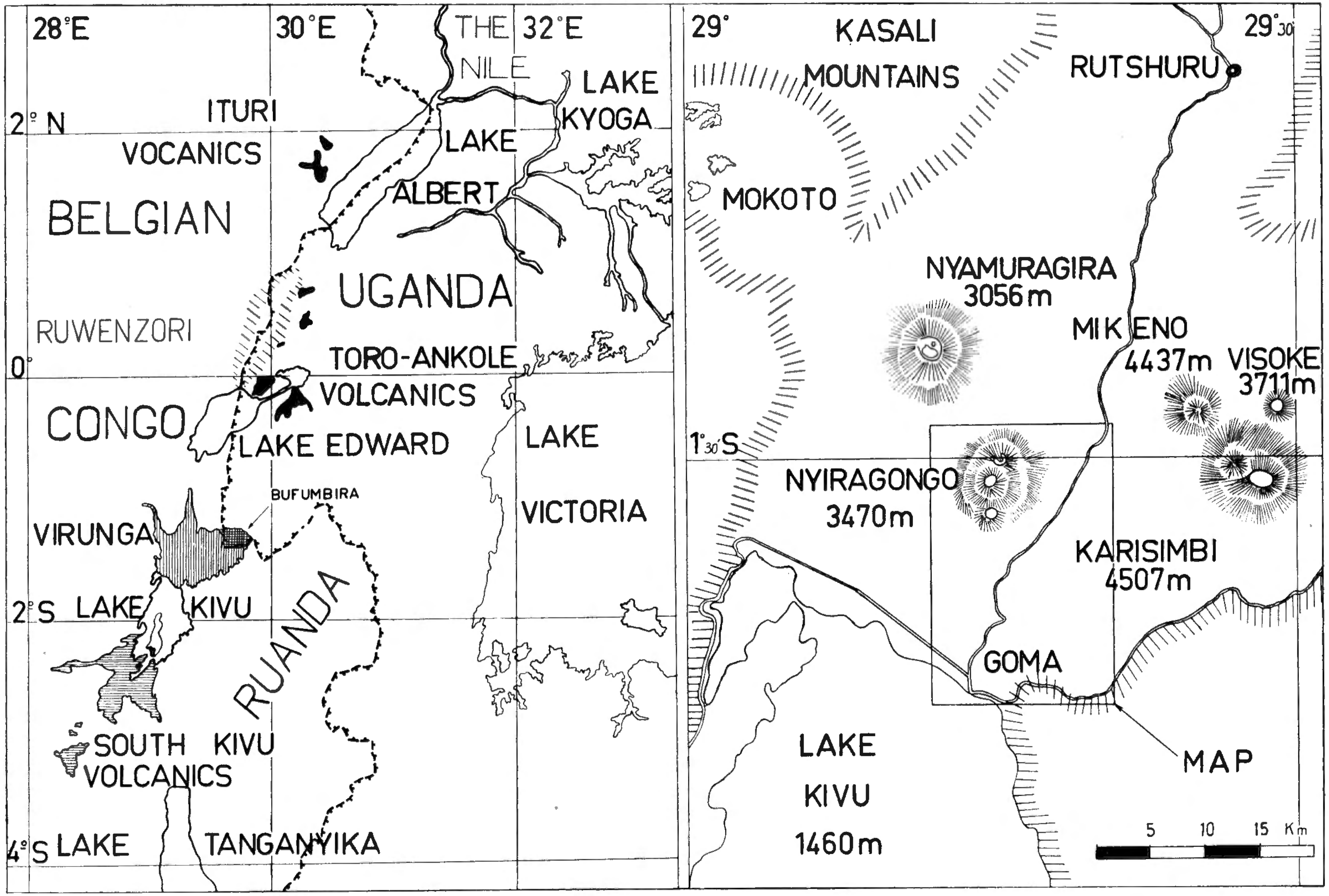
A. — SEDIMENTS AND OLDER IGNEOUS ROCKS.

a) Rift Valley sediments : gravels, sands and clays of Pleistocene age. Their thickness is unknown, but must be considerable. Along Lake Albert, drilling for oil has disclosed a sediment filling at least 1.200 m thick.

b) « Urundi system » correlated with the « Karagwe-Ankole » system of Uganda. Schists, quartzites and dolomitic limestone lenses of pre-Cambrian age, subjected to considerable tectonic disturbances. Dating of minerals related to intrusions give results ranging between 900×10^6 and 1.400×10^6 years.

c) « Ruzizi system » : quartzites, variously metamorphosed schists and gneisses.

d) Younger granites and minor intrusions of basic rocks cutting the Urundi sediments.



A

B

Fig. 1. — A: Volcanic areas associated with the Western Rift.
B: The central and western part of the Virunga.

e) Older granites, intrusive into the Ruzizi sediments alone, as is demonstrated by the existence of granitic pebbles in the basal conglomerate of the Urundi system.

f) At least one major carbonatite intrusion of hitherto unknown age has been discovered in the scarp SW of Lake Edward [1, 2].

B. — **VOLCANIC FORMATIONS** (fig. 1, A).

Late-Tertiary to recent volcanics occur in sizable quantities on the Ituri plateau W of Lake Albert, at the foot of Ruwenzori, between Lakes Kivu and Edward (Virunga-region) and around the southern end of Lake Kivu (South Kivu volcanics). The three last regions are related to major disturbances in the Rift : the Ruwenzori horst, the Bufumbira bay and the intersection of the Kivu-Edward section of the Rift with the Tanganyika section. The fascinating relations between rift tectonics and volcanism will not be discussed here and the subject will be treated elsewhere.

The characteristics of these regions may be summed up as follows :

a) The Ituri volcanics are formed by basalts extruded from numerous fissures. Advanced erosion leaves only two small occurrences of flows between Bunia and Djugu but many doleritic dykes are found in the region between Irumu and Mahagi, testifying to the former extent of the volcanics.

b) Toro-Ankole volcanics. Along the E foot of the Ruwenzori range six small fields are found that consist of recent explosion craters, tuffs and rare flows of potash-ankaratrite-melaleucitite and related rock types (katungite with melilite, mafurite carrying kalsilite, ugandite with leucite). The rocks have been studied by HOLMES [15, 16, 17, 18, 19, 20] who proposed to account for their genesis by the interaction of a carbonatite magma and granitic basement rocks.

c) Virunga volcanic region, including the Bufumbira area. This later name covers the part of the region that falls within the political boundaries of Uganda and that amounts to ca. 10 % of the bulk of volcanics in the entire Virunga field while ca. 90 % is in the Belgian Congo and Ruanda. The Bufumbira region was mapped by A. D. COMBE during the years 1925 to 1929 and the collected material studied by A. HOLMES. The work of these geologists [4, 21] remains the main source of information on the Bufumbira, but much new evidence has been recently collected from the other parts. Plio-Pleistocene basalts in the Mokoto area, olivine-leucitites (Mikeno) and potash trachyandesites (Sabinyo) were followed by a suite of rocks ranging in composition from olivine-leucitite and melilite-nephelinite to trachyte. The Virunga region (fig. 1, B), comprises eight major massifs and more than a hundred minor cones. The activity was mainly of the effusive type. Some confusion seems to have crept into recent literature as to the relative amounts of the Toro-Ankole and Virunga volcanics. The total bulk of the Toro-Ankole volcanics is probably less than the volume of any one of the major Virunga massifs.

d) South Kivu volcanic region : Plio-Pleistocene trachytes, basalts derived from fissure eruptions, followed by recent rhyolites and basalts.

An up-to-date summary of the main relations and new data has been given by one of us (Meyer, in press).

Around 1°30′ S, the Rift Valley presents an important embayment to the east, roughly 45 km long and 25 km wide. That is the « Bufumbira Bay », a tectonic feature badly known and even less understood. By 1°15′ S, a smaller bay to the west is believed to represent a cauldron subsidence. It is the « Mokoto depression » communicating with the main Rift Valley through the « Kamatembe Gap ». Of the eight major Virunga volcanoes, three (Muhavura, Gahinga, Sabinyo) are aligned along the axis of the Bufumbira Bay, three (Visoke, Mikeno, Karisimbi) cluster at the junction with the main Rift, while the two western massifs (Nyiragongo, Nyamuragira) straddle squarely the main Rift depression.

In pre-volcanic time, one single lake occupied the Rift from Ruwenzori until the S end of what is now Lake Kivu. This former lake drained into the Semliki valley, W of Ruwenzori and was part of the Nile drainage system. The Ruindi and Rutshuru plains S of Lake Edward are the ancient bottom of this lake. Mapping of the bottom of Lake Kivu by echo-sounding has shown it to be a remarkably flat surface at an average altitude of 1.000 m. As this is also the average altitude of the plains N of the volcanoes, it is concluded that the top of the Plio-Pleistocene sediment filling of the Rift Valley under the two western volcanoes probably also is a nearly flat surface at the same altitude of 1.000 m.

Flows pouring out from the basaltic vents on the crest of the western scarp and from the Mikeno massif in the east have invaded at least part of the main Rift Valley, covering the pre-existing sediments. These flows were probably followed by Karisimbi lavas invading the valley more to the south. As the level of the greater Lake Edward sunk, drainage still remained directed northwards. Sections drawn across the Rift Valley show that these older flows have probably not completely blocked the valley, even if the drainage was progressively shifted westwards.

In comparatively recent times, vents opened along the floor of the main Rift Valley and their lavas formed a dam, causing the waters to accumulate in the southern part of the depression and thus creating Lake Kivu with the jagged shorelines characteristic of a drowned topography. This fact was already noticed by Moore as long ago as 1900 [27].

The dispersal of vents is shown not only in the visible topography but also by the presence of basin-topped mounds up to 150 m high on the bottom of Lake Kivu. The waters of this lake rose to about 110 m above the present level of 1.460 m. Around the 1.570 m level the mounting lake reached a notch in the watershed south of Bukavu and started flowing towards Lake Tanganyika which is part of the Congo River basin. The eruptions thus caused a migation of the Mediteranean-Atlantic watershed and diverted a sizable portion from the Nile to the Atlantic basin. Rapid erosion of the valley by the resulting Ruzizi river lowered the level of Lake Kivu to 1.460 m.

The volume of igneous material between the top of the lacustrine sediments and the present level of Lake Kivu amounts to about 500 km^3.

Unpublished C^{14} datings carried out on fossil shells from terraces on the north shore of Lake Kivu show that the high level of the lake occurred between 10.000 and 15.000 years ago and that the lake sank at the average rate of about 1 m per 100 years.

The visible part of the Nyiragongo massif is thus posed on a pile of lavas erupted from the eastern volcanoes, from its own vents and from an aureole of satellites. Below the 1.000 m level there are lacustrine sediments of unknown thickness.

The older basement rocks cannot be observed directly. The nearest outcrops are granites and pegmatites, 13 to 20 km S and SE from Nyiragongo. Towards SW, Urundi sediments are found in the Mbuzi peninsula, 22 km from the mountain. Quartzites, schists, dolomitic limestones and pegmatites on the western scarp are found 22 to 25 km from it. Ejected blocks of sedimentary material, while abundant in the Nyamuragira, are completely absent in the Nyiragongo. This fact suggests a granitic substratum under the Nyiragongo.

THE VOLCANO NYIRAGONGO.

PHYSIOGRAPHY.

The Nyiragongo massif is formed by three major volcanic cones welded together and disposed along a N-S trending arc, slightly concave towards E. Their alignment is exactly on the continuation of the main eastern scarp of the Rift. The cones are :

A. — Shaheru, elevation 2.800 m.

B. — Baruta, elevation 3.100 m.

C. — Terminal cone of Nyiragongo, elevation 3.470 m.

Seen from N or S, the profile is that of a steep-sloped truncated cone while seen from W or E, the outline shows a massive smoking cone, flanked by two lower buttresses.

Because of gradual passage into the surrounding lava plain, the apparent base of the massif is hard to define. It can be considered as roughly following the 2.200 m contour line. The flows have advanced 6-7 km E before having been diverted to S by the older Karisimbi flows and 12-15 km to S untill the shore of Lake Kivu. To W and N, they disappear under the younger Nyamuragira lavas. Flows derived from the Nyiragongo massif are not much younger than the last flows originating at the SW foot of the Karisimbi massif.

The length of the massif between the N foot of Baruta and the S foot of Shaheru is nearly 10 km. The absolute age cannot be given. The only sure element is the fact that flows from Nyiragongo cover previous flows incrusted by fossil-bearing sinter at the 1.560 m stand of Lake Kivu.

Compared with such giants as the Mauna Loa, the Nyiragongo massif is not impressive. But it's features make up for the lack of size.

A. — Shaheru.

The cone of Shaheru has remarkably steep slopes inclined at 28° and is covered by dense forest growing on a thick layer of soil derived from weathered ash. Exposures are few and deeply weathered. The top holds a steep-sided crater, 700 m across and 80 m deep. A flow of « Nepheline Aggregate lava » from the main cone has filled the saddle between Shaheru and Nyiragongo and, cascading down the N wall, has invaded the W half of the Shaheru crater. The walls display ash and coarse cinder with a few ejected blocks. These blocks are of variable composition and most often massive. They are supposed to derive from older intercrateral flows cut by later vents and ejected during phases of explosive activity rather than representing bombs of ejected molten material. V- and U-shaped outcrops of vesicular lava along the rim are believed to represent fillings of valleys cut in the old cindercone and filled by later flows from a central vent. The older crater must have been considerably enlarged in the later stages of activity while the main lava column was withdrawn. The base of the Shaheru is ringed by satellite cones and disappears under their flows. At the end, activity migrated from the terminal cone to the foot of the mountain.

B. — Baruta.

Baruta is a massive complex cone whose slopes rise at 15° in the lower parts and at 30°-32° above the 2.600 m level. The main crater is 1.100 m across and 300 m deep. Exposures on the outer slopes are few and poor. The inner sub-vertical walls display good outcrops of massive lava, partly covered by thick vegetation. The NW wall is breached along the whole height by several smaller craters. The breach is exactly in line with the « weakness zone » [24, 49] of the Nyamuragira massif.

The thickly forested floor of the Baruta crater carries at least six big crescent-formed depressions whose steep walls are lined by benches of glassy lava. Except for a bigger size, they are similar to the lava lake of

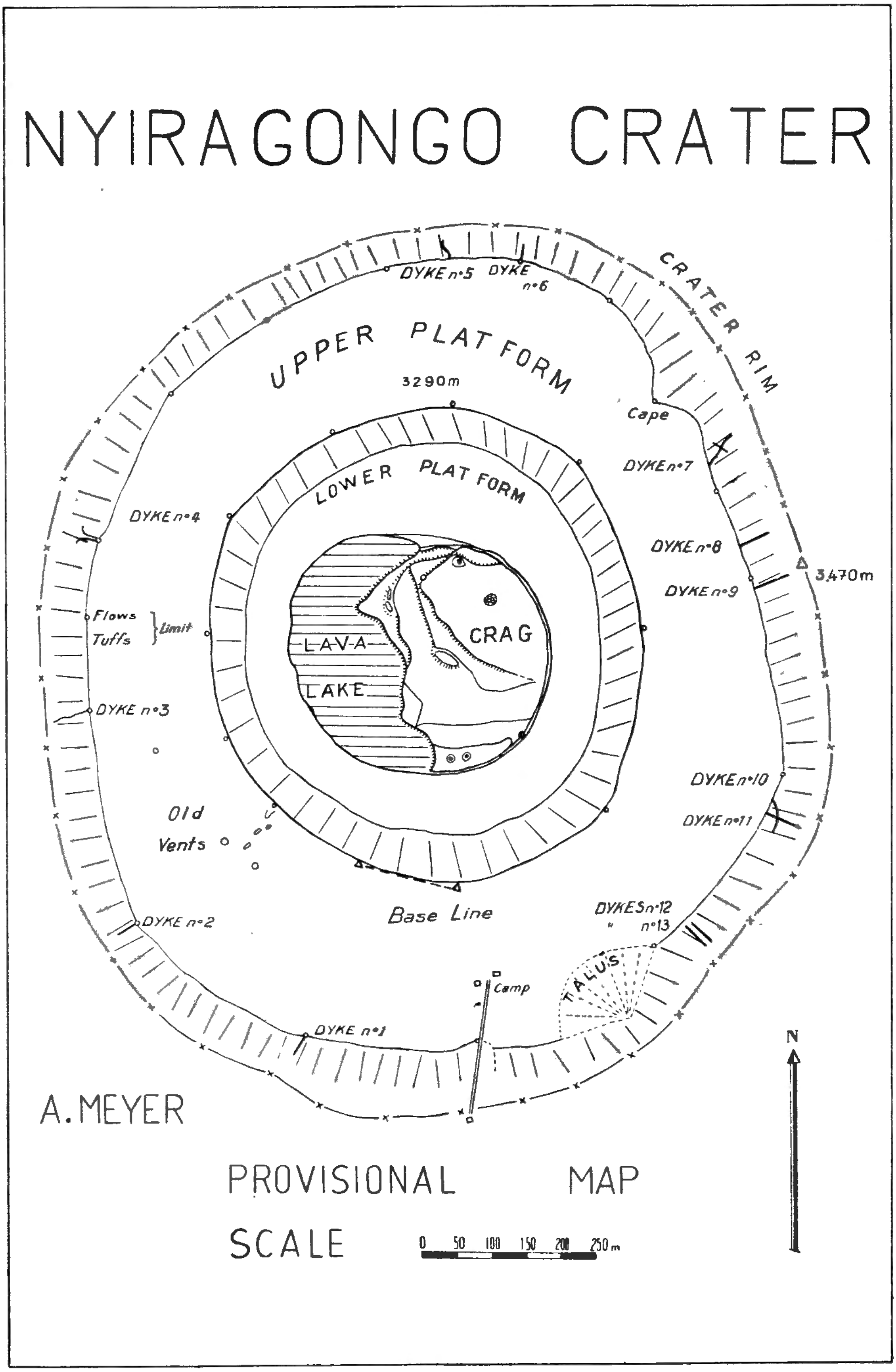


FIG. 2. — The crater of the Nyiragongo.

the Tshambene eruption of 1938-1940 on the SW foot of Nyamuragira [24]. In the upper S part of Baruta, there is an older crater, partly incorporated into the rim and providing a good shelter for visitors. This crater is drained towards the east through a small valley.

There is no trace of any recent activity in the Baruta, nor are there any native traditions on the subject. The statement found in Heim [12] (p. 54) : « Nach einer Aufnahme des Herzogs zu Mecklenburg in 1908 war der Baruta in Eruption » is contested. The quoted photograph shows usual clouds and on no other photograph are there any signs of activity. No reference to such an event is found in the text — on the contrary, both lateral craters are stated as long extinct.

C. — Terminal cone of Nyiragongo.

When seen from a distance, the terminal cone of Nyiragongo appears very regular. The flanks rise at 31° on the W side, 32° on the N side and 28° on the E side, respectively. The SSW slope is irregular and displays a lava-covered spur whose sides dip up to 40°. The W slope is completely barren, probably because of the prevailing sulphur-bearing winds along this flank. The other flanks are covered by the giant heather *Hagenia abyssinica*, followed upwards by a mixed vegetation of *Ericacea*, *Lobelia* and *Senecio*.

The slopes are covered by flows of what the authors term « Nepheline Aggregate lava ». Below 3.000 m, the pahoehoe prevailing near the summit frequently grades into « aa »-type flows. Scattered outcrops of leucitite occur as windows in this main type of flow. In the upper part, numerous trenches lined with glassy lava represent old channels. Some of the channels originate in visible tunnels, others may be followed untill notches in the rim of the crater and their origin must be sought at higher levels and inside the present outline of the crater. These interrupted channels are convincing proof of the recent enlargement of the terminal crater. At the time of emission of these flows, the upper part of the cone probably displayed an activity similar to the present « Sciara del Fuoco » of Stromboli.

The flow channels play an important role in the erosion of the volcano. As built-in trenches, they canalise the run-off from the heavy rains and are quickly changed into erosion guillies.

Terminal crater of Nyiragongo (fig. 2).

The terminal crater has been named « Graf Götzen Krater » by the german expedition of 1907-1908.

The components of the crater are : the walls, the upper platform, the sink, the lower platform, the fire-pit with the lava lake and the crag. The upper platform is located at the 3.285 m level. The section of the crater, measured along this plaform, is an ellipse with a N-S axis of 1.140 m and an E-W axis of 960 m. The terminal crater has been called a caldera but the use of this term seems to be incorrect because authorities agree that a characteristic feature of a caldera is a diameter multiple of the biggest vent enclosed.

The first man to try the descent was the Oberleutnant WEISS in 1907, and the first man to succeed was R. D. BURTT in 1930.

a) **The walls.**

The height of the crater walls of Nyiragongo varies between 160 and 185 m. In the rocky parts, the slope is regular, averaging 70°, and is very irregular in the tuffs. The walls are subjected to active erosion. After strong rains, the loosely consolidated tuffs discharge torrents of water exercising a strong caving action, dislodging loose boulders and overhanging slabs of interstratified flows. The net effect is one of widening the crater by recession of the walls and subsequent lowering the rim. Granted sufficient time, such an erosion is apt to produce effects of astonishing size. Provided the eroded material is periodically removed, it is believed that this « creeping » process can be as potent as the two violent processes of explosion and engulfment.

In the SW and S walls, coarse tuffs with blocks of all sizes up to 1 m contribute up to 90 % of the material. Some interstratified flows occur as thick lenses and, in the uppermost 15-20 m, there is a capping of flows. The other walls display up to 80 % flows and only a minor amount of relatively thin tuff beds. There are two distinct formations in the tuffs, the upper resting unconformably on the lower one and dipping towards the centrum of the crater. It is believed that the upper formation is derived from an adventive cone located on the SSW slope and now buried under subsequent flows. The rounded spur of the SSW flank would be the topographical expression of this buried mound. The upper surface of the tuff beds shows U-shaped notches filled by piles of horizontal flows. This feature represents valleys cut in the tuff cone and filled by overflowing lava from an ascending column. The contact between tuffs and overlaying lavas plunges towards NE and disappears under the platform. From the geometrical characters of the contact it is inferred that the oldest feature of the top of Nyiragongo probably was a tuff cone erected around a relatively small crater centered in the SSW part of the present crater. The erection of this cone occurred during a phase of explosive activity. A change in the type of activity took place, the lava column climbed and frequent overflows occurred, mainly towards NE and E. The change from explosive to effusive activity was marked by a change in the mineralogical composition of the flows (see below). At a later stage, the center of activity migrated northwards, perhaps in several stages with intermediate breakdowns of the successive craters.

To account for the present features, a substantially higher cone must be postulated. If the upper extensions of flows on the outer flanks are drawn on profiles across the cone, the extended slopes meet above the present fire-pit at a height near to 3.850 m. This elevation is assumed to represent the maximum possible level of the lava column. A crater 400 m across (diameter of the present fire-pit) would have its rim located around 3.720 m high, and this is considered a reasonable assumption. The lava column withdrew later and the crater took the present shape by successive breakdowns and engulfments of the walls. That such a process occurred, is clearly demonstrated by the presence of numerous dykes and cone-sheets now seen in the walls, the injection of which could not be conceived under the present conditions. Thirteen main dykes and numerous small feeders are visible, with steep conesheets outlined in irregular outcrops. At a very recent stage, glassy lava was ejected from the fissure surrounding the upper platform plastering the wall in several places with the coating reaching a height of about 140 m in the ENE wall.

b) **The upper platform.**

The upper platform is a horizontal annular surface with a net extension of 52 ha covered by ropy or cellular lava and littered with blocks fallen from the walls. In the SW part, half a dozen small lava domes, 2-3 m high, appear approximately at the place where the old « tuff phase crater » is supposed to have been located. Flows have also come from fissures in the NW part. Frozen « waves » of lava along the base of the walls mark the true level of emitted flows. A circular crack, up to 3 m wide, separates the platform from the wall. Shrinkage of the plug during cooling has lowered the platform by around 2 m as compared with the level of the « waves ».

The denivellation between platform and rim was measured in 1907 by the German Oberleutnant WEISS, topographer of the Duke of Mecklenburg's expedition. His figure of 155 m is close enough to our measure of 160 m as to warrant the conclusion that no substantial changes in level of the platform have occurred since 1907.

c) **The sink.**

The sink is cylindrical, 180 m deep, with a nearly circular section, 680 m across in N-S direction and 620 m in E-W direction. The walls are sub-vertical, built up by horizontal flows with an average thickness of 1 ½ m. Important changes have occurred during the last 60 years. In 1894, VON GÖTZEN found two distinct vents separated by a wall. On a photograph taken in 1905, the wall is seen crumbling and the two vents start uniting. On later photographs, the process is seen to go on and in a panoramic view taken in 1918 one single big vent is visible. The outline of this central vent has undergone no important changes during later years.

Easily identified blocks and fissures visible on the 1918 photograph can still be found today. Reports of the crater taking a clover-leaf form during the years 1930-1940 are based on hearsay evidence and are contradicted by the facts mentioned.

d) **The lower platform.**

The lower platform is a horizontal annular surface with a net area of 22,7 ha littered by blocks fallen from the walls of the sink. This platform is most probably the remnant of the plug formed during withdrawal of the lava column and the temporary extinction of the volcano around the year 1924.

e) **The fire-pit.**

The fire-pit is a cylinder with an elliptical section of 10 ha. The major axis is directed N 70° W and is 400 m long. The minor axis is 330 m long and trends N 10°-20° E. The W part holds a crescent-shaped lava-lake 320 m long and 160 m across in the broadest part. The lake covers a little more than 40 000 m². The E part of the pit is occupied by a tilted and partially broken block of solid lava covering 6 ha and is similar to the « crag » in the Halemaumau during the years 1916-1917. The sides of the fire-pit are draped by sheets of black lava and display narrow horizontal benches showing former levels of the fluctuating lake.

Sometimes big sections, measuring several thousands cubic meters, are detached from the walls and tumble into the lake where the fallen material is quickly engulfed. The fresh section thus revealed shows that the interior of the walls above the lava lake is composed of massive, red glowing material the surface of which darkens quickly through loss of heat by radiation and assumes the external aspect of solid rock. It may be pointed out that the conditions revealed inside the walls are favorable for the development of coarse crystallization and, should this semi-molten rock be broken by explosions, the ejected material would probably be identified as of plutonic origin. It is the authors' opinion that the blocks of « niligongite », defined by A. Lacroix as « ijolite leucitique » and the « leucite-kentallenites » ejected by Nyamuragira have originated in this way. The process is probably rather common and there is a definite possibility of many supposed plutonic rocks ejected by volcanoes having been formed at a depth of only some hundreds of meters.

f) **The lava lake.**

To the knowledge of the authors, Nyiragongo displays the only easily accessible permanent lava lake in the world. The lake is essentially a pasty mass of lava, covered by a thick black « skin » and kept in a molten condition by the heat of ascending gases.

In daylight, the lake appears as a flat, black to dark grey surface cut by pink to cherry red wrinkles. When a cycle of activity starts, the surface undulates slowly and fountains appear, projecting cherry-colored to bright red packages of lava. The fountaining liberates considerable amounts of steam quickly hiding the lake. Night time allows better observations.

Fountaining is the most conspicuous feature. There are two types of fountains : the « fixed emplacement » and the « travelling » types.

The « fixed emplacement » fountains, located at several points, are characterized by the escape of considerable amounts of gas throwing packages of molten lava sometimes as much as 20 m high. As soon as a fountain springs in action a streaming effect occurs in the vicinity. The black crust breaks up, forming rafts that glide towards the fountain like ice-floes on a river. When the rafts reach the turbulent zone at the foot of the fountain they are engulfed. This goes on during several minutes and the process ends abruptly. This type of fountain probably represents the apertures of deep-reaching vertical channels.

The « travelling »-type fountain is distinctly smaller, has a shorter lifetime, the amounts of gas generated are less and the stream effect in the adjacent lake is scarcely noticeable. This type of fountain probably represents the escape of local pockets of gas trapped in the mass of molten material.

One of us (A. M.) has observed and filmed several times the general flow of the lake. The sequence of events has always been the same : appearance of numerous small fountains in the N part of the lake, coalescence of several small fountains into larger ones, progressively accelerated movement towards S of the resulting fountains and of the whole adjoining strip of the lake, disappearance of the fountains, but not of the movement, appearance of a vortex in the S half of the lake with numerous small blisters and fountains, reversal of the movement, the displaced portions of the skin gliding back to the vicinity of the starting point. The horizontal amplitude of the displacement is 100-150 m. No satisfying explanation for this succession of events has been found so far.

From numerous temperature readings taken in night time with an optical pyrometer, the following average figures were obtained :

Glowing cracks of the crust	770°-800° C.
Travelling fountains	850°-870° C.
Fixed emplacements fountains	850°-900° C.

The highest reading recorded in the top of the fixed fountain was 960° C.

The constant upwelling of gas from the lower levels is the driving mechanism of the lake. In the present conditions, it seems that the same lava is stirred over and over by the escaping gases and that the lake remains at a nearly constant temperature. Here also good conditions for crystallization and growth of minerals may be found, especially as very small amounts of a particular substance carried by the gases can produce considerable enrichment of it in the stirred lava. The Nyiragongo lava lake may be compared to a giant-sized crystallization dish. This hypothesis is now developed and tested against all available evidence.

The level of the lake changes frequently, as may be seen by the benchmarks on the walls of the fire-pit. The fluctuations seem to be rather short-timed and range within narrow limits (usually less than 10 m). A major variation occurred during the year 1956. On February 20th, 1956, the level of the lake was 224 m under the upper and 44 m under the lower platform at an elevation of 3.061 m. In the beginning of June, the lake was 12 m higher, at the level of 3.073 m and in November of the same year the level dropped 35 m to the 3.038 m level. In the beginning of 1957, the level was rising.

The gases emitted by the lake and by the peripheral small cones are mostly steam with varying amounts of SO_2. Because of topographic conditions, no sampling of uncontaminated gas has been attempted. The cloud rising from the pit is mainly steam with varying amounts of SO_2. As no flames can be seen in the fountains, oxydation of the combustible fraction of gas must occur during the passage through the molten mass. Gases escaping from small cones around the crag can be seen burning in the darkness with grey, greenish or yellow flames.

g) **The crag.**

The crag is a big triangular block, 180 × 160 m, tilted 20° towards SE and surrounded by horizontal terraces. The fissure between crag and lower platform is filled by broken material and dotted with small cones. During the night, the fissure glows red showing that the crag is surrounded by molten lava. Thus the crag floats on the lake and probably grades downwards into epimagma. That the crag is independent of the lower platform was demonstrated by its behavior during the rise and fall of the lake in 1956. The crag rose 5 m while the lava lake ascended 12 m and sank 20 m while the lake sank 35 m. The crag is a part of the lower platform, broken up and tilted.

h) **Evolution of activity in historic time.**

When VON GÖTZEN climbed Nyiragongo on June 11th, 1894, he found two distinct circular vents, one of them belching steam. Judging by reports of various travellers, the volcano was permanently active during the following years. On a good photograph taken by the Swiss topographer THEVOZ in 1905, two vents may be seen, distinctly elongated in an E-W direction. The thin wall separating the vents has started crumbling and from the N vent there rises a cloud of steam. Shortly before the arrival of the Duke of Mecklenburg's expedition in 1907, activity stopped, to return in the end of 1908.

On a photograph taken by H. Meyer in 1911, the S vent smokes. The activity has thus migrated and the wall between the vents is breaking down.

Activity slowed down and even disappeared during the years 1915-1916. During the interval 1912-1918, the two vents were united into one single sink, the outlines of which have not changed since. The situation in 1918 is shown on a panorama taken by M. X. Dierckx, one of the oldest settlers in the region. The statement of Heim [12] (p. 54) : « ... doch vom April 1927 an ereigneten sich grosse Eruptionen, wobei die beiden inneren Kraterlöcher vereinigt wurden » is incorrect. The 1918 photograph shows that neither lower platform nor crag existed at that time.

The statement of Bailey Willis [50] (p. 128) : « Nina Gongo (Mother of the Congo), the great truncated cone that rolls out cumulus clouds of steam, had two vents up to 1918, when it blew its crater out » apparently originated with A. D. Combe, whose knowledge of local conditions Willis drew upon during their trip in 1929. Nothing more definite is known about the formation of the pit.

Nyiragongo remained active untill the middle of 1924. It is possible that the volcano suffered temporary extinction during the second half of 1922. No activity is recorded from 1924 to the end of 1926 or to the beginning of 1927. It is most probable that the lower platform was formed at that time. The lava column must have sank very deep because witnesses deny any solfataric activity in the crater during that time. This point is important because withdrawals of lava in Hawaii have been supposed to be related to submarine eruptions. Nyiragongo demonstrates that substantial sinking of the lava column can occur without lateral outpourings at the base of the massif.

Since 1927, the volcano has remained permanently active and the situation has changed little during the last years, except for the rise and fall of lava lake and crag in 1956.

D. — The lava plains E and S of Nyiragongo.

The lower reaches of the Nyiragongo massif grade into long slopes leading towards the foot of the Karisimbi massif in E and towards Lake Kivu in S. These slopes are formed by a multitude of flows and are interrupted by smaller volcanoes of all sizes, from the minute spatter-cone 2 m high to satellite massifs 1-2 km in length and with heights reaching 150 m. Many cones are partly covered by younger flows coming from the Nyiragongo massif or other vents located at higher levels. In extreme cases, the crest alone emerges from the engulfing flows and one or two more flows would completely bury the old formation.

The satellite vents display a definite tendency to occur more frequently in two bands where their agglomeration has produced arcuate crests in the landscape. The first crest runs roughly from Baruta to Mikeno and is marked by the hills Nyamushwa, Guberebya, Gisi and Mushushwe. The second crest runs from Shaheru to the N end of the main E scarp of the Rift Valley, E of Goma. In both cases, individual vents frequently display an elongation roughly parallel to the direction of alignment.

The lava plain may be divided into two distinct parts :

1. The Buhumba plateau, E of Nyiragongo, is a trough limited by the two said ridges and the foot of the Karisimbi massif. The plateau has been filled to the present average level of 2.000 m by Nyiragongo flows. Some small volcanoes and isolated groups of vents are scattered across this plateau.

2. The Bukumu slope falls 550 m in 12 km from the S foot of Shaheru to the shore of Lake Kivu. The upper part of this slope is thickly studded with cones the number of which decreases at lower levels.

When crossing the passes between neighboring cones, the younger flows frequently form very steep slopes up to 30-40 m high. The alignment of several of these slopes was noticed at an early stage of the study and the suggestion was made in an unpublished report by one of the authors (Th. G. S.) that the younger flows may be covering scarps due to recent faulting. This interpretation was disproved by later mapping. This working hypothesis has been introduced into literature as an established fact by M. E. Denaeyer [5] (p. 62). The present authors do not believe any transverse faults exist in the mapped area.

NW of Baruta-Nyiragongo, the saddle joining this massif to Nyamuragira is a part of the Congo-Nile watershed. Here is one of the heaviest concentrations of eruptions in the whole region, the last one occurring in 1954. In spite of the short distance from the Nyiragongo lava lake, only 6 km horizontally, the recent and historical outflows in the saddle are petrographically quite different from the Nyiragongo lavas characterized by the absence of feldspars. The saddle flows are feldspar-bearing, viz. basanites of the kivite type similar to the bulk of the Nyamuragira lavas and the eruptions are related to the main weakness zone of the last-named volcano.

The map reproduced at the end of this paper shows the collection area of the samples described. It must be understood that this map is a provisional document, designed to locate the main units and on which all details are omitted. The definitive map will be established from shortly forthcoming aerial photographs.

PETROGRAPHY.

ROCK CLASSIFICATION.

The most conspicuous feature in the petrography of the Nyiragongo area lavas is the absence of feldspars, particularly of plagioclases. No phenocrysts of feldspars of any kind have ever been detected in these rocks and potash feldspar occurring as a thin rim around large leucite phenocrysts or interstitially in the groundmass in small amounts has been discovered only in a few of the specimens microscopically studied and is to be considered an unessential constituent. No single occurrence of plagioclase in the lavas of the Nyiragongo area proper is known to the authors.

Of the feldspathoids, leucite and nepheline (kalsilite) are quantitatively important and the amounts of these minerals may be regarded as distinctive for the petrographical classification of the lavas of the area. Other feldspathoids of which only sodalite has so far been identified with certainty are not characteristic. In addition to leucite and nepheline, melilite forms a constituent the presence or absence of which is distinctive to that particular lava type.

Accordingly, the petrographical classification of the Nyiragongo area lavas is to be based on the presence and amount of the three constituents leucite, nepheline and melilite. This classification will be analogous to the classification of the ugandite-mafurite-katungite series from the Bunyaruguru and Katunga areas in SW Uganda proposed by Holmes [18]. In chemical and mineralogical composition there are, however, major differences between the Nyiragongo and the Bunyaruguru-Katunga lavas that do not allow the Holmes' classification and the rock names proposed by him to be applied to the Nyiragongo lavas.

The range of variation of the composition of the Nyiragongo area lavas is illustrated by Table I at the end of this paper that summarizes the results of 30 chemical analyses made of the rocks of the area. Of these analyses, 27 are new and unpublished and three (Nos. 8, 9 and 13) have been previously published by one of the authors (Sahama) [31 and 32]. For convenience of the reader, Niggli values and molecular norms are also given in Tables II and III, respectively. In this progress report, chemical analyses of Nyiragongo area rocks published by previous authors will not be summarized.

For a general petrographical characterization of the Nyiragongo area rocks, it is of some importance to compare the Nyiragongo rocks on the basis of the analyses contained in Table I with the Bunyaruguru and Katunga area rocks of which chemical analyses have been given by Holmes [15, 16, 17, 18], Holmes and Harwood [20], Combe and Holmes [3], Higazy [14], Neuvonen [28] and Sahama [33].

In literature that will not here be referred to in detail, the Nyiragongo rocks have been often characterized as being predominantly potassic. This statement is certainly true as far as a comparison of the Nyiragongo area with many other areas with nepheline and melilite rocks is concerned. The preponderance of potassium over sodium in Nyiragongo rocks is, however, not as pronounced as is often imagined. A calculation of the average alkali ratio from the analyses of Table I, that may be regarded as representative for the Nyiragongo area, gives the following results :

NYIRAGONGO LAVAS.

Average ratio (weight %) $Na_2O : K_2O = 1 : 1.12$.
Average atomic ratio $Na : K = 1 : 0.74$.

For the Bunyaruguru-Katunga lavas that represent the ugandite-mafurite-katungite series, the alkali ratio is :

BUNYARUGURU-KATUNGA LAVAS.

Average ratio (weight %) $Na_2O : K_2O = 1 : 4$.
Average atomic ratio $Na : K = 1 : 2\frac{1}{2}$.

The figures presented above show a very striking difference in the alkali ratio between the two groups of lavas mentioned. This difference in alkali ratio between the Nyiragongo and the Bunyaruguru-Katunga rocks results in the fact that lavas containing kalsilite as virtually the only leucocratic constituent and, accordingly, corresponding to mafurite, have not been found in the Nyiragongo area. In all rocks of this area in which kalsilite has been discovered, this mineral is by far less abundant than nepheline. In addition, rocks analogous to ugandite of the Bunyaruguru lavas, viz. strictly nepheline-free leucitites, are not included among the lava types known so far from the Nyiragongo area. Further, a feature characteristic of the Nyiragongo area is the fact that lava types containing melilite virtually without leucite or nepheline (kalsilite), corresponding to katungite, have not been discovered.

The leucocratic rock types found in the lava family of the Nyiragongo area are schematically presented in figure 3. On studying the figure, the reader may be reminded that the pure leucitite as well as the pure nephelinite end member of the family are not actually represented among the lavas of the area. These extreme rock names have been marked in the figure only for clarity. A greater part of the lavas having a groundmass either cryptocrystalline or fine-grained, modal compositions of rocks based on accurate planimetric analyses can not be given. For that reason, the scheme presented in figure 3 must be taken only in a qualitative or semi-quantitative manner.

In addition to the alkali ratio, there is another major difference between the Nyiragongo and the Bunyaruguru-Katunga lavas. In the last-named lava group of which a good collection of representative specimens has been at the authors' disposal, olivine is the most important melanocratic constituent. This mineral is characteristic of the entire ugandite-mafurite-katungite series and, unlike melilite, is not distinctive to any rock species

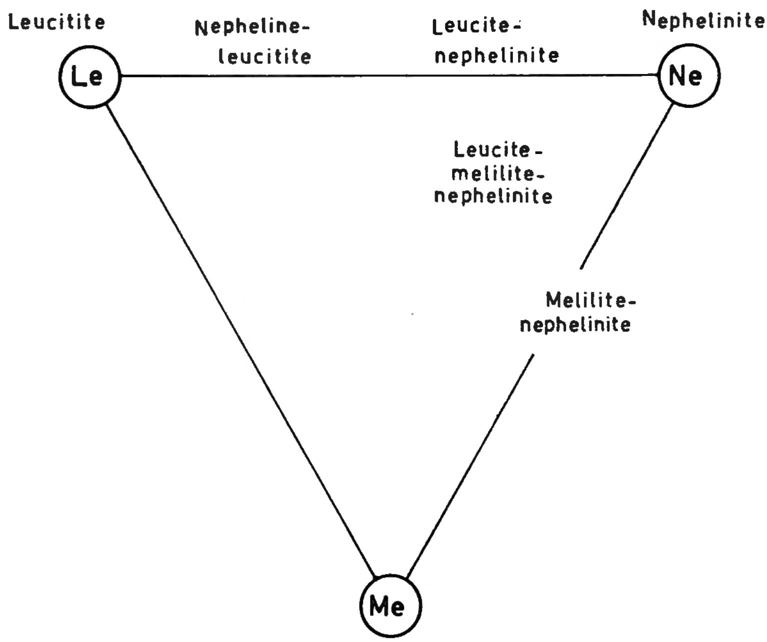


FIG. 3. — The Nyiragongo area rocks.
Schematical presentation of the nomenclature used in this paper.

within the series. Clinopyroxene is present but, in amount, is second to olivine. In the Nyiragongo area the quantitative importance of olivine and clinopyroxene is reversed. The latter mineral is virtually always present either as a titanian variety or as a type colorless to slightly greenish in transmitted light. Olivine plays a much less important role. This fact is especially conspicuous in the more melanocratic lava types.

The petrographic classification and naming of lavas found in the Nyiragongo area that is summarized in figure 3 needs a few comments. The terminology in designating rocks in this paper follows partly JOHANNSEN [22] but deviates from the system put forward by him mainly in two points. First, the use of the designation « basalt » as an indication of the olivine content of leucite-, nepheline- or melilite-bearing lavas free from plagioclase as recommended by him was rejected. As has been pointed out by several previous authors, such rocks deviate in composition from true basaltic lavas. The use of terms like « leucite-basalt », etc. for Nyiragongo lavas would probably be apt to cause confusion as to the petrographically exceptional character of these rocks. Second, no rock designations derived from locality names have been used. As has been discussed above, the rock names referring to the Bunyaruguru-Katunga lava group are not applicable to the Nyiragongo area lavas. Several of the analyzed rocks listed in Table I, have their closest counterparts outside the Nyiragongo area, in the leucite-nephelinites from Etinde on the flank of Mt. Cameroon, West Africa. These lavas, called etindites by ESCH [8] and later re-investigated by TILLEY [48], deviate from the Nyiragongo rocks of Table I in being clearly more sodic. For that reason, the name etindite was not adopted in designating Nyiragongo lavas. The rejecting of the designation etindite in this progress report must, however, be considered only tentative. The conception of the term niligongite originally proposed by A. LACROIX for an ejected block from the top of Nyiragongo has been revised and redefined by DENAEYER [6]. Also that designation was not adopted in this paper. The authors feel that they do not yet master the entire range of compositional and textural variations in the Nyiragongo lavas sufficiently well in order to propose the most suitable limits for the rocks that should be included into the niligongite family. Even after DENAEYER's welcomed redefinition, the conception of niligongite is still based only on a few specimens collected more or less arbitrarily. Unfortunately, the feldspathoidal lavas in general and certainly not least in the Nyiragongo area, display such a maze of varieties that an application of a separate designation derived from locality names for each variety would burden the petrographic nomenclature too heavily. For that reason, the authors like not to take any definite standpoint as to the term niligongite in this paper. For the same reason, the term ankaratrite or potash ankaratrite as used by HOLMES [19] was tentatively omitted.

Recently, RITTMANN [29] has proposed a petrographic nomenclature for volcanic rocks giving determinative tables for naming the rocks. Most of the rocks the compositions of which are given in Table I of this paper, fall within RITTMANN's groups D5 or D6 and, accordingly, should be called nephelinites or potash-nephelinites. It seems to the authors that a strict application of RITTMANN's nomenclature to the naming of the Nyiragongo rocks would probably not give sufficient justice to the variations in mineralogical composition. Therefore, also his classification was tentatively rejected.

DESCRIPTION OF SPECIMENS.

In the following, the Nyiragongo area rocks will be petrographically described. To provide the specimens with their geological setting within the area, brief notes on the main rock units are added to the descriptions.

The order of description is purely geographical. Starting with Shaheru, Baruta and with the main cone of Nyiragongo, the description proceeds down the mountain to E and follows the lava plain clockwise to Lake Kivu.

In addition to optical methods, mineral determinations were largely made by X-ray methods using Philips Norelco diffractometer for powder pattern and Philips Weissenberg camera for single crystal work. The composition of nepheline, kalsilite and olivine were determined by powder pattern using the method by SMITH and SAHAMA [41] for nepheline, that by SAHAMA, NEUVONEN and HYTÖNEN [34] for kalsilite and that by YODER and SAHAMA [51] for olivine. The specific gravities of bulk lavas were made on powdered material with the « Notari » volumeter. Thus the result indicates the specific gravity of the rock excluding vesicles. In several instances, the presence of kalsilite in parallel growth with nepheline and, on the other hand, the presence of zoning in olivine, nepheline, etc. was detected and checked with a Leitz rotating (elliptical) mica compensator.

For brevity, the grain size of the rock is given in brackets in a way used by HOLMES [19] as follows :

Groundmass :

vf (very fine)	average grain diameter	0,02	mm or less.
f (fine)	average grain diameter	0,02-0,07	mm.
m (medium)	average grain diameter	0,07-0,2	mm.
c (coarse)	average grain diameter	0,2-0,5	mm.
vc (very coarse)	average grain diameter	0,5	mm or more.

Phenocrysts :

S (small)	maximum length	3	mm or less.
M (medium)	maximum length	3-6	mm.
L (large)	maximum length	6	mm or more.

The letter symbols of the specimens have the following significance :

FEAE : The Finnish East African Expedition, 1952.
S : Collected by SAHAMA in 1954.
VM : Collected by MEYER in 1954 and 1956-1957.
R.G. : Specimen from older collections, stored in the Musée Royal du Congo Belge, Tervuren.

A few specimens, collected jointly, have both S- and VM-numbers.

The zeolites found in many of the specimens have not yet been subjected to closer study.

Reviews dealing with the variation of composition, etc. and with the mode of occurrence of the constituting minerals will not be included in this paper but will be published later. The following chemical analyses of minerals from the Nyiragongo area lavas are added at the end of this paper : four clinopyroxenes in Table IV, three melilites in Table V, one leucite in

Table VI, one apatite in Table VII. None of these analyses has been published previously. A number of previously published mineral analyses from the Nyiragongo lavas are not reproduced here.

SHAHERU.

Exposures are few and poor. The general physiography is outlined above (p. 9). The following specimens will be described :

Specimen S. 79 = VM. 396. E wall of crater, near to the rim. Flow that fills a former valley incising the rim.

Specimen S. 80 = VM. 395. NE wall of crater. Loose block found embedded in the ground.

Specimen S. 81 = VM. 398. Foot of S wall of crater. Fallen block.

Specimen S. 83 = VM. 397. S wall near to the rim. Flow filling an ancient valley.

Specimen S. 79 = VM. 396.

Olivine-leucite-nephelinite. (vf, S). Dark grey, very vesicular lava with a few phenocrysts of titanian clinopyroxene and, more scarcely, of olivine and leucite. Very strong preponderance of nepheline over leucite. Accessorily yellow melilite. Nepheline occurs in micrographic intergrowth with clinopyroxene and melilite. Abundant magnetite.

Specimen S. 80 = VM. 395 (1).

Complex kalsilite-bearing melilite-nephelinite. The rock is of outstanding mineralogical interest. In hand specimen, it is dark grey with irregular cream-colored spots. The rock is holocrystalline, phaneritic and massive, without vesicles. Under the microscope, the rock shows a few fair-sized aggregates of subhedral nepheline crystals, up to 4 mm in diameter, embedded in a medium-grained (average 0,1 mm) mesostasis. The size of the nepheline crystals is larger in the margins of the aggregate and decreases towards the core. The following minerals have been identified in the rock : clinopyroxene, nepheline, kalsilite, melilite, götzenite, sodalite, kirschsteinite, combeite, magnetite, perovskite, apatite, brown hornblende, pale biotite and an unknown mineral in sparing amounts the investigation of which has not yet been completed. Despite this unique mineralogical composition, no new name for the rock will be suggested. In this paper, the rock will be simply called complex kalsilite-bearing melilite-nephelinite.

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(1) VM.395 = M. 2 and 3. The M-numbers were given in the field during the mapping in 1954 and were later changed into VM-numbers that refer to the whole collection, made by the Geological Survey of the Belgian Congo.

The result of a bulk chemical analysis of the rock is presented in Table I, No. 1. Chemically the rock is characterized by its low content of aluminum in relation to the alkalis and by its relatively high content of calcium. The very high contents of fluorine and chlorine are especially noteworthy.

The quantitatively most important mafic constituent of the rock is a non-pleochroic clinopyroxene, very slightly greenish in transmitted light. Brownish violet tints typical of the titanian variety are lacking. Zoning very slight, almost absent. The mineral was separated and chemically analyzed. The result of the analysis with optical data are summarized in Table IV, No. 4. According to the analysis, the atomic ratio (Fe + Mn) : Mg : Ca = 18,3 : 33,9 : 47,8. The mineral represents a salite. The optical properties agree with those of salite. It is worth noting that the clinopyroxene is free from aluminum and relatively poor in alkalis.

Nepheline is the most important salic constituent. The crystals are euhedral to subhedral. No zoning is visible by any optical means. For determining the composition of the nepheline, a small amount of the mineral was separated from the rock. The powder pattern taken of the fraction showed strong lines of both nepheline and kalsilite. Centrifuging the fraction in Clerici's solution resulted in an almost complete separation of the two minerals from each others. The composition of nepheline yielded 31,5 mol. % Ks. The powder pattern of kalsilite proved the mineral to be entirely free from the sodium component. So far, the kalsilite of this specimen is the only sodium-free kalsilite found in natural rocks. Careful examination of several thin sections cut of the rock revealed no sign of perthitic exsolution texture in nepheline. All crystals are completely clear and homogeneous. Accordingly, nepheline and kalsilite must occur as separate crystals, not in parallel growth with each others. Unfortunately, nepheline and kalsilite may be microscopically distinguished from each others only if they occur in parallel growth. If in separate grains, their identification is very difficult. For that reason, it is not possible to tell the mode of occurrence of kalsilite in the rock on the basis of a microscopic study.

Melilite occurs as stout prisms, sometimes with visible crystal forms. It is optically negative with a positive sign of elongation. $\varepsilon = 1{,}632$, $\omega = 1{,}637$. The crystals are often zoned with higher birefringence in a thin margin. The crystals show clear signs of being under resorption and have been altered wholly or partly into a granular aggregate of kirschsteinite and clinopyroxene.

The mineral götzenite that is rather abundant in the rock represents a new species found in this specimen. It is triclinic with a formula approximating to $(Ca, Na, Al)_7(Si, Ti)_5O_{15}F_{3.5}$. A detailed description of the mineral has been published by SAHAMA and HYTÖNEN [37] and will not be repeated here. The mineral shows a prismatic habit, elongated along the crystallographic b-axis. Strong dispersion with abnormal bluish interference colors, prismatic cleavage and twinning are diagnostic for the mineral in thin section. Formally, the mineral is related to the mosandrite-johnstrupite-rinkite group. As has been recently shown by SAHAMA and HYTÖNEN [38], the unit cell dimensions of götzenite differ clearly from those of that mineral group. Owing to lack of material for calcium rinkite available to the authors, a comparison of that mineral with götzenite could not be made.

Sodalite forms a rather abundant interstitial constituent of the rock. It is completely isotropic with $n = 1{,}490 \pm 0{,}002$. The identification was made by powder pattern from a small batch separated from the rock.

Kirschsteinite, the second new species found in the rock, represents a magnesium-bearing Ca Fe-orthosilicate of the olivine group. It is the closest natural analogue to synthetic iron monticellite known so far and contains 69,4 mol. % $CaFeSiO_4$. A detailed chemical, optical and X-ray study has been published by SAHAMA and HYTÖNEN [39]. The mineral never shows crystal forms but occurs as irregular grains. It often forms coronas around the melilite crystals.

Combeite is the third new species found in the rock. It is rhombohedral with a formula approximately $3\,[Na_4Ca_3Si_6O_{16}(OH,F)_2]$. A detailed description of the mineral and of its alteration has been published by SAHAMA and HYTÖNEN [37].

The magnetite crystals are mostly euhedral. Perovskite is less abundant than magnetite. It occurs as well-developed cubes sometimes with small octahedral faces. The crystals are dark violet brown, isotropic. Sp. gr. = 4,1. The identification was made by powder pattern. The powder lines show a marked zoning for the mineral. Average $a_0 = 7{,}67 \pm 0{,}01$ Å. Apatite prisms are not uncommon.

Brown hornblende and pale biotite occur in sparing amounts. The following optical properties were determined for the hornblende : $\alpha = 1{,}629$, $\beta = 1{,}636$, $\gamma = 1{,}644$, $2V_\gamma = 86°$, $c\Lambda\gamma = 33°$, $b//\beta$. The color is pale yellowish brown. Pleochroism weak. The pale brownish biotite, weakly pleochroic, shows $\gamma = 1{,}586$ and $2V_\alpha = 28°$.

It seems evident that the complex kalsilite-bearing melilite-nephelinite from Shaheru represents a rock crystallized at a low temperature range. Two facts in the mineralogical composition favor this interpretation. First, heating experiments made with götzenite (SAHAMA and HYTÖNEN, 37) indicate that the mineral is decomposed at $955° \pm 10°$ C. Accordingly, the rock must have crystallized below that temperature. Second, a joint crystallization of the relatively potassium-poor nepheline with the sodium-free kalsilite in separate grains is possible only at a very low temperature range. These facts together with the exceptionally high contents of fluorine and chlorine make it possible that the entire rock was formed under conditions comparable with the filling of amygdules that are often found in lavas and that contain a relatively low temperature association of minerals. As long as the origin of the loose complex kalsilite-bearing melilite-nephelinite block from Shaheru remains unknown, this interpretation must be considered tentative.

Specimen S. 81 = VM. 398.

Olivine-melilite-leucite-nephelinite. Non-porphyritic, phanerocrystalline, remarkably coarse-grained (grain size up to 2 mm), grey vesicular rock. Nepheline, clinopyroxene (pale-colored, non-pleochroic with slightly greenish tint), melilite, leucite, olivine, magnetite, apatite and perovskite. Olivine was separated from the rock and subjected to chemical, optical and X-ray study. The results of this study that will be published elsewhere indicate that the mineral contains slightly more calcium than the ordinary olivines of the forsterite-fayalite series and shows a ratio Mg : (Fe + Mn) = 67 : 33.

Specimen S. 83 = VM. 397.

Pheno-leucitite. Abundant small phenocrysts of titanian clinopyroxene and some leucite in a dark vesicular, cryptocrystalline matrix, probably partly glassy. A few small olivine phenocrysts visible.

BARUTA.

Southern upper part.

The old crater above the saddle between Nyiragongo and Baruta, incorporated into the S part of Baruta proper, is filled with ash and is drained towards E by a small stream fed by a group of springs. In the valley of this stream cutting the rim, there occur a number of loose blocks. The following specimens collected from these blocks will be described :

S. 86 = VM. 356	S. 90
S. 87 = VM. 360	S. 91 = VM. 357
S. 88 = VM. 358	

NE of this valley, a notch occurs in the rim of the main crater. Specimens VM. 362 and VM. 363 were taken from blocks in the notch and are probably lying in situ.

Specimen S. 86 = VM. 356.

Melilite-nephelinite. (f-m, S). Porphyritic, dark grey, massive rock. Microscopically, the rock consists of very abundant melilite laths and clear, subhedral to euhedral nepheline (34,9 mol. % Ks) crystals in a mesostasis rich in colorless clinopyroxene. Melilite is slightly more abundant than nepheline. Melilite shows a steel grey, not anomalous, interference color and is optically negative with positive sign of elongation. The larger crystals are very slightly zoned. Especially at both ends, the laths are often hollow, filled by the mesostasis. The hollow development is still more pronounced for the relatively abundant apatite prisms in which the core regularly consists of the mesostasis. In addition, apatite is characteristically full of tiny inclusions the presence of which is diagnostic for the mineral. The very few olivine phenocrysts are always surrounded by coronas of clinopyroxene. Olivine is apparently not in equilibrium in the rock but was undergoing resorption. Magnetite occurs in two generations, as a few phenocrysts and as a constituent of the mesostasis. Small amounts of violet perovskite are detectable. Along with apatite and the first generation of magnetite, melilite and nepheline evidently represent early crystallizates of the rock. The crystallization of clinopyroxene belongs to the final consolidation of the lava.

Specimen S. 87 = VM. 360.

Nepheline-leucitite. (vf, L). The rock is characterized by numerous large (up to 2 cm) crystals of leucite and aggregates of nepheline in a slightly greenish, very fine-grained groudmass. A few smaller phenocrysts of titanian clinopyroxene are present. The groundmass consists of the same minerals and, in addition, of apatite and magnetite. The clinopyroxene of the groundmass is mostly green in color, sometimes with a brownish core. Especially around some of the leucite phenocrysts and in sparing amounts in the groundmass, an optically negative uniaxial potash feldspar may be detected. Perovskite is scarce. No melilite nor olivine were found. The closest counterpart for the rock elsewhere in the Nyiragongo area is represented by specimen S. 97 from the E slope of the mountain.

Specimen S. 88 = VM. 358.

Kalsilite-bearing olivine-melilite-nephelinite. (f, L). Large aggregates of turbid nepheline and phenocrysts of dark yellow melilite in a brownish grey vesicular groundmass. Under the microscope, the nepheline crystals of the aggregates are seen to consist of non-perthitic kalsilite cores surrounded by a nepheline margin. The specimen was the first one in the Nyiragongo area in which this mode of occurrence was observed for kalsilite. For that reason, the complex phenocrysts were subjected to a closer study. The results have been published by SAHAMA, NEUVONEN and HYTÖNEN [34] and will not be repeated here in detail. The following compositions were found for the two phases : nepheline 31,1 mol. % Ks and kalsilite 98,3 mal. % Ks. Further X-ray work is in progress.

A bulk chemical analysis of the rock is reproduced in Table I, No. 2. The chemical composition of this rock is not very different from that of specimen S. 96, the main difference being in the contents of aluminum, calcium and potassium. The mineralogical compositions of these two specimens are so similar that a separate microscopic description of specimen S. 88 seems not necessary. The only notable difference is the absence ot titanian clinopyroxene phenocrysts in specimen S. 88.

Specimen S. 90 = (No VM.).

Olivine-leucite-nephelinite. (f. L). Numerous large (up to 2 cm) euhedral phenocrysts of leucite and aggregates of subhedral to euhedral nepheline (18,9 mol. % Ks) in a fine-grained, grey, slightly vesicular groundmass. The leucite crystals are often surrounded by a crust of potash feldspar. The groundmass consists mainly of titanian clinopyroxene, nepheline, leucite and relatively abundant potash feldspar. A small amount of dark-colored greenish yellow subhedral olivine is characteristic of the rock. The olivine is very iron-rich. The mineral was separated from the rock and subjected to chemical, optical and X-ray studies. The results will be published elsewhere.

Specimen S. 91 = VM. 357.

Dark olivine-nephelinite. (vf, M). The rock is dark grey, vesicular. Abundant phenocrysts of pale-colored titanian clinopyroxene and less olivine in an almost cryptocrystalline groundmass. Small phenocrysts of magnetite and apatite. Nepheline was identified in the groundmass and as a few small phenocrysts. The groundmass is very rich in clinopyroxene and magnetite.

Specimen VM. 362.

Melilite-nephelinite. (vf, M). Large aggregates of nepheline and phenocrysts of smoky melilite in a massive, greyish, very fine grained groundmass. Melilite always contains tiny inclusions that cause the turbidity of the crystals. The mineral is optically negative with a positive sign of elongation. In habit and in optical properties, the melilite of this rock differs from the melilite of specimen S. 86 (p. 27). In sections parallel to the optic axis, the melilite crystals of specimen VM. 362 are seen to represent no thin laths but stout prisms with a ratio length/width averaging to $2/3$. The crystals are invariably very heavily zoned with a rather large homogeneous core surrounded by a relatively thin mantle in which the interference color rises rapidly towards the margin. A measurement of the birefringence with Berek compensator yielded 0,004 for the core and 0,011 for the outer margin. These optical properties indicate that the core is rich in åkermanite. The gehlenite content increases in the marginal zones and the outermost zones are very rich in it, probably with an increased content of alkali melilite. The nepheline crystals contained in the aggregates are slightly zoned as indicated by the regular arrangement of inclusions. Kalsilite in intergrowth with nepheline could not be detected under the microscope. A few phenocrysts of titanian clinopyroxene have clearly been undergoing resorption and are mantled by a homoaxial growth of colorless clinopyroxene with sharp boundaries against the titanian clinopyroxene core. Some phenocrysts of olivine also occur in the rock. They are partly or wholly transformed into a fine-grained mixture of colorless clinopyroxene and magnetite and, accordingly, represent a relictic constituent. Apatite prisms are characteristically turbid. The groundmass consists of nepheline, colorless clinopyroxene, magnetite and perovskite.

Specimen VM. 363.

Olivine-melilite-nephelinite. (vf, S). A few small phenocrysts of clinopyroxene and olivine in a massive, dark, steel-grey groundmass. The clinopyroxene is a pale-colored titanian variety. Small melilite laths with very low anomalous interference colors reach a grain size above that of the almost cryptocrystalline groundmass. The groundmass consists of colorless to slightly greenish clinopyroxene, magnetite, nepheline and very sparing amounts of pale biotite.

Northwestern breach.

The NW breach of the main crater of Baruta is caused by at least two smaller craters perforating the side of the main cone. Specimen S. 92 was collected on the NW external rim at an elevation of 2.850 m and represents a pile of flows probably filling an old valley that has been cut in the main cone. Specimen S. 93 comes from the NW inner wall at the 2.725 m level where brown-red piled flows form a conspicuous landmark.

Specimens VM. 365 to VM. 368 are bombs embedded in the coarse ash of the E wall, about 15 m above the crater floor.

Specimen VM. 369 comes from a big (1 m^3) block on the bottom of an extinct lava lake located in the SE part of the breach.

Specimen S. 96 is part of several big massive blocks lying at the foot of the rocky wall immediately NW of the threshold to the main crater. The wall itself is formed by piled vesicular flows not described here. The level from which the buried blocks originate is not yet known. The rock is described because of its mineralogical importance.

Specimen S. 92 = VM. 352.

Dark olivine-nephelinite. (vf, S). Abundant small phenocrysts of olivine, titanian clinopyroxene and, very rarely, of nepheline in an almost opaque, cryptocrystalline, very vesicular groundmass.

Specimen S. 93 = VM. 353.

Dark olivine-nephelinite. (vf, S). Phenocrysts of olivine and titanian clinopyroxene in a cryptocrystalline, vesicular groundmass. The olivine crystals are strongly altered to a reddish brown mass, probably through steam action. Minute amounts of nepheline could be identified in the groundmass.

Specimens VM. 365-368.

Dark olivine-nephelinites. (vf, S-M). These specimens are so similar to each others that they may be described together. Phenocrysts of olivine and pale-colored titanian clinopyroxene in a very vesicular dark grey groundmass. Only in one of the specimens (VM. 365) a few clots of nepheline are visible to the unaided eye. Small amounts of leucite are contained in the clots. The groundmass is cryptocrystalline, very dark, with sparing amounts of detectable nepheline. Specimens VM. 366 and VM. 368 contain pale biotite as an accessory.

Specimen VM. 369.

Olivine-leucite-nephelinite. (f, S). Titanian clinopyroxene and euhedral zoned olivine in a fine-grained, dark grey, vesicular, holocrystalline groundmass. The groundmass consists of the same minerals and, in addition, of nepheline with small amounts of leucite.

Specimen S. 96 = VM. 355.

Kalsilite-bearing olivine-melilite-nephelinite. (f, L). The rock is porphyritic and contains large aggregates of perthitic nepheline-kalsilite crystals and separate phenocrysts of melilite, clinopyroxene and olivine in a dark grey vesicular groundmass.

The result of a bulk chemical analysis of the rock is quoted in Table I, No. 3. The high state of oxidation of iron is especially noteworthy and is apparently a result of volcanic steam action. The rock is not weathered but looks fresh.

A chemical, optical and X-ray study of the perthitic nepheline-kalsilite phenocrysts has been published by SAHAMA, NEUVONEN and HYTÖNEN [34]. The detailed results of that study will not be repeated here. Only the compositions of the kalsilite and nepheline phases of the complex perthitic crystals will be mentioned : nepheline 30,2 mol. % Ks and kalsilite 95,0 mol. % Ks. Further X-ray work with the perthitic nepheline-kalsilite crystals is in progress. Nepheline occurs in the rock also as separate homogeneous phenocrysts outside the large complex aggregates. The composition of the separate nepheline phenocrysts is 32,3 mol. % Ks. Refractive indices are : $\varepsilon = 1{,}542$ and $\omega = 1{,}546$.

The abundant melilite phenocrysts, up to 3 mm in size, show a characteristically yellow color thus differing from the two other analyzed melilites from the Nepheline Aggregate lava (specimen FEAE No. 93) and from the Kabfumu lava (specimen FEAE No. 83). Table V, No. 3 presents composition, physical and optical data for the melilite from specimen S. 96. The melilite from this specimen represents a ferrian variety thus differing from the two other analyzed melilites mentioned above. The contents of the åkermanite and of the alkali melilite components, on the other hand, are approximately the same for all three melilites. The higher state of oxidation of iron is apparently the cause of the somewhat higher refractive indices of the Baruta melilite and, in addition, of the dark yellow color not common for the members of the melilite family. Under the microscope, the optically uniaxial negative melilite phenocrysts are always euhedral with positive sign of elongation and are often zoned with higher interference colors along the margin. Extremely weak pleochroism, with absorption $\omega > \varepsilon$. The crystals are full of tiny transparent inclusions with a refractive index higher than for melilite. These inclusions are too small in size to be identified microscopically.

The phenocrysts of titanian clinopyroxene show color, hour-glass texture and twinning of this pyroxene variety. Chemical composition and physical and optical data are summarized in Table IV, No. 3. The phenocrysts of olivine are less abundant than those of clinopyroxene. The olivine crystals show a thin crust of a dark brown, strongly pleochroic alteration product, probably iddingsite. As for melilite, the olivine crystals are not clear but contain tiny inclusions. The composition of olivine is 82,7 mol. % Fo.

Numerous apatite prisms reach a size well above that of the groundmass. The crystals are often hollow containing groundmass in the core. The color is very slightly yellowish, in thin section colorless. The common zoning may be detected in loose crystals under the binocular microscope or, in thin section, with a rotating mica compensator. Table VII presents the composition, physical and optical data.

The groundmass is fine-grained, not cryptocrystalline, containing nepheline, greenish clinopyroxene, yellow melilite, magnetite, hematite, perovskite, calcite, apatite.

Main crater.

In the W wall of the main crater of Baruta, the most conspicuous outcrop is a massive-appearing rock about 120 m high. No banding nor horizontal flows appear on its face. In the top of the talus, ca. 30 m high, that gives access to the foot of the wall, proper, specimen VM. 370 was taken from a fallen block. The lower part of the rock wall is a light grey, slightly vesicular lava carrying numerous crystals of pyroxene up to 1 cm long and flattened so as to appear acicular in section. Specimens VM. 371 and VM. 376 represent this rock.

Specimen VM. 372 was taken from a bomb embedded in tuff at the shore of the southernmost extinct lava lake.

Specimen VM. 374 comes from a big massive block of violet-colored lava, at the foot of a conspicuous spur in the SE wall, probably fallen from an unknown level.

Specimen S. 94 = VM. 354 is a vesicular ropy lava from a flow that forms the threshold into the main crater. This is the last lava emitted in the main crater.

Specimens VM. 375, VM. 377 and VM. 378 come from the E wall, where a massive blue lava forms an outcrop symmetrical to the W main outcrop.

Specimen VM. 370.

Dark olivine-leucite-nephelinite. (vf, M). Numerous large phenocrysts of pale-colored titanian clinopyroxene, less numerous and smaller phenocrysts of zoned olivine and a few small aggregates of leucite in a dark grey, almost cryptocrystalline groundmass in which small amounts of nepheline could be identified.

Specimens VM. 371 and VM. 376.

Olivine-leucite-melilite-nephelinites. (f, L). These two specimens are very similar. In hand specimen, large and numerous pyroxene crystals are seen in a light grey, slightly vesicular groundmass. Under the microscope, the clinopyroxene proves to be a titanian variety. Small olivine phenocrysts are strongly altered into a dark reddish brown material. The groundmass is holocrystalline, fine-grained. It consists of nepheline, leucite, zoned melilite, slightly yellowish green clinopyroxene and magnetite. Melilite occurs only in the groundmass, not as phenocrysts and fills the interstices between the nepheline crystals. Melilite shows a relatively strong yellow color with absorption $\omega > \varepsilon$. It is optically negative with positive sign of elongation. The birefringence, measured with Berek compensator from specimen VM. 376, is remarkably high, viz. 0,03. $\omega = 1{,}661$ and $\varepsilon = 1{,}630$. These optical properties and the mode of occurrence as one of the later crystallizates of the rock seem to indicate that the composition of the mineral deviates from the compositions of the melilites found in most melilite-bearing rock types of the Nyiragongo area. The melilites of these two specimens are probably very rich in the alkali melilite component.

Specimen VM. 372.

Melilite-nephelinite. (m, M). Massive, grey lava with a few black spots of titanian clinopyroxene. Under the microscope, the clinopyroxene is found to be strongly corroded. Melilite occurs as phenocrysts that sometimes reach the size of 3-4 mm. Despite their considerable size, the melilite crystals are hardly seen in hand specimen. This circumstance is caused by the poikilitic development of the melilite crystals that enclose patches of the mesostasis of the rock. The birefringence of melilite is remarkably high, like in specimens VM. 376 and VM. 371. The melilite of specimen VM. 372 evidently belongs to the later crystallizates of the rock. The mineral will be subjected to closer study. Nepheline occurs in the groundmass as subhedral crystals. No nepheline phenocrysts were found. The holocrystalline mesostasis between the melilite and nepheline crystals consists mainly of colorless clinopyroxene, magnetite and perovskite. Turbid apatite prisms are common. A few granular aggregates of colorless clinopyroxene with magnetite show contours of former olivine phenocrysts that have been completely transformed into a mixture of these two minerals.

Specimen VM. 374.

Olivine-melilite-leucite-nephelinite. (vf, S). Dark grey vesicular lava with a few phenocrysts of yellow melilite and pyroxene. Under the microscope, the rock shows abundantly phenocrysts of yellowish turbid melilite with low, slightly anomalous interference colors. Only the largest of these crystals are visible to the unaided eye. Phenocrysts of titanian clinopyroxene and olivine are less abundant. Small aggregates of nepheline and a few leucite crystals are found. Some apatite is present. The groundmass is dark, cryptocrystalline.

Specimen S. 94 = VM. 354.

Dark olivine-nephelinite. (vf, S). The result of a bulk chemical analysis of the rock is presented in Table I, No. 4. The rock is very vesicular with olivine and clinopyroxene phenocrysts in a dark grey groundmass. Under the microscope, the rock is seen to be very melanocratic with only minor amounts of nepheline in the groundmass. The composition of the olivine phenocrysts is 84,5 mol. % Fo. The clinopyroxene is very pale-colored with slightly violet tints of the titanian variety. Not pleochroic. Hour-glass texture, twinning and zoning very marked. The clinopyroxene of the groundmass is pale greenish. Clinopyroxene is quantitatively the dominant constituent of the rock. Magnetite occurs in the groundmass partly as euhedral crystals and partly in skeletal development. Also hematite and apatite were found in the almost cryptocrystalline groundmass.

Specimens VM. 375, VM. 377 and VM. 378.

Olivine-melilite-nephelinites. (vf, M). These three specimens are very similar to each others and may be here described together. The rocks contain large rounded aggregates of nepheline-melilite and separate phenocrysts of titanian clinopyroxene, olivine, melilite and apatite. The core of the aggregates is usually rich in melilite and is surrounded by a mantle of nepheline crystals. No kalsilite could be detected microscopically. The groundmass is rich in magnetite and almost cryptocrystalline.

TERMINAL CONE.

MAIN CRATER OF NYIRAGONGO.

Petrographic descriptions of rocks from the main crater of Nyiragongo will be limited in this paper to the specimens listed below. These specimens have been chosen from a bulk of 84 sets of samples collected during systematic geological mapping of the crater that was carried out in February and June, 1956. The specimens here described are arranged according to the localities at which they have been collected, starting from the talus of fallen blocks at the foot of the SSE wall that forms a convenient landmark and turning clockwise around the crater.

The oldest flows exposed in the crater above the upper platform occur as thin lenses in the tuffs of the lower walls in the SW and W parts of the crater. The layers dip slightly towards NE and, accordingly, the flows outcropping in the N and E parts of the crater represent higher horizons. In establishing a rough stratigraphy of the flows, dykes visible in the walls are useful when their connection with flows as feeding channels is observable. Cone sheets and ring-dykes occur and their true nature is sometimes difficult to recognize.

The following specimens will be described :

VM. 246, VM. 147, VM. 163 and VM. 165 come from blocks in the SSE part of the talus mentioned above and represent flows in the upper third of the wall.

VM. 201 is from the border of a small ring-dyke outcropping ca. 6 m above the top of the said talus.

VM. 208 comes from an injected mass of lava, 50 m E of dyke No. 1. VM. 210 was taken from a horizontal lava bed related to the injected mass.

VM. 212 and VM. 213 come from the composite dyke No. 1 that is formed by greenish leucite-nephelinite with clinopyroxene phenocrysts injected into an older dyke of leucite-nephelinite with large aggregates of leucite and nepheline.

VM. 217 was taken from a lenticular flow, 5 m thick, located half-way between dykes Nos. 1 and 2.

VM. 157 represents the border and VM. 220 the heart of dyke No. 2.

VM. 158 is from the heart of dyke No. 3 that is visible on a vertical distance of more than 120 m.

VM. 230 comes from a small ring-dyke immediately N of dyke No. 3.

VM. 232 represents the highest of three horizontal flows outcropping in a spur 200 m N of dyke No. 3.

Specimens VM. 233 and VM. 234 come from dyke No. 4.

VM. 235 was taken 10 m above platform, 400 m N of dyke No. 3 and is typical of the main mass of flows overlying the tuffs in the NW part of the crater.

VM. 239 is a fallen block from a higher level of the N wall.

VM. 241 is the border phase of the important dyke No. 6 that feeds the flows occurring 100-120 m high in the N wall.

VM. 243 represents the big (sometimes nearly 1 m^3) blocks carrying conspicuous giant leucite phenocrysts found in the SW part of the upper platform, fallen from the upper third of the wall.

VM. 268 was taken from an isolated lava lens interstratified in a tuff bed half-way between dyke No. 6 and the « cape » jutting from the NE wall.

VM. 269 represents the lava flow capping the tuffs at the base of the « cape ».

VM. 270 comes from the coating of glassy lava that covers the NE wall and that has been erupted from the circular fissure running around the upper platform.

VM. 271 represents dyke No. 7 that may be followed up to a height of 130 m above the platform and perhaps extends even higher.

VM. 273 represents dyke No. 10. This dyke is older than dyke No. 11 and feeds flows located 25-30 m above the platform.

VM. 274 comes from the heart of dyke No. 11. This dyke cuts dyke No. 10 and feeds a massive flow underlying the highest tuff bed in the wall of that locality, at a height of 50-60 m.

R.G. 22770 was taken by the Reverend Van der Auwera in 1948 at a height of about 115-120 m (40 m below the rim). It is a bomb embedded in the main tuff layer.

From the relations observed, the following succession of flows from bottom to top is inferred :

Specimens VM. 208, VM. 210, VM. 217, VM. 232, VM. 235 and VM. 268 represent the oldest flows visible above the upper platform. The rocks are olivine-melilite-nephelinites.

Specimens VM. 269 and VM. 273 are melilite-nephelinites, following the olivine-bearing lavas, with olivine very scarce or absent.

Specimens VM. 157 and VM. 220 are melilite-leucite-nephelinites that, by appearance of leucite in the rock, represent a transition towards the leucite- and nepheline-bearing rocks of the higher levels. These last-named rocks can be conveniently split into lower and upper leucite-nephelinites.

Specimens VM. 274 (nepheline-leucitite), VM. 241 and VM. 212 (leucite-nephelinites with large leucite-nepheline aggregates) represent a leucite-dominated phase of the lower leucite-nephelinites. The SW and NW parts of the upper platform are littered with big leucitite blocks carrying giant leucite crystals (VM. 243), sometimes up to 15 cm in diameter (Plate III-*b*).

Specimens VM. 271, VM. 213 and VM. 158 are leucite-nephelinites, fine-grained, with some phenocrysts of nepheline and clinopyroxene, devoid of leucite phenocrysts. These flows will be called the upper leucite-nephelinites.

These rocks are followed by the Nepheline Aggregate lava that forms a thin coating op top of the main cone.

The following scheme summarizes the succession of flows visible above the upper platform of Nyiragongo crater, each phase being named after its distinctive mineral :

Top.	
Nepheline phase	Nepheline Aggregate lava. Upper leucite-nephelinites.
Leucite phase	Lower leucite-nephelinites. Nepheline-leucitites (sometimes giant-crystal facies).
Transitional phase	Melilite-leucite-nephelinites. Melilite-nephelinites.
Melilite phase	Olivine-melilite-nephelinites.
Bottom.	

In a recent paper, DENAEYER and TAZIEFF [7] give a tentative succession of lavas in the Nyiragongo crater that is substantially different from the succession listed here. As the conclusions of the present authors are based on abundant observations and on a map on the scale 1 : 2.000, chances are that the discrepancies are due to the conditions under which TAZIEFF visited the crater and that have been described by him separately [47]. More puzzling is the fact that the blocks containing the giant leucite crystals of Plate III-*b* seem to have been mistaken for Nepheline Aggregate lava as the reference « Des blocs de la même lave, à agrégats parfois énormes, sont éboulés sur le plancher de la caldère » [7, p. 219] can hardly apply to any other rock.

Specimen VM. 246.

Melilite-leucite-nephelinite. (f). Massive, even-grained lava with melilite (low, not anomalous interference color), leucite, nepheline, slightly greenish clinopyroxene, magnetite and apatite. Small amounts of green glass.

Specimen VM. 147.

Leucite-nephelinite. (c). Rather coarse-grained, grey-red lava, non-porphyritic. Under the microscope, the rock is seen to be holocrystalline with titanian clinopyroxene, subhedral nepheline, leucite, apatite and magnetite. Calcite is common, especially as a coating of the vesicles. No melilite.

Specimen VM. 163.

Leucite-nephelinite. (f, S). Aggregates of subhedral nepheline and leucite in a mesostasis very rich in violet to yellowish green clinopyroxene. Magnetite, apatite. No melilite.

Specimen VM. 165.

Leucite-nephelinite. (vf, L). Large phenocrysts of nepheline and leucite in a cryptocrystalline groundmass. A few small phenocrysts of pale-colored titanian clinopyroxene, apatite and magnetite. No melilite, nor olivine.

Specimen VM. 201.

Leucite-nephelinite. (vf, S). Slightly vesicular grey-black lava with a few aggregates of nepheline, leucite and titanian clinopyroxene in a very fine-grained groundmass that consists of the same minerals and, in addition, of magnetite and hematite. The clinopyroxene of the groundmass, partly greenish in color, occurs in small radial clots.

Specimen VM. 208.

Olivine-melilite-nephelinite. The rock is virtually identical with the specimen VM. 210. The only notable difference between the two specimens is the fact that the olivine of specimen VM.208 has been almost completely altered to a dark reddish brown mass.

Specimen VM. 210.

Olivine-melilite-nephelinite. (f, S). This specimen is considered the type rock for the oldest lava beds above the upper platform of Nyiragongo crater. The rock is light brown, sprinkled with dark melilite crystals, up to 2 mm in size. The lath-shaped melilite is optically negative with positive sign of elongation, shows low, not anomalous, interference colors and is very slightly zoned. The zoning becomes clearly visible only on using a rotating mica compensator. Optically the mineral is very similar to the melilites Nos. 1 and 2 of Table V that are both rich in åkermanite. The cores of the melilite crystals of specimen VM. 210 are prefectly fresh. On the margins, on the other hand, the crystals are altered to a yellow, extremely fine-grained material the identification of which is not possible under the microscope. Nepheline is mostly euhedral, clear and never shows any alteration. The mesostasis that fills the interstices between the melilite and nepheline crystals consists of colorless clinopyroxene, small amounts of olivine (large optic axial angle), magnetite, perovskite, calcite, probably zeolite, and, in addition, a slightly pleochroic, optically uniaxial negative mica, very faintly yellowish in color. Apatite prisms are rather common. The clinopyroxene has $c\Lambda\gamma=48°$, $2V_\gamma=67°$.

Specimens VM. 212 and VM. 213.

Leucite-nephelinites. Dyke No. 1. The dyke is composite. Specimen VM. 212 is finely vesicular, bluish, with abundant medium-sized phenocrysts of nepheline and leucite and smaller phenocrysts of titanian clinopyroxene in a cryptocrystalline leucite- and nepheline-rich groundmass. Specimen VM. 213, collected from the W border of the dyke, is greenish grey in color and contains acicular crystals of titanian clinopyroxene in a fine-grained, not cryptocrystalline groundmass of leucite, nepheline, titanian clinopyroxene and magnetite.

Specimen VM. 217.

Olivine-melilite-nephelinite. (f, S). Massive, brown lava with black crystals of melilite visible to the unaided eye. Microscopically the rock is similar to specimen VM. 210. The only difference between the two specimens is in the content of olivine that is more abundant in specimen VM. 217. The olivine of this specimen is never euhedral but occurs in poikilitic crystals enclosing nepheline, etc.

Specimens VM. 157 and VM. 220.

Melilite-leucite-nephelinite. Dyke No. 2. Large aggregates and separate phenocrysts of nepheline, melilite and leucite in a groundmass mainly consisting of the same minerals and magnetite. In specimen VM. 220 the groundmass is fine-grained and in specimen VM. 157 almost cryptocrystalline.

Specimen VM. 158.

Leucite-nephelinite. Dyke No. 3. (f, L). Compact greenish rock with aggregates of nepheline and phenocrysts of pale-colored titanian clinopyroxene. No leucite phenocrysts were found. The holocrystalline groundmass consists of nepheline, leucite, clinopyroxene and magnetite. Denaeyer and Tazieff [7] have published a chemical analysis of a specimen collected from this dyke. It shows a composition similar to that of specimen R.G. 4922 (Table I, No. 11), but is relatively more rich in potassium. In the material available to the authors, no microperthitic kalsilite was detected.

Specimen VM. 230.

Olivine-melilite-leucite-nephelinite. (m). Grey-brown compact rock. The predominating constituents of the rock are a low-birefringent melilite in thin laths and nepheline. Leucite and olivine are less abundant. Titanian clinopyroxene occurs in small quantities. Magnetite, apatite, probably zeolite, calcite and traces of pale brownish biotite.

Specimen VM. 232.

Olivine-melilite-nephelinite. (f, M). Finely vesicular lava. Abundant medium-sized phenocrysts of pale-colored titanian clinopyroxene. Less numerous phenocrysts of olivine, heavily altered melilite and nepheline. Holocrystalline groundmass consisting of the same minerals and magnetite. Apatite prisms. Numerous vesicles filled with calcite.

Specimens VM. 233 and VM. 234.

Olivine-melilite-nephelinites. Dyke No. 4. (m, S). The two specimens are similar to each others. Compact brownish grey rocks. Small phenocrysts of melilite in a medium-grained granular groundmass that consists of subhedral nepheline, melilite, almost colorless clinopyroxene, perovskite, magnetite and apatite. Olivine is scarce and occurs as a few very small phenocrysts. Some calcite and probably zeolite. The rocks are very similar to specimen VM. 210.

Specimen VM. 235.

Olivine-melilite-nephelinite similar to specimen VM. 217.

Specimen VM. 239 (fallen block).

Nephelinite. (vf). Blue-black slightly vesicular lava without phenocrysts. Almost cryptocrystalline. Greenish clinopyroxene, nepheline, magnetite.

Specimen VM. 241.

Leucite-nephelinite. Dyke No. 6. Similar to specimen VM. 165 except that the groundmass is more coarse-grained.

Specimen VM. 243.

This specimen contains gigantic crystals of leucite, up to 15 cm in diameter, in an almost cryptocrystalline groundmass very rich in greenish clinopyroxene and magnetite and containing a few small phenocrysts of violet-colored titanian clinopyroxene and apatite.

Specimen VM. 268.

Olivine-melilite-nephelinite. (f, M). Grey-brown vesicular lava with a few well-formed dark augite and yellow melilite crystals. Microscopically, the rock contains phenocrysts of pale-colored titanian clinopyroxene, low-birefringent melilite, olivine and nepheline in a granular holocrystalline groundmass of the same minerals with magnetite, perovskite and apatite. Numerous calcite veins.

Specimen VM. 269.

Melilite-nephelinite, kalsilite-bearing. (vf, L). Bluish vesicular lava with phenocrysts of melilite and nepheline, partly collected into aggregates. The nepheline crystals often show a non-perthitic core of kalsilite. The very fine-grained holocrystalline groundmass consists of the same minerals and colorless clinopyroxene, magnetite, perovskite. Apatite prisms. Calcite. Olivine is very scarce.

Specimen VM. 270.

Nephelinite. Very vesicular, almost opaque glassy lava with a few very small phenocrysts of nepheline.

Specimen VM. 271.

Leucite-nephelinite. Dyke No. 7. (vf, S). Grey-brown lava. Numerous aggregates of nepheline and leucite too small for detection by the unaided eye. Groundmass very fine-grained with the same minerals and colorless clinopyroxene and magnetite.

Specimen VM. 274.

Nepheline-leucitite. (f, S). Dyke No. 11. A few phenocrysts of pale-colored clinopyroxene. Numerous small crystals of leucite and nepheline in a groundmass of the same minerals and colorless clinopyroxene. Magnetite.

Specimen VM. 273.

Melilite-nephelinite. Dyke No. 10. The rock is similar to specimen VM. 269 except that olivine could not be found in the two thin sections available. Kalsilite cores in some of the nepheline crystals.

Specimen R.G. 22770.

Olivine-leucitite, nepheline-bearing. (f, S). Crystals of leucite, sometimes collected in small aggregates, and olivine in a fine-grained groundmass consisting mostly of titanian clinopyroxene, magnetite, leucite, nepheline and olivine. Apatite and minute amounts of potash feldspar. The chemical composition of the rock is presented in Table I, No. 5.

EJECTED BLOCKS.

The rim of the crater and the upper slopes of the cone of Nyiragongo are littered with ejected blocks displaying considerable differences in texture and composition. In spite of keen search, no rocks of sedimentary origin have been discovered. In the neighbouring Nyamuragira, ejected sedimentary material is abundant. The only foreign material found on Nyiragongo is represented by sponges of completely molten quartz. The type rock for « niligongite » of A. LACROIX was collected from an ejected block. No representative of the olivine-biotite-pyroxenite family of A. HOLMES has been found either.

Only two specimens will be described in this paper. Specimen VM. 12 was collected from an inclusion in the Western Spur flow at an elevation of 3.130 m and specimen R.G. 22778, collected on the S rim in 1945 by the native guide ISHAHUNDA.

In the description of the fire-pit, a possible mode of origin was suggested for the ejected holocrystalline blocks.

Specimen VM. 12.

Melilite-leucite-nephelinite with sparing amounts of olivine. (vc). A grey, even-grained, coarse (grain size up to 5 mm), holocrystalline, massive rock. Nepheline (26,0 mol. % Ks) is slightly more abundant than leucite. Melilite has a somewhat higher birefringence than the melilite that occurs in the Nepheline Aggregate lava. The amount of the mineral present in the rock is rather small. The clinopyroxene shows the typical appearance and colors of a titanian variety. Magnetite, apatite and traces of biotite. The result of a bulk chemical analysis of the rock is given in Table I, No. 7. Compared with the Nepheline Aggregate lava, this rock contains less alumina and alkalis and slightly more calcium and magnesium.

Specimen R.G. 22778.

Melilite-leucite-nephelinite. (f). This specimen is of a special mineralogical interest. It is massive to slightly vesicular grey lava without visible phenocrysts. Microscopically, the rock proves to be granular, leucocratic with nepheline, melilite, leucite and some colorless clinopyroxene, magnetite and apatite. The result of a bulk chemical analysis of the rock is given in Table I, No. 6. In the few small cavities that are found in the rock, an olivine-looking mineral was found that was subjected to closer chemical, optical and X-ray study. The results of this study will be published elsewhere. The mineral represents a sub-calcium magnesian kirschsteinite, a member of the olivine group the chemical composition of which lies between the monticellite-kirschsteinite and the forsterite-fayalite series. So far, such a calcium olivine has been recognized only from this specimen.

NEPHELINE AGGREGATE FLOWS.

The name Nepheline Aggregate flows is applied to a large number of flows in which the composition of the lava may vary within rather wide limits but share the common character of carrying conspicuous aggregates of nepheline crystals. The name is used as a field name. These flows cover the terminal cone of Nyiragongo like the icing on a cake. Their bulk is much less than what their areal extension would suggest. Most specimens from Nyiragongo collected by previous visitors represent this lava type, on which undue emphasis is thus placed in collections and literature.

The origine of the Nepheline Aggregate flows has been discussed above (p. 37). The lower ends of the flows are hidden in the dense forest that covers the lower reaches of the mountain. In the upper part, nearly all Nepheline Aggregate flows are of the « pahoehoe » type and grade into « aa » near to the 3.000 m level where a distinct break in the slope occurs. This type of lava must have been highly viscous on emission because some flows stop on slopes inclined at 25°.

The age of these flows is unknown. They are posterior to the extinction of Shaheru and anterior to the collapse of the main crater.

Origins of specimens cited in the text below are as follows :

Specimen R.G. 4922. Specimen No. 1650 of F. DELHAYE. Exact locality unknown.

Specimen S. 76. Path on Kanega, SE slope of Shaheru at an elevation of 2.300 m.

Specimen VM. 21. Upper saddle between Shaheru and Nyiragongo at an elevation of 2.810 m.

Specimen S. 77. NE slope of Shaheru at an elevation of 2.530 m.

Specimen S. 82 = VM. 400. Flow invading the bottom of the Shaheru crater.

Specimen R.G. 4925. Top of Nyiragongo. Exact locality unknown.

Specimen S. 95 = VM. 361. Saddle between Nyiragongo and Baruta at an elevation of 3.045 m.

Specimen S. 84 = VM. 387. NE slope of the main cone of Nyiragongo at an elevation of 3.300 m.

Specimen R.G. 5033. Main crater of Nyiragongo. Collected by J. FONTAINE in 1924. Exact locality unknown.

Specimens FEAE No. 87 and FEAE No. 89. Near to km point 224 on the Goma-Rutshuru road.

Specimen FEAE No. 93. S slope of Nyiragongo at an elevation of 2.950 m.

Notes on the mineralogy and petrography of the Nepheline Aggregate flows have been published by SAHAMA and WIIK [30] and SAHAMA [31]. In the last named paper two bulk chemical analyses of the lava were given. Since then, two new chemical analyses have been made of rocks probably belonging to the Nepheline Aggregate lava. All these analyses are collected in Table I, Nos. 8, 9, 10 and 11. As will be seen from that table, the lava of the Nepheline Aggregate flows varies remarkably in chemical composition. Despite the variations, some distinct characteristics are in common to these lavas. In addition to the low silica content, the Nepheline

Aggregate lava is characterized by high contents of aluminum, calcium and alkalis and by a low content of magnesium. In weight percent, potash is mostly in excess over soda.

In literature, the Nepheline Aggregate lava has sometimes been erroneously called leucite lava. Such a statement was probably based only on field observations and not on microscopic study of the specimens.

Probably the most characteristic feature in the mineralogy of the Nepheline Aggregate lava is the richness in potassium component of the nepheline phenocrysts. In the two papers mentioned above, seven chemical analyses have been presented of nepheline occurring as phenocrysts in the lava. According to these analyses, that will not be reproduced here, the composition of nepheline ranges from 36,6 to 42,1 mol. % Ks. Original material for the analyzed nephelines have been used by SMITH and SAHAMA [41] in establishing a method for determining the composition of natural nepheline by X-ray powder pattern. Further determination of the compositions of nepheline in Nepheline Aggregate lava are summarized below :

Specimen.	Composition of nepheline.
R.G. 9422	25,6 mol. % Ks.
S. 76	26,7
VM. 21	42,7
S. 77	43,3
S. 82	43,7
R.G. 4925	44,6
S. 95	44,6
S. 84	44,8
R.G. 5033	45,5

With the exception of the two first specimens listed, viz. R.G. 4922 and S. 76, the nepheline compositions found range between 42,7 and 45,5 mol. % Ks. The contents of the potassium components in the nephelines of specimens R.G. 4922 and S. 76 is much lower. Both these specimens look like Nepheline Aggregate lava proper. For explaining the relatively low potassium contents in these two specimens, two alternatives are possible. Either these specimens belong the other flows than the Nepheline Aggregate lava proper or there are locally considerable variations in the potassium content of the Nepheline Aggregate lava nepheline. No matter which one of these possible explanations will prove to be correct, the fact still remains that the potassium content found in the nepheline of the Nepheline Aggregate lava is among the highest recorded so far in natural rocks. At present, such potassium-rich nephelines are not known outside the Nyiragongo area.

According to synthetic studies of the phase equilibrium relationships in the nepheline-kalsilite system by Drs. O. F. TUTTLE and J. V. SMITH at the Geophysical Laboratory of the Carnegie Institution of Washington (both now at the Pennsylvania State College, University City, Penn.), a very large gap in solid solubility exists in the nepheline-kalsilite series in the sub-solidus temperature range. The exact location of the two-phase area in the phase diagram of that system has not yet been published. Preliminary data about the phase diagram of that system has kindly been put at the author's disposal by Dr. SMITH. According to this information, it seems that the composition of the very potassium-rich nephelines of the Nepheline Aggregate lava would fall into the two-phase area of the phase diagram at low temperatures. Accordingly, these nephelines must have crystallized at higher temperatures, say, above 750°-950° C depending on the composition. On cooling below that temperature range, an exsolution into a more sodic nepheline and a kalsilite phase may be expected. In the paper previously published by one of the authors [31], no sign of exsolution was reported for the nepheline of the Nepheline Aggregate lava. Later, Professor C. E. TILLEY, of Cambridge, found one single crystal of perthitic nepheline-kalsilite in a thin section of one of the specimens (personal communication) and, still later, the authors found another similar case in another specimen. These observations prove that exsolution occurs in the nepheline of this lava, and that the exsoluted nepheline-kalsilite crystals are extremely rare and may be found only with good luck. Careful examination of quite a number of thin sections of Nepheline Aggregate lava has revealed no sign of exsolution. The fact that the exsolution is extremely rare may be explained by the rapid cooling of the lava or by a remarkable sluggishness of the exsolution for nephelines of composition around 40 mol. % potassium component.

Strongly exposed single crystal Weissenberg photographs taken of the nepheline from Nepheline Aggregate lava have revealed a complex structure similar to that previously found for the nepheline from Iivaara, Finland [36]. Further X-ray work on this point is in progress. The Weissenberg photographs invariably give a pattern corresponding to the space group $P6_322$ instead of $P6_3$. This fact probably indicates that the nepheline of the Nepheline Aggregate lava is intimately twinned. Of the six nephelines of which chemical analyses have been published by SAHAMA [31], unit cell dimensions have been determined by powder patterns. The results will be published on a later occasion and are not reproduced here. The values for a_0 and c_0 are very slightly lower than those found for synthetic nepheline preparations by SMITH and TUTTLE [43]. Of specimen FEAE No. 87, a prism was ground of a nepheline crystal. Using an optical goniometer and a Leitz monochromator, the refractive indices were measured for a number of different wave lengths. The results are summarized in Table VIII. Of several nephelines from the Nepheline Aggregate lava and of more sodic nephelines from other sources, a number of heat of solution experiments have been made. The nephelines were dissolved in an acid mixture containing 15 % HF and 5 % HCl at a temperature of 75° C. The results that will be published on a later occasion show heats of solution for the nephelines of the Nepheline Aggregate lava that are ca. 10 cal./gram higher than would be expected if the heats of solution found for the more sodic nephelines are extrapolated to the Nepheline Aggregate lava nephelines. This difference is 4-5 times as great as the uncertainties of the measurements.

Of specimen FEAE No. 93, melilite and titanian clinopyroxene were separated and chemically analyzed. The results of the analyses with optical and physical data are summarized in Tables V, No. 2 and IV, No. 2, respectively.

Outcrops surrounded by the Nepheline Aggregate flows.

Two important outcrops of older rocks have been found on the upper slopes of Nyiragongo that are surrounded by the Nepheline Aggregate flows. On the SW flank of the mountain, the spur previously mentioned (p. 12) is covered by leucite-nephelinite flows of the type of dyke No. 3. Specimen VM. 401 was collected on the SW rim of Nyiragongo and represents the spur. On the other hand, on the eastern flank of the mountain, at an elevation of 2.900 m, a small crater is visible in the forest. In the wall of that crater, leucite-bearing lavas and pyroclastics carrying leucite crystals up to 1 cm across are found. Specimen S. 98 represents the flows, while specimen S. 97 comes from a bomb embedded in the lavas.

Specimen VM. 401.

Leucite-nephelinite. (f, L). The rock is very similar to that of specimen VM. 158.

Specimen S. 98.

Leucite-nephelinite. (m, L). The rock is porphyritic. The phenocrysts, mostly collected in aggregates, are leucite, nepheline and titanian clinopyroxene. Apatite prisms are found under the microscope. The dark grey groundmass is holocrystalline medium-grained. It consists mainly of green clinopyroxene, often brownish in the core, nepheline, leucite and magnetite.

Specimen S. 97 = VM. 383.

Nepheline-leucitite. (vf, L). In hand specimen, the rock is characterized by numerous leucite crystals, up to 1 cm in size, and by slightly smaller well-developed nepheline (19,2 mol. % Ks) prisms. Microscopically, titanian clinopyroxene and apatite are also found as small phenocrysts. The nepheline shows an unusually well-developed basal and prismatic cleavage. Further X-ray work with this nepheline is in progress. The groundmass is almost cryptocrystalline with mainly green clinopyroxene, magnetite and nepheline. The chemical composition of the rock is presented in Table I, No. 12.

FLOWS AND CONES SURROUNDING THE MASSIF.

KABFUMU FLOW.

The Kabfumu flow consists of block lava and is cut by the Goma-Rutshuru road near to km point 234. The extension and origin of the flow is unknown. The flow is partly covered by ash and disappears under younger flows. From topographic features and from the presence of ejected blocks on the Kabfumu hill, it is suggested that the small crater of that hill, situated E of km point 234,4 of the said road, might represent the source of the flow. This correlation is, however, only tentative.

Specimen FEAE No. 83 was taken as a batch of more than 100 kg at km point 234,7 on the road. This specimen is considered the type specimen of the Kabfumu flow.

Petrographic characteristics and bulk chemical composition of the rock have already been reported on a previous occasion [32]. However, the name Kabfumu flow was not applied to this lava in that paper. Since 1953, some of the constituents of the Kabfumu flow lava have been subjected to more detailed investigation. The chemical analysis of the rock previously published is reproduced in Table I, No. 13. According to its mineralogical composition, the rock may be called olivine-melilite-nephelinite, kalsilite-bearing. The amount of modal olivine is considerably smaller than indicated by the norm, yet it is characteristic of the rock and can not be regarded only as an unessential accessory.

The rock is typically glomeroporphyritic with large aggregates of complex nepheline-kalsilite and melilite phenocrysts in a medium-grained groundmass. Melilite was chemically analyzed and the result of the analysis with additional optical and physical data are presented in Table V, No. 1. The mineralogy of the complex nepheline-kalsilite phenocrysts and their history of crystallization has been recently described by SMITH and SAHAMA [42], SAHAMA and SMITH [40] and SAHAMA [35]. The phenocrysts consist of a core of perthitic nepheline-kalsilite of average composition 72 ± 3 mol. % Ks, surrounded by a nepheline margin of 40 mol. % Ks in parallel orientation. The perthitic core consists of the following phases in parallel growth : nepheline I (59 mol. % Ks), nepheline II (35 mol. % Ks), d-kalsilite with $a_0 \backsim 5{,}15$ Å (ordinary disordered form of kalsilite), o-kalsilite with $a_0 \backsim 8{,}9$ Å (ordered form of kalsilite), trikalsilite with $a_0 \backsim 15{,}3$ Å. On heating, the core inverts at $860° \pm 10°$ C into homogeneous tetrakalsilite with $a_0 \backsim 20{,}5$ Å. The inversion is very rapid and reversible. At a temperature of ca. 1.000° C, tetrakalsilite inverts into extremely potassian nepheline. Trikalsilite is considered entirely metastable. Transitional forms between d-kalsilite and o-kalsilite occur. It is concluded that the phase transitions in the complex nepheline-kalsilite phenocrysts have not reached equilibrium.

TEMBO FLOW.

The Tembo (= elephant) flow has been so named because of the frequent appearance of these animals in this area where geographical denominations are sadly lacking. The flow is a thin sheet of pahoehoe and aa with badly marked borders. It originates somewhere W of km points 233-234 of the Goma-Rutshuru road, probably near to the Gisi hill. This hill must not be confused with the Gisi or Kisi near to Nyundo which is supposed to be the type locality of kivite. Towards NE, the flow dies out in small tongues in the hilly terrain N of Kibumba.

Specimen S. 6 was taken at km point 234,2 and specimen S. 3 comes from the layer on top of the Kabfumu flow at km point 234,7 of the road.

Specimen S. 6.

Melilite-nephelinite. (m, S). A dark grey lava with a few small clinopyroxene phenocrysts. The rock was chemically analyzed as the type specimen of the flow and the result is presented in Table I, No. 14. The main leucocratic constituent is euhedral nepheline (23,3 mol. % Ks). No kalsilite lines were found in the powder pattern of the isolated nepheline fraction of which the determination was made. The optically negative melilite occurs as stout prisms with positive sign of elongation. $\varepsilon = 1{,}634$, $\omega = 1{,}638$. The clinopyroxene shows color and hour-glass texture typical of the titanian variety. The composition of the euhedral olivine that occurs in small amounts is 61,2 mol. % Fo. Leucite is very scarce. Magnetite abundant. Small amounts of apatite and calcite present. Interstitially, a greenish glass is common.

Specimen S. 3.

Melilite-nephelinite similar to specimen S. 6, except that a few small phenocrysts were found that consist of a kalsilite core surrounded by a nepheline margin.

LEUCITE FLOWS.

This important rock unit has been named for the presence of conspicuous leucite aggregates that make the lava easily recognizable in the field. All the flows encountered were of the pahoehoe type, often with beautiful structures of ropy lava.

The origin of the Leucite flows lies on the E slope of Nyiragongo somewhere in the dense forest that covers the lower central part of the massif. No representative of this lava type has been found in the upper part of the main cone of the mountain. As the Leucite flows cover advanced tongues of the Nepheline Aggregate flows, they can not be correlated with the leucite-nephelinites occurring in the main crater of Nyiragongo but represent a leucite-dominated phase of the Nyiragongo lavas that is posterior to the nepheline phase. The absence of important eruptive structures in the area of the supposed origin of the Leucite flows is not astonishing, since the demonstration of the emission of about 4×10^8 m^3 of lava during the 1938-1940 eruption of Nyamuragira from a vent that would just hold a good-sized bungalow [49].

With the exception of some cracks and groups of hornitos, the Leucite flows are the youngest volcanic feature in the region E of Nyiragongo. They surround or bury partly or nearly completely the smaller cones and cover adjacent flows. They have invaded and filled the depression of nearly 50 km^2 between Kibati and Kibumba, overflowing towards S and creating lava scarps in the constricted passages.

The main types are represented by the following specimens :

Specimen S. 45. SW of Tshawato.

Specimen FEAE No. 85. Near to km point 232 of the Goma-Rutshuru road.

Specimen S. 42. W foot of Tshawato.

Specimen S. 106. 1 km W of the Goma-Rutshuru road along the path leading to Nyamushwa.

The vesicular Leucite flow lava is glomeroporphyritic with aggregates or single crystals of leucite and titanian clinopyroxene as phenocrysts. The aggregates may reach 1 cm in diameter. The number of the large leucite aggregates varies. In most parts of the flow they are very abundant, in others less numerous and sometimes they are almost entirely lacking. The size of the clinopyroxene crystals occurring as phenocrysts does not usually exceed a few tenths of a millimeter. In the hand specimen, the clinopyroxene phenocrysts or phenocryst aggregates are by far less pronounced than the leucite aggregates. The groundmass is fine- to medium-grained and shows a dark grey color. In some spots the groundmass of a thin layer of the lava surface is glassy.

According to chemical and mineralogical composition, the Leucite flow lava represents olivine-leucitite, more or less nepheline-bearing. Microscopic examination of specimens collected on a number of spots throughout the flow reveals certain variations. Accordingly, the lava material may be divided into a few types each of which has its own characteristics. These types differ in the groundmass, not in the phenocrysts.

The main type.

The specimen S. 45 was selected as the type specimen for the main type of the lava of the Leucite flows. A microscopic description of this specimen is given below.

Leucite occurs as phenocrysts that are beautifully twinned and as small euhedral crystals in the groundmass. n = 1,509.

The clinopyroxene occurring as phenocrysts shows a pale brownish color, very slightly violet, without noteworthy pleochroism. The crystals are often strongly zoned with the margin slightly darker than the core. The zoning causes relatively large variations in optical properties :

$$\alpha = 1{,}711\text{-}1{,}722,$$
$$\beta = 1{,}722\text{-}1{,}729,$$
$$\gamma = 1{,}732\text{-}1{,}744,$$
$$2V_\gamma = 49°\text{-}63°,$$
$$c\Lambda\gamma = 46°\text{-}64°.$$

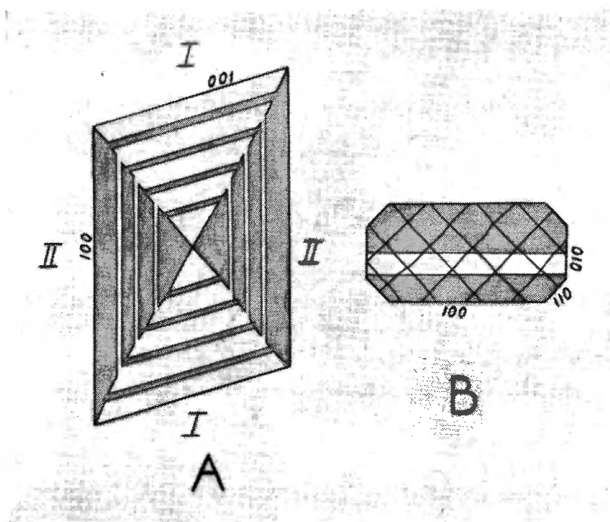

FIG. 4. — Schematical presentation of hour-glass texture (A) and twinning (B) in the clinopyroxene of specimen S. 45. Leucite flows.

These optical properties are virtually identical with those of the titanian clinopyroxene from specimen FEAE No. 85 of which a chemical analysis will be given below. Accordingly, also the clinopyroxene of specimen S. 45 must represent a titanian variety. In addition to the zoning, almost every clinopyroxene crystal occurring as a phenocryst or in the groundmass shows a well-developed hour-glass texture. Because the hour-glass texture in a similar development is extremely common in the titanian clinopyroxene of the Nyiragongo area lavas, it may be briefly described taking the clinopyroxene of this specimen as a type mineral.

The hour-glass texture is schematically shown in figure 4-A that represents a section parallel to (010). The crystal consists of two pairs of sectors that are marked I and II in figure 4-A. The boundaries between the sectors are sharp but irregular. The position of extinction is slightly differing for the two pairs of sectors. A preliminary universal stage study revealed the fact that the crystallographic c-axes of the both pairs of sectors are closely, but not exactly, parallel with each others. In both pairs of sectors a number of relatively thin and very sharp lamellae are seen that lie parallel with the outer faces of the clinopyroxene crystal. These lamellae seem not to represent alternate zones of differing chemical compositions. Between crossed nicols the lamellae found in sector I extinguish simultaneously with sector II and the lamellae occurring in sector II show an extinction position parallel with that of sector I. Accordingly, the lamellae occurring in sector I have the same orientation as sector II and vice versa. An X-ray

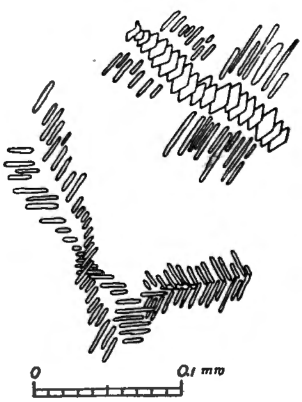

FIG. 5. — Leaf-like skeletons of basaltic hornblende in the main type of lava of the Leucite flows. Specimen S. 45.

study of the hour-glass texture will be undertaken later. In addition to the hour-glass texture, the clinopyroxene crystals are often twinned on (100), sometimes in lamellar development. The twinning, schematically illustrated in figure 4-B, is mostly seen in sections closely perpendicular to the crystallographic c-axis. The color of clinopyroxene of the groundmass varies from brownish violet to greenish and to almost colorless.

In addition to clinopyroxene, the groundmass contains a relatively large amount of basaltic hornblende. It occurs only as leaf-like skeletons schematically illustrated in figure 5. The angle between the two prism faces corresponds to that of an amphibole. The optic axial plane is parallel to (010). The extinction angle $c \wedge \gamma$ is small. Because of the small grain size (0,01 mm or less), its accurate value is difficult to determine. Pleochroism very strong : γ and β dark brown, α yellowish green.

According to planimetric analysis, the amount of olivine present in the rock is ca. 1 %. It occurs as small euhedral phenocrysts with notable signs of resorption. Its composition corresponds to 68,8 mol. % Fo.

Magnetite occurs in two generations, as euhedral crystals and in skeletal development in the groundmass. The groundmass contains small amounts of nepheline detectable only with very high power. The extremely small grain size made its identification difficult. For the same reason, it can not be enriched with heavy liquids for X-ray determination of composition. Small apatite prisms are present.

The small grain size of the groundmass does not allow a planimetric analysis with the integration stage. The bulk chemical composition of the rock is presented in Table I, No. 15. The chemical compositions of basaltic hornblende and of nepheline not being known, the modal mineralogical composition of the rock can not be calculated from the bulk analysis.

The more coarsely crystalline type.

The specimen FEAE No. 85 was selected as the type specimen for this type of lava of the Leucite flows. In the field, the more coarsely crystalline type can not be distinguished from the main type described above. Microscopically the more coarsely crystalline type differs from the main type by the somewhat larger grain size of the groundmass that averages 0,05 mm. Basaltic hornblende is absent and, therefore, no skeletal leaf-like texture occurs in the groundmass. Like the main type, also the more coarsely crystalline type contains leucite and clinopyroxene as most abundant constituents, both occurring as phenocrysts and in the groundmass. The leucite crystals are always twinned. The mineral was separated and chemically analyzed. Table VI gives the result of the analysis indicating 6,8 mol. % sodium component. The clinopyroxene phenocrysts were also separated and chemically analyzed. The result of the analysis and the optical properties are reproduced in Table IV, No. 1. The mineral represents a typical titanian variety of clinopyroxene. According to the analysis, the atomic ratio Ca : Mg : ($Fe^{3+}+Fe^{2+}$) is 51,9 : 32,6 : 15,5. The mineral thus represents a titanian salite. Zoning, hour-glass texture and twinning are similar to those found in specimen S. 45. The color of the clinopyroxene varies in the groundmass more than in the phenocrysts. The margins in the crystals of the groundmass do not often show the brownish violet color typical for titanian clinopyroxene but are pale greenish to colorless. Accordingly, the chemical composition of clinopyroxene in the groundmass varies more than in the phenocrysts and is probably partially poor in titanium. Because of the small grain size of the groundmass, the optical orientation of its clinopyroxene was not accurately determined. The euhedral olivine crystals sometimes reach a grain size above that of the groundmass. The crystals show no sign of resorption. A determination of the composition of olivine yielded 71,0 mol. % Fo. In contrast to the main type, the more coarsely crystalline type contains relatively abundant nepheline in well detectable grains in the groundmass. Its composition is 11 mol. % Ks and is, accordingly, unusually poor in potassium. The low potassium content of nepheline is probably a result of the high leucite content of the rock. Magnetite occurs in two generations, as euhedral crystals that may reach a grain size somewhat larger than that of the average groundmass and, on the other hand, in a skeletal development in the groundmass together with the interstitial leucite and nepheline. In addition, the groundmass contains small apatite prisms and brownish to greenish isotropic glass with $n = 1,50$-$1,51$. Some few amygdules of quartz have been found that contain small amounts of a cristobalite-looking mineral. The powder pattern of that material gives the two strongest lines of cristobalite.

The bulk chemical composition of specimen FEAE No. 85 is given in Table I, No. 16. A comparison of the analyses of Table I, Nos. 15 and 16 with each others reveals a similarity between these two rocks of the Leucite flows. The slightly higher figure for silica for specimen FEAE No. 85 may be partly caused by the quartz amygdules not found in specimen S. 45. In alkali ratio, however, the two specimens differ from each others, the figure for potash being clearly higher for specimen FEAE No. 85. The groundmass of specimen FEAE No. 85 is too fine-grained for a complete planimetric analysis. Only the amounts of olivine and leucite could be approximately measured with the integration stage. On the basis of the chemical analysis supported by the integration stage measurements, the following very rough modal composition may be given :

Modal composition of specimen FEAE No. 85.

Leucite	36 %
Nepheline	17 %
Clinopyroxene	38 %
Olivine	1 %
Magnetite	5 %
Apatite	3 %
Total	100 %

Highly nepheline-rich type.

In addition to the rock types described above in which leucite definitely predominates over nepheline, the lava of the Leucite flows may sometimes show an amount of nepheline that exceeds that of leucite. The leucite phenocrysts are relatively scarce. The clinopyroxene phenocrysts are similar to those of the main type and of the more coarsely crystalline type. The clinopyroxene of the groundmass, on the other hand, is mostly greenish or colorless and only to a lesser extent brownish violet.

The specimens S. 42 and S. 106 represent glassy surface of the lava of Leucite flows. In these specimens euhedral phenocrysts of clinopyroxene, leucite, olivine and apatite are in a glassy groundmass. The glass of specimen S. 42 has n = 1,599.

TSHAWATO.

The small cone Tshawato is the easternmost outpost of the cluster of satellite cones SE of Shaheru. The volcano is relatively old and is completely surrounded by the Leucite flows. Cored bombs containing basement rocks and isolated fragments of mica-schists and pegmatitic material are abundant. The location of Tshawato near to the strike of the Uashungwe ridge, the N end of which is situated 2 km S of Tshawato, leads to the suggestion that this ridge of basement rocks has a northern extension now buried under lava flows.

Specimens collected : S. 44 and S. 43 are pieces of bombs from the N rim of the crater.

Specimen S. 44.

Very dark olivine-leucitite. (vf, M). Phenocrysts of pale-colored titanian clinopyroxene and olivine (84,5 mol. % Fo) in an almost cryptocrystalline groundmass that consists of clinopyroxene, magnetite, small amounts of olivine and traces of leucite.

Specimen S. 43.

Nepheline-leucitite. (f, L). Chemical composition summarized in Table I, No. 17. Phenocrysts of leucite, often collected in aggregates, titanian clinopyroxene, magnetite and apatite. Holocrystalline, fine-grained groundmass containing clinopyroxene, leucite, nepheline (28,0 mol. % Ks), magnetite and traces of accessory olivine.

WAR CEMETERY FLOW.

The War Cemetery flow has been named after the double Cemetery of World War I, situated at Kibati between the main flow and its W tongue. The region covered by this study is cut by the border between the Belgian Congo and Ruanda, formerly part of German East Africa, and was the scene of fierce fighting in 1914-1915.

The material of the flow is block lava in the N part and grades into aa towards S. The flow originates in the group of small cones N of Kibati called Kabfumu and Kanenemohange but these names have not been applied to the flow because of their confusing or cumbersome character. To E, the flow disappears under the Leucite flows while to W it is first covered by the Nyakabanda flow and then skirts the Buhama and Bushwaga hills.

Towards S, one tonge crosses the Goma-Rutshuru road between km points 211,1 and 211,6 and stops close to the Goma aerodrome while the main mass forms rocky knolls SE of Bushwaga.

Localities of specimens collected :

Specimen S. 40. E of Badgiru hill.
Specimen S. 46. W of Mukondo hill.
Specimen S. 67. S of Bukanda hill.
Specimen S. 22. Km point 211,5 of the Goma-Rutshuru road.

In the field, the War Cemetery lava shows only a few phenocrysts of pyroxene and leucite. Specimen S. 40 was selected as a type specimen and was chemically analyzed. The result is presented in Table I, No. 18. According to its chemical and mineralogical composition, the rock may be called leucite-nephelinite.

Under the microscope, the clinopyroxene phenocrysts show the brownish violet colors typical of the titanian variety. Hour-glass texture and twinning is common. The following optical properties were measured on material from specimen S. 40 :

$$\alpha = 1{,}713\text{-}1{,}726,$$
$$\beta = 1{,}719\text{-}1{,}731,$$
$$\gamma = 1{,}735\text{-}1{,}748,$$
$$2V_{\gamma} = 56°\text{-}60°,$$
$$c\Lambda\gamma = 44°\text{-}50°.$$

The large variations in the optical properties are caused by heavy zoning. The leucite phenocrysts form sometimes small aggregates that, unlike those in the lava of the Leucite flows, are never numerous. The constituents of the almost cryptocrystalline groundmass are clinopyroxene, magnetite, nepheline, leucite and, in minute quantities, greenish glass. The clinopyroxene of the groundmass is pale greenish to colorless. The magnetite crystals are usually euhedral, mostly very small and only very rarely reach a grain size slightly above that of the average groundmass. Nepheline is very abundant and is usually sprinkled with small magnetite and clinopyroxene crystals. The composition of nepheline was determined of the following specimens :

Specimen.	Composition of nepheline.
S. 40	29,7 mol. % Ks.
S. 46	28,0
S. 67	27,2
S. 22	25,4

Leucite occurs as twinned rounded crystals. The apatite prisms often reach a size considerably larger than that of the average groundmass. Olivine is very scarce. Only a few small crystals were detected.

Mudjoga flow.

The small Mudjoga flow originates in the saddle between the Buyinga and Mudjoga cones and seems to be related to the latter. The official map uses the spelling Djoga but the authors retained the native denomination. The flow is block lava, only 2 km long, and partly surrounds the Lemera hill. The flow is older than the Buyinga and Nyakabanda flows. In the field, only a few minute phenocrysts of pyroxene and very rarely small aggregates of leucite may be detected in the dark grey groundmass.

Specimen S. 107 was collected immediately N of Lemera and represents the lava. This specimen was chemically analyzed and the result of the analysis is presented in Table I, No. 19. The composition of this rock is not very different from those of the Nyakabanda and Buyinga flow lavas. The Mudjoga flow lava is, however, slightly less melanocratic. According to its mineralogical composition, the Mudjoga flow lava represents leucite-nephelinite. Microscopically, the pyroxene of specimen S. 107 occurring as phenocrysts proved to be a titanian clinopyroxene. Small leucite aggregates or separate crystals, apatite needles and magnetite grains reach a size well above that of the average groundmass. Nepheline phenocrysts are small and rare. A small amount of nepheline was isolated with Clerici's solution. Its composition was determined to 27,6 mol. % Ks. Olivine, as small euhedral phenocrysts, is very scarce. The groundmass is almost cryptocrystalline. It is very rich in nepheline, pale greenish clinopyroxene and magnetite. A small amount of green glass is detectable.

Buyinga flow.

The Buyinga flow represents one of the main rock units being second in extension only to the Leucite flows. The lava is of the pahoehoe type and flowed at least 10 km towards SSW. Excavations made during the construction of the new aerodrome at Goma show that the S part of the Buyinga flow is a thin sheet of lava covering another flow of similar characters that flows into Lake Kivu. It is not clear wheather this lower flow also belongs to the Buyinga lava. The flow originates in the composite cone called Luyaka, the two main craters of which are separated by the Buyinga spur. This flow is the youngest in the area and would probably be historical if records were kept during times as long as in Europe.

Specimen S. 12, collected 2 km SW of Lemera hill, is the type specimen.

Specimen S. 12.

Dark leucite-nephelinite with nepheline predominating over leucite. (f, S). The result of the chemical analysis made of the specimen is summarized in Table I, No. 21. The small rounded crystals of leucite, sometimes collected to small aggregates, are by far less abundant than in the lava of the Leucite flows. The clinopyroxene that is the dominant constituent of the rock shows the typical brownish violet color of a titanian variety. $2V_{\gamma} = 54°\text{-}64°$; $c\Lambda\gamma = 52°\text{-}58°$. The mineral is heavily zoned. Because of the small grain size, the hour-glass texture and the twinning are less pronounced than in the lava of the Leucite flows. Nepheline is abundant and occurs as thin lamellae in a graphic intergrowth with clinopyroxene and greenish glass. The composition of nepheline is 29,5 mol. % Ks. Olivine plays only the role of an accessory constituent. It's scarcity makes it difficult to collect in sufficient amounts for X-ray determination of composition. The pleochroic basaltic hornblende occurs in the same manner as in the main type of the lava of the Leucite flows although in much smaller amounts. Magnetite shows the two generations described from the Leucite flows. The green glass occurring as graphic intergrowth with nepheline and clinopyroxene is very abundant. Some apatite crystals and small amounts of calcite were also found.

A specimen of the glassy surface of the flow collected NE of the Kinyunzo crater, S. 30, shows phenocrysts of leucite, clinopyroxene, apatite, magnetite and olivine in a completely isotropic glassy matrix. The refractive index of the glass is $n = 1{,}607$.

Nyakabanda flow.

The small Nyakabanda flow, about 3 km long, is perhaps a branch of the Buyinga flow but will be treated separately as long as the eventual identity with the Buyinga flow is not established. The name is for Nyakabanda, a knoll surrounded by this lava. The flow is of pahoehoe type and originates between the foot of Shaheru and the Buyinga-Luyaka-Buhonogo group of cones where relationships are not clear. Different tongues of the flow invade the depressions in the hilly terrain N of Kibati and stop short off the Goma-Rutshuru road. The Nyakabanda flow is the youngest flow in this area, butting into or covering all other flows.

Specimen S. 10 was collected at the tip of the tongue outcropping immediately NW of the Kibati Rest House.

Specimen S. 10.

Dark leucite-nephelinite. (f, S). The chemical composition of this specimen is summarized in Table I, No. 20. The chemical composition and the microscopic characteristics of the rock are virtually identical with the Buyinga flow lava. Therefore, no closer description is needed here. The only difference between specimens S. 12 and S. 10 is in the texture. The graphic intergrowth of nepheline, clinopyroxene and glass is less pronounced in specimen S. 10. The composition of nepheline was found to be identical with that of nepheline of specimen S. 12.

NOT INDIVIDUALIZED OLDER LAVA FLOWS NORTH OF GOMA.

The flows briefly described above are the youngest flows of the gigantic pile filling the Rift Valley. A systematic study of ejected blocks in Mt. Goma, where road and harbour building operations have provided exceptionally good outcrops, has shown that fragments of leucite-bearing older flows are most commonly ejected. The results of the study of that mountain will be published in another paper by one of us (A. M.). In the lava plain rising from the shore of Lake Kivu towards N and NE, there is a maze of flows the origins of which are hidden by the individualized flows. Some of them can be correlated with visible cones, such as the Bushwaga massif. However, much detailed field work dealing with these older flows is still needed, but must be postponed untill the general mapping in other parts of the region has been completed.

A major part of the older lavas of that area are represented by very leucocratic melilite-nephelinites, usually poor in olivine and sometimes containing only traces of clinopyroxene. In several instances the rocks contain aggregates of phenocrysts that consist of microperthitic nepheline-kalsilite, melilite and small amounts of olivine. Melilite and nepheline are quantitatively most important. The groundmass is medium-grained with characteristically euhedral nepheline crystals.

Three of the specimens collected have been subjected to chemical analyzing, viz. specimens S. 68 (SE of Bukanda hill), S. 75 (Kibati Rest House) and S. 16 (SE foot of the Kabashambara crater). The results of the analyses are given in Table I, Nos. 22, 23 and 24, respectively.

Specimen S. 68 represents a kalsilite-bearing olivine-melilite-nephelinite with large aggregates of perthitic nepheline-kalsilite crystals. Under the microscope, the rock resembles much the specimen FEAE No. 83 of the Kabfumu lava. Further X-ray work with the complex nepheline-kalsilite crystals is in progress. Melilite is abundant as phenocrysts. The composition of the rare olivine phenocrysts is 75,7 mol. % Fo.

Specimen S. 75 is a representative of a melilite-nephelinite with abundant phenocrysts of melilite. Nepheline occurs only in the groundmass. For determining the composition of nepheline, a small batch of the mineral was separated from the rock. The powder pattern indicated the composition 28,7 mol. % Ks. Traces of leucite and olivine and no kalsilite were detected. The composition of olivine is 66,2 mol. % Fo.

Specimen S. 16 is olivine-melilite-leucite-nephelinite containing phenocrysts of titanian clinopyroxene, olivine and melilite in a very fine-grained groundmass rich in nepheline. Leucite is scarce.

The leucocratic olivine-melilite-nephelinites and melilite-nephelinites mentioned above are mostly characterized by a medium-grained groundmass in which the microscopic identification of the constituents can be readily made. In addition to these rock types, similar rocks were found S of Kabashambara underlying the Buyinga flow and W of Buhama that are more melanocratic. Relatively large phenocrysts of titanian clinopyroxene and olivine are numerous and small phenocrysts of melilite detectable. The almost cryptocrystalline groundmass is very rich in clinopyroxene and magnetite. Small rounded crystals of leucite and, in some instances, nepheline may be identified.

Small craters between Goma and Kibati.

Several small craters mark the line joining the Nyiragongo massif to the main E scarp of the Rift that makes the E shore of Lake Kivu. The most important of these craters are : the Bushwaga complex, 2 ½ km long and built on both sides of a crack in N-S direction, the neighboring Mugara and the smaller Lemera, Buhama, Badgiru, Kabashambara and Kinyunzo. Specimens from these craters studied in thin section are all very melanocratic. They contain phenocrysts of olivine and titanian clinopyroxene in a more or less cryptocrystalline, sometimes partly glassy, groundmass. The crystalline part of the groundmass consists mainly of clinopyroxene and magnetite with small amounts of olivine. Leucite is constantly present in small rounded crystals sometimes reaching a grain size above that of the groundmass. In some of the specimens also nepheline is detectable in the groundmass.

According to their mineralogical composition, the rocks may be termed dark olivine-leucitites or dark olivine-leucite-nephelinites. Two of the specimens, both olivine-leucitites, were chemically analyzed, viz. specimens S. 9 b from the bottom of the Mugara crater and S. 69 from a point W of the small Kanyamagashu crater in the N end of the Bushwaga massif. The results of these analyses are presented in Table I, Nos. 25 and 26, respectively.

Mudja.

Mudja, also spelled Mutsa, is a composite cone more than 100 m high, situated 8 km NW of Goma. It is completely surrounded by younger flows coming from the foothills of Shaheru. The structure of the massif is rather exceptional because of the presence of alternating layers of olivine-rich and leucite-rich lava. The olivine-rich type is the rock by far richest in this mineral discovered in the Virunga area.

The specimens S. 13 and S. 14 were taken on the NW slope.

Specimen S. 13.

Dark olivine-leucitite. (vf, L). Phenocrysts of leucite, olivine and titanian clinopyroxene in an almost cryptocrystalline groundmass. Some small phenocrysts of magnetite and apatite occur. The groundmass consists mainly of clinopyroxene with small amounts of olivine, leucite and traces of nepheline.

Specimen S. 14.

Picrite. (vf, L). The specimen was chemically analyzed and the result is summarized in Table I, No. 27. The rock is characterized by large and very abundant phenocrysts of olivine of composition 90,2 mol. % Fo. Among the phenocrysts only a few crystals of titanian clinopyroxene and no leucite were detected. The groundmass is cryptocrystalline in which olivine, clinopyroxene and magnetite could be identified. A few quartz inclusions were noticed.

Kahembwe flows.

The E scarp of the Rift Valley that forms the E shore of Lake Kivu ends in the Rubavu hill N of Kisenyi. This hill represents a pegmatite massif rising 400 m above the lake. Lavas emitted by numerous small volcanoes NE of the hill have filled the depression of that area termed the Nyundo Bay. Flows coming from N follow the W foot of it. The small Nyabutwa ridge, continued by the bigger Uashungwe ridge, form the prolongation of Rubavu towards NNE. These ridges consist of pegmatites and mica-schists and are completely surrounded by flows. The small volcanoes Kakombe, Kakombe Mudogo, Bugu, Uashungwe South and Uashungwe North are arranged along these ridges in a pattern that strongly suggests their eruption along faults that border the ridges. The ridges probably represent the crest of a small horst, nearly completely submerged by recent flows.

Between the Nyabutwa and Uashungwe ridges on one side and a group of volcanic cones on the E side of the Nyundo Bay, there occurs a depression called the Kahembwe plain. This depression has collected virtually all the flows coming from N and NE. In an area of ca. 4 km^2, not less than 14 different flows have been recognized. Specimens of only two of them will be described here : the Bugu flow emitted from the breach of the S crater of the Bugu volcano, represented by specimen S. 59, and Kahembwe flow No. 1 from which specimen S. 55 was taken at the terminal N spur of Nyabutwa ridge.

Specimen S. 59.

Olivine-melilite-nephelinite. (m, L). Very vesicular, dark grey rock containing numerous large (up to 1 cm) prismatic phenocrysts of titanian clinopyroxene. Phenocrysts of olivine (80,3 mol. % Fo) are less abundant. The groundmass contains laths of melilite, subhedral nepheline, violet brownish or partly greenish clinopyroxene, magnetite and traces of green glass. The result of a bulk chemical analysis of the rock is presented in Table I, No. 28.

Specimen S. 55.

Dark olivine-melilite-nephelinite. (vf, S). Phenocrysts of titanian clinopyroxene and olivine (77,6 mol. % Fo) in an almost cryptocrystalline groundmass. For the clinopyroxene the following optical properties were determined : $\alpha = 1{,}696\text{-}1{,}724$; $\gamma = 1{,}721\text{-}1{,}744$; $2V_{\gamma} = 56°\text{-}69°$; $c\Lambda\gamma = 38°\text{-}50°$. The groundmass consists mainly of clinopyroxene and magnetite and contains some melilite and nepheline (26,0 mol. % Ks). The result of a bulk chemical analysis is given in Table I, No. 29.

MUTI CRATER.

Muti is a conspicuous isolated volcano on the edge of the Bugoyi plateau. The crater is breached towards NE. The Muti cone heralds the feldspar-bearing small volcanoes of Bugoyi and Tamira, forming the E part of the ring of basanitic lavas surrounding the all-feldspathoidal Nyiragongo massif.

Specimen S. 51, a block collected on the NE slope of the cone, is representative for Muti.

Specimen S. 51.

Olivine-rich kivite B. (vf, M). Phenocrysts of titanian clinopyroxene and smaller phenocrysts of olivine and leucite in a very fine-grained, almost cryptocrystalline groundmass consisting of the same minerals and, in addition, of magnetite and basic plagioclase. The result of a bulk chemical analysis of the rock is presented in Table I, No. 30.

INSTITUTE OF GEOLOGY.
Helsinki, Finland.
GEOLOGICAL SURVEY OF BELGIAN CONGO

EXPLANATION FOR TABLES I, II AND III.

NYIRAGONGO AREA.

List of specimens chemically analyzed.

No. 1. — Complex kalsilite-bearing melilite-nephelinite (specimen S. 80 = VM. 395). Loose block from the NE wall of Shaheru crater. Analyst : PENTTI OJANPERÄ, 1957.

No. 2. — Kalsilite-bearing olivine-melilite-nephelinite (specimen S. 88 = VM. 358). Loose block from the SE part of the upper crater of Baruta. Analyst : PENTTI OJANPERÄ, 1955.

No. 3. — Kalsilite-bearing olivine-melilite-nephelinite (specimen S. 96 = VM. 355). Fallen block from the NW breach of Baruta. Analyst : PENTTI OJANPERÄ, 1955.

No. 4. — Dark olivine-nephelinite (specimen S. 94 = VM. 354). Ropy lava flow on the bottom of the main crater of Baruta. Analyst : PENTTI OJANPERÄ, 1955.

No. 5. — Olivine-leucitite. Bomb in upper tuff layers. Musée Royal du Congo Belge, specimen labeled : « R. G. 22770. 40 m à l'intérieur du cratère du Nyiragongo. R.P. VAN DER AUWERA, 1948 ». Analysts : M. LHEUREUX and J. CORNIL, 1954.

No. 6. — Melilite-leucite-nephelinite. Probably loose block. Musée Royal du Congo Belge, specimen labeled : « R. G. 22778. Prélevé près sommet sud cratère. P.N.A. No. VIII le 27.XII.1945. Récolteur : garde ISHAHUNDA. Nyiragongo ». Analysts : M. LHEUREUX, J. CORNIL and H. B. WIIK, 1954.

No. 7. — Melilite-leucite-nephelinite (specimen VM. 12). Inclusion in Western Spur flow. SW slope of Nyiragongo, elevation 3.130 m. Analyst : PENTTI OJANPERÄ, 1955.

No. 8. — Melilite-nephelinite (specimen FEAE No. 89). Nepheline aggregate lava. Km point ca. 224 on the Goma-Rutshuru road. Analyst : H. B. WIIK, 1953.

No. 9. — Melilite-leucite-nephelinite (specimen FEAE No. 93). Nepheline Aggregate lava. S slope of Nyiragongo, elevation 2.950 m on the path. Analyst : PENTTI OJANPERÄ, 1955.

No. 10. — Melilite-leucite-nephelinite. Nepheline Aggregate lava. Musée Royal du Congo Belge, specimen labeled : « R. G. 5033. Cratère du Nyiragongo. J. FONTAINE (1924) ». Analysts : M. LHEUREUX and J. CORNIL, 1954.

No. 11. — Melilite-leucite-nephelinite. Nepheline Aggregate lava. Musée Royal du Congo Belge, specimen labeled : « R. G. 4922. Nyiragongo. F. DELHAYE No. 1650. 23.X.1922 ». Analysts : M. LHEUREUX and J. CORNIL, 1954.

No. 12. — Nepheline-leucitite (specimen S. 97 = VM. 383). Bomb embedded in lava. E slope of Nyiragongo, elevation 2.910 m. Analyst : M. LHEUREUX, 1955.

No. 13. — Kalsilite-bearing olivine-melilite-nephelinite (specimen FEAE No. 83). Kabfumu flow. Km point 234,4 on the Goma-Rutshuru road. Analyst : PENTTI OJANPERÄ, 1953.

No. 14. — Melilite-nephelinite (specimen S. 6). Tembo flow. Km point 234,2 on the Goma-Rutshuru road. Analyst : M. LHEUREUX, 1955.

No. 15. — Olivine-leucitite (specimen S. 45). Leucite flow. SW of Tshawato. Analyst : PENTTI OJANPERÄ, 1955.

No. 16. — Olivine-leucitite (specimen FEAE No. 85). Leucite flow. Km point 232 on the Goma-Rutshuru road. Analyst : PENTTI OJANPERÄ, 1955.

No. 17. — Nepheline-leucitite (specimen S. 43). N rim of Tshawato crater. Analyst : PENTTI OJANPERÄ, 1955.

No. 18. — Leucite-nephelinite (specimen S. 40). War Cemetery flow. E of Badgiru. Analyst : M. LHEUREUX, 1955.

No. 19. — Leucite-nephelinite (specimen S. 107). Mudjoga flow. N of Lemera. Analyst : PENTTI OJANPERÄ, 1955.

No. 20. — Dark leucite-nephelinite (specimen S. 10). Nyakabanda flow. NW of Kibati Rest House. Analyst : PENTTI OJANPERÄ, 1955.

No. 21. — Dark leucite-nephelinite (specimen S. 12). Buyinga flow. 2 km SW of Lemera. Analyst : PENTTI OJANPERÄ, 1955.

No. 22. — Kalsilite-bearing olivine-melilite-nephelinite (specimen S. 68). Not individualized older flows. SE of Bukanda. Analyst : M. LHEUREUX, 1955.

No. 23. — Melilite-nephelinite (specimen S. 75). Not individualized older flows. Kibati Rest House. Analyst : PENTTI OJANPERÄ, 1955.

No. 24. — Olivine-melilite-leucite-nephelinite (specimen S. 16). Not individualized older flows. SE foot of Kabashambara. Analyst : PENNTI OJANPERÄ, 1955.

No. 25. — Dark olivine-leucitite (specimen S. 9 b). Flow on bottom of Mugara crater. Analyst : Pentti Ojanperä, 1955.

No. 26. — Dark olivine-leucitite (specimen S. 69). Between Kanyamagashu and the Goma-Rutshuru road. Analyst : Pentti Ojanperä, 1955.

No. 27. — Picrite (specimen S. 14). NW slope of Mudja. Analyst : M. Lheureux, 1955.

No. 28. — Olivine-melilite-nephelinite (specimen S. 59). Bugu flow. S side of Bugu crater. Analyst : M. Lheureux, 1955.

No. 29. — Dark Olivine-melilite-leucitite (specimen S. 55). Kahembwe flow No. 1. N. of Nyabutwa. Analyst : M. Lheureux, 1955.

No. 30. — Olivine-rich kivite B (specimen S. 51). Loose block. NE slope of Muti. Analyst : M. Lheureux, 1955.

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* *

All the analyses have been made at the Geological Survey of Finland, Helsinki, and at the « Laboratoire de Recherches chimiques du Ministère des Colonies », Tervuren.

TABLE I. — **Chemical analyses of Nyiragongo area rocks.**

	1	2	3	4	5	6	7	8	9	10
SiO_2	39,34	36,48	35,97	40,32	44,97	39,22	38,51	38,60	39,88	39,92
TiO_2	2,79	2,60	2,85	3,00	3,76	3,40	3,71	2,18	2,38	2,98
Al_2O_3	12,06	14,78	12,04	13,09	12,17	15,91	13,82	18,00	17,07	20,01
Fe_2O_3	4,73	9,74	11,50	5,04	4,51	1,52	5,33	4,29	5,75	2,12
FeO	8,04	2,08	0,85	6,92	7,15	9,55	8,21	6,28	5,94	7,28
MnO	0,41	0,24	0,27	0,21	0,35	0,28	0,27	0,23	0,28	0,26
MgO	3,99	4,62	6,19	8,72	3,63	4,60	5,07	3,98	3,28	3,15
CaO	13,45	12,99	17,70	13,86	9,96	13,31	13,57	11,19	10,54	9,46
Na_2O	5,61	4,85	4,42	3,45	3,04	5,23	4,39	6,01	5,72	5,47
K_2O	5,55	6,42	4,57	3,22	3,20	5,25	4,29	6,76	7,03	6,29
P_2O_5	1,39	1,72	2,06	1,25	1,45	1,44	1,84	1,15	1,12	0,89
CO_2	0,30	2,43	0,94	0,00	n. d.	0,00	0,42	0,32	0,36	n. d.
H_2O^+	0,98	0,83	0,75	0,68	3,82	0,28	0,43	0,63	0,39	1,61
H_2O^-	0,28	0,40	0,16	0,24	2,00	0,03	0,16	0,31	0,16	0,53
Total	99,72 (*)	100,18	100,27	100,00	100,01	100,05 (**)	100,02	99,93	99,90	99,97
Sp. gr.	2,99	2,99	3,06	3,11	n. d.	n. d.	3,11	2,89	2,94	n. d.

(*) Including : F = 0,61; Cl = 0,37; SO_3 = 0,16; — 0 = 0,34.
(**) Including : Cr_2O_3 = 0 00; S = 0,05; — 0 = 0,02.

TABLE I. — **Chemical analyses of Nyiragongo area rocks** (continued).

	11	12	13	14	15	16	17	18	19	20
SiO_2	42,54	46,39	36,56	38,47	41,70	44,10	40,93	39,77	39,16	39,51
TiO_2	2,87	1,80	3,13	3,37	3,44	2,84	2,91	3,82	3,08	3,25
Al_2O_3	19,08	19,85	12,85	14,91	15,45	16,97	15,94	12,53	14,75	14,83
Fe_2O_3	2,84	5,56	4,80	3,90	3,44	3,09	3,90	6,02	5,54	3,95
FeO	6,65	3,25	7,10	9,00	8,55	7,21	8,02	8,62	7,80	8,96
MnO	0,29	0,20	0,28	0,42	0,26	0,20	0,28	0,27	0,28	0,30
MgO	3,25	1,57	5,12	4,73	4,70	3,73	3,64	4,45	4,20	4,29
CaO	9,52	5,30	14,56	12,88	10,67	8,41	10,67	11,88	12,10	12,15
Na_2O	6,20	6,83	5,38	5,05	4,57	4,31	4,26	4,86	4,96	4,98
K_2O	5,13	8,81	5,80	5,41	4,79	7,24	7,01	5,35	5,30	5,19
P_2O_5	0,93	0,25	2,31	1,02	1,49	1,17	1,73	1,35	1,73	1,73
CO_2	n. d.	n. d.	0,85	n. d.	0,00	0,00	0,04	n. d.	0,09	0,00
H_2O^+	0,52	0,52	0,65	0,72	0,49	0,29	0,31	0,60	0,55	0,33
H_2O^-	0,10	0,09	0,49	0,15	0,17	0,19	0,11	0,32	0,21	0,18
Total	99,92	100,42	99,88	100,03	99,72	99,75	99,75	99,84	99,75	99,74 (*)
Sp. gr.	n. d.	2,78	2,92	2,99	3,01	2,92	2,99	3,99	3,03	3,08

(*) Including : S = 0,17; — O = 0,08.

TABLE I. — **Chemical analyses of Nyiragongo area rocks** (continued).

	21	22	23	24	25	26	27	28	29	30
SiO_2	39,56	37,65	36,10	40,37	40,30	40,68	41,00	40,06	39,36	44,67
TiO_2	3,17	3,57	3,10	2,77	3,40	3,71	2,00	4,12	4,12	3,74
Al_2O_3	14,72	11,95	13,07	16,58	13,19	11,97	7,93	8,76	12,31	14,74
Fe_2O_3	3,89	6,85	5,28	6,50	5,48	6,53	2,88	8,12	8,38	3,59
FeO	8,96	7,00	6,68	5,65	6,90	6,64	8,49	6,90	7,40	6,95
MnO	0,30	0,27	0,30	0,29	0,24	0,21	0,15	0,20	0,20	0,10
MgO	4,32	5,05	5,56	3,66	8,15	8,43	27,17	9,00	8,78	7,86
CaO	12,37	13,68	15,89	10,42	13,28	15,50	7,60	16,37	11,77	11,32
Na_2O	4,95	4,92	4,52	5,42	3,28	2,15	1,39	2,37	2,62	2,50
K_2O	5,19	5,02	4,96	5,72	3,53	2,75	0,95	2,39	3,34	2,95
P_2O_5	1,65	1,35	1,93	1,58	1,28	0,78	0,23	0,90	1,22	0,31
CO_2	0,21	n. d.	0,53	0,20	0,00	0,00	n. d.	n. d.	n. d.	n. d.
H_2O^+	0,33	1,71	1,40	0,47	0,74	0,65	0,48	0,77	0,61	1,06
H_2O^-	0,17	0,57	0,56	0,20	0,30	0,20	0,03	0,23	0,14	0,29
Total	99,86 (*)	99,59	99,88	99,83	100,07	100,20	100,30	100,19	100,25	100,08
Sp. gr.	3,08	2,92	2,92	2,98	3,13	3,19	3,29	3,22	3,21	3,05

(*) Including : S = 0,14; — O = 0,07.

TABLE II. — **Niggli values for Nyiragongo area rocks.**

	1	2	3	4	5	6	7	8	9	10
si	84	77	69	79	119	81	80	82	87	91
ti	4,5	4,1	4,1	4,4	7,5	5,3	5,8	3,5	3,9	5,1
al	15,1	18,3	13,6	15,2	18,9	19,4	16,8	22,4	22,0	26,9
fm	35,2	33,9	36,2	44,9	39,8	33,6	38,6	30,9	31,5	28,8
c	30,6	29,3	36,4	29,3	28,1	29,6	30,1	25,3	24,6	23,1
alk	19,1	18,5	13,8	10,6	13,2	17,4	14,5	21,4	21,9	21,2
k	0,39	0,47	0,41	0,38	0,41	0,40	0,39	0,43	0,45	0,43
mg	0,36	0,43	0,49	0,57	0,36	0,42	0,41	0,41	0,34	0,37
o	0,22	0,45	0,46	0,17	0,23	0,07	0,22	0,22	0,30	0,13
c/fm	0,87	0,86	1,01	0,65	0,71	0,88	0,78	0,82	0,78	0,80
qz	−81	−97	−86	−63	−34	−89	−78	−104	−101	−94

TABLE II. — **Niggli values for Nyiragongo area rocks** (continued).

	11	12	13	14	15	16	17	18	19	20
si	98	119	74	79	93	105	92	85	83	84
ti	5,0	3,5	4,8	5,5	5,8	5,1	4,9	6,1	4,9	5,2
al	25,8	29,9	15,3	18,0	20,3	23,9	21,0	15,8	18,5	18,6
fm	29,4	24,1	35,2	36,6	37,7	33,6	34,2	39,7	36,5	36,4
c	23,5	14,5	31,5	28,3	25,4	21,5	25,6	27,2	27,6	27,7
alk	21,3	31,5	18,0	17,1	16,6	21,0	19,2	17,3	17,4	17,3
k	0,35	0,46	0,42	0,41	0,41	0,53	0,52	0,42	0,41	0,41
mg	0,38	0,25	0,44	0,40	0,41	0,40	0,36	0,36	0,36	0,37
o	0,17	0,45	0,21	0,16	0,15	0,17	0,19	0,24	0,24	0,17
c/fm	0,80	0,60	0,89	0,77	0,67	0,64	0,75	0,69	0,76	0,76
qz	–88	–107	–90	–90	–74	–79	–85	–80	–86	–85

TABLE II. — **Niggli values for Nyiragongo area rocks** (continued).

	21	22	23	24	25	26	27	28	29	30
si	84	78	72	89	81	80	63	77	78	98
ti	5,1	5,6	4,6	4,6	5,2	5,5	2,3	6,0	6,2	6,2
al	18,4	14,5	15,3	21,7	15,7	13,9	7,2	9,9	14,4	19,1
fm	36,3	38,7	35,9	33,9	44,8	45,8	77,2	49,0	51,2	44,7
c	28,1	30,3	33,8	24,7	28,6	32,7	12,6	33,8	25,1	26,7
alk	17,2	16,5	15,0	19,7	10,9	7,6	3,0	7,3	9,3	9,5
k	0,41	0,40	0,42	0,41	0,42	0,46	0,31	0,40	0,46	0,44
mg	0,38	0,40	0,46	0,36	0,55	0,54	0,81	0,53	0,51	0,58
o	0,17	0,28	0,22	0,32	0,19	0,21	0,04	0,24	0,25	0,13
c/fm	0,77	0,78	0,94	0,73	0,64	0,71	0,16	0,69	0,49	0,60
qz	−85	−82	−88	−89	−63	−50	−49	−52	−59	−40

TABLE III. — **Molecular norms for Nyiragongo area rocks.**

	1	2	3	4	5	6	7	8	9	10
Or	—	—	—	—	20,6	—	—	—	—	—
Ab	—	—	—	—	23,3	—	—	—	—	—
An	—	—	—	10,9	11,0	4,4	5,4	2,1	0,2	11,5
Lc	26,0	30,2	21,4	15,1	—	24,5	20,5	31,4	32,9	29,7
Ne	19,7	25,6	23,0	18,7	3,9	27,9	23,9	31,9	30,5	29,5
Kp	—	—	—	—	—	—	—	—	—	—
Salic	46,8 (*)	55,8	44,4	44,7	58,8	56,8	49,8	65,4	63,6	70,7
Ac	11,5	0,6	0,8	—	—	—	—	—	—	—
Di	3,3	11,1	15,3	33,4	26,0	8,0	25,1	—	11,5	4,2
Wo	—	—	—	—	—	—	—	—	—	—
Ol	13,5	5,4	7,0	5,6	1,1	13,4	4,4	11,1	4,1	9,5
Ca_2SiO_4	14,1	7,2	12,9	2,5	—	12,5	4,9	12,9	8,3	7,3
Mt	0,6	—	—	6,9	5,1	1,6	5,6	4,4	6,0	2,2
Hm	—	6,6	7,8	0,1	—	—	—	—	—	—
Il	3,9	3,6	1,7	4,2	5,7	4,7	5,2	3,0	3,3	4,2
Ap	3,2	3,6	4,3	2,6	3,3	3,0	3,9	2,4	2,3	1,9
Cc	0,8	6,1	4,7	—	—	—	1,1	0,8	0,9	—
Femic	53,2 (**)	44,2	55,6 (***)	55,3	41,2	43,2	50,2	34,6	36,4	29,3

(*) Including : Na Cl = 1,1. (**) Including : CaF_2 = 2,1; $CaSO_4$ = 0,2. (***) Including : Ru = 1,1.

TABLE III. — **Molecular norms for Nyiragongo area rocks** (continued).

	11	12	13	14	15	16	17	18	19	20
Or	—	8,9	—	—	2,8	6,5	—	—	—	—
Ab	—	—	—	—	—	—	—	—	—	—
An	9,0	—	—	2,1	7,6	5,6	3,7	—	2,4	2,8
Lc	23,9	33,4	18,3	25,6	20,6	29,0	33,3	25,7	25,3	24,6
Ne	32,9	32,9	21,5	27,3	24,8	23,2	23,1	22,4	27,0	26,9
Kp	—	—	6,8	—	—	—	—	—	—	—
Salic	65,8	75,2	46,6	55,0	55,8	64,3	60,1	48,1	54,7	54,3
Ac	—	3,9	10,0	—	—	—	—	5,6	—	—
Di	23,2	8,4	—	9,5	28,7	22,8	17,8	18,7	21,5	20,1
Wo	—	5,4	—	—	—	—	—	—	—	—
Ol	1,5	—	15,3	11,6	3,9	3,2	5,5	6,7	4,0	6,5
Ca_2SiO_4	0,8	—	15,5	13,0	—	—	4,7	8,3	5,8	6,4
Mt	2,9	4,2	1,3	4,1	3,6	3,2	4,1	4,3	5,8	4,1
Hm	—	—	—	—	—	—	—	—	—	—
Il	3,9	2,4	4,4	4,7	4,8	4,0	4,1	5,4	4,3	4,5
Ap	1,9	0,5	4,8	2,1	3,2	2,5	3,6	2,9	3,7	3,6
Cc	—	—	2,1	—	—	—	0,1	—	0,2	—
Femic	34,2	24,8	53,4	45,0	44,2	35,7	39,9	51,9	45,3	45,7 (*)

(*) Including : Pr = 0,5.

TABLE III. — **Molecular norms for Nyiragongo area rocks** (continued).

	21	22	23	24	25	26	27	28	29	30
Or	—	—	—	—	—	—	1,0	—	7,4	17,7
Ab	—	—	—	—	—	—	—	—	—	8,0
An	2,6	—	0,7	4,0	11,0	15,2	11,9	6,4	12,2	20,6
Lc	24,6	21,3	23,8	27,1	16,8	13,3	3,4	11,6	10,2	—
Ne	26,7	20,8	24,7	29,2	17,9	11,8	7,1	13,1	14,4	7,7
Kp	—	1,4	—	—	—	—	—	—	—	—
Salic	53,9	43,5	49,2	60,3	45,7	40,3	23,4	31,1	44,2	54,0
Ac	—	6,7	—	—	—	—	—	—	—	—
Di	20,5	—	10,4	21,9	31,8	39,3	17,9	47,8	31,4	27,5
Wo	—	—	—	2,9	—	—	—	—	—	—
Ol	6,4	20,5	9,9	—	7,0	3,7	52,7	1,3	7,0	8,7
Ca_2SiO_4	6,4	17,3	15,0	0,4	2,2	2,7	—	3,4	—	—
Mt	4,1	4,5	5,6	6,8	5,8	7,0	2,9	8,2	8,9	3,8
Hm	—	—	—	—	—	—	—	0,3	—	—
Il	4,4	4,8	4,4	3,9	4,8	5,3	2,6	5,9	5,9	5,3
Ap	3,4	2,7	4,1	3,3	2,7	1,7	0,5	2,0	2,6	0,7
Cc	0,5	—	1,4	0,5	—	—	—	—	—	—
Femic	46,1 (*)	56,5	50,8	39,7	54,3	59,7	76,6	68,9	55,8	46,0

(*) Including : Pr = 0,4.

EXPLANATION FOR TABLE IV.

Chemical analyses and optical properties of clinopyroxene from Nyiragongo area rocks.

No. 1. — Titanian clinopyroxene from olivine-leucitite (specimen FEAE No. 85). Leucite flows. Km point 232 on the Goma-Rutshuru road. Analyst : PENTTI OJANPERÄ, 1955.

No. 2. — Titanian clinopyroxene from melilite-leucite-nephelinite (specimen FEAE No. 93). Nepheline Aggregate lava. S slope of Nyiragongo, elevation 2.950 m on the path. Analyst : PENTTI OJANPERÄ, 1955.

No. 3. — Titanian clinopyroxene from kalsilite-bearing olivine-melilite-nephelite (specimen S. 96 = VM. 355). Fallen block from the NW breach of Baruta. Analyst : PENTTI OJANPERÄ, 1955.

No. 4. — Clinopyroxene (salite) from complex kalsilite-bearing melilite-nephelinite (specimen S. 80 = VM. 395). Loose block from the NE wall of Shaheru crater. Analyst : PENTTI OJANPERÄ, 1957.

TABLE IV. — **Chemical analyses and optical properties of clinopyroxene from Nyiragongo area rocks.**

	Weight per cent					Cation per cent			
	1	2	3	4		1	2	3	4
SiO_2	42,89	44,50	45,74	51,74	Si	40,49	41,50	42,34	48,97
TiO_2	5,10	3,57	2,90	0,81	Ti	3,62	2,51	2,02	0,57
Al_2O_3	8,91	8,01	7,90	0,05	Al	9,91	8,81	8,62	0,06
Fe_2O_3	3,56	3,38	3,69	2,70	Fe^{3+}	2,53	2,37	2,57	1,92
FeO	5,58	4,55	2,88	8,34	Fe^{2+}	4,41	3,55	2,23	6,60
MnO	0,16	0,15	0,10	0,46	Mn	0,13	0,12	0,08	0,37
MgO	10,33	11,57	12,92	11,68	Mg	14,53	16,09	17,82	16,48
CaO	22,86	23,76	23,38	22,90	Ca	23,12	23,75	23,19	23,22
Na_2O	0,69	0,72	0,63	0,91	Na	1,26	1,30	1,13	1,67
K_2O	0,00	0,00	0,00	0,11	K	—	—	—	0,13
P_2O_5	0,06	n. d.	n. d.	n. d.					
CO_2	n. d.	0,00	0,00	n. d.					
H_2O^+	0,09	0,17	0,20	0,09					
H_2O^-	0,04	0,00	0,00	0,02					
Total	100,27	100,38	100,34	99,81					
Sp. gr.	3,406	3,395	3,365	3,406					
α	1,707-1,723	1,705-1,724	1,694-1,730	1,695					
β	1,720-1,730	1,712-1,730	1,702-1,739	1,703					
γ	1,731-1,747	1,731-1,747	1,718-1,754	1,723					
$2V\gamma$	48°-68°	57°-65°	54°-63°	64°					
$c\Lambda\gamma$	52°-64°	42°-55°	48°-56°	46°					

EXPLANATION FOR TABLE V.

Chemical analyses, optical properties and unit cell of melilite from Nyiragongo area rocks.

No. 1. — Melilite from kalsilite-bearing olivine-melilite-nepheline (specimen FEAE No. 83). Kabfumu flow. Km point 234,4 on the Goma-Rutshuru road. Analyst : PENTTI OJANPERÄ, 1956.

No. 2. — Melilite from melilite-leucite-nephelinite (specimen FEAE No. 93). Nepheline Aggregate lava. S slope of Nyiragongo, elevation 2.950 m on the path. Analyst : PENTTI OJANPERÄ, 1955.

No. 3. — Ferrian melilite from kalsilite-bearing olivine-melilite-nephelinite (specimen S. 96=VM. 355). Fallen block from the NW breach of Baruta. Analyst : PENTTI OJANPERÄ, 1955.

TABLE V. — **Chemical analyses, optical properties and unit cell of melilite from Nyiragongo area rocks.**

	Weight per cent				Unit cell content (*)		
	1	2	3		1	2	3
SiO_2	42,70	42,24	42,16	Si	3,95	3,88	3,96
TiO_2	0,08	0,17	0,13	Ti	0,01	0,01	0,01
Al_2O_3	6,56	6,88	6,39	Al	0,71	0,74	0,71
Fe_2O_3	0,46	0,96	4,11	Fe^{3+}	0,03	0,07	0,29
Fe O	3,05	3,78	0,32	Fe^{2+}	0,24	0,29	0,03
Mn O	0,11	0,11	0,08	Mn	0,01	0,01	0,01
Mg O	8,40	7,87	8,26	Mg	1,16	1,08	1,15
Ca O	34,86	34,19	33,82	Ca	3,45	3,36	3,29
Na_2O	3,12	3,04	3,16	Na	0,56	0,54	0,57
K_2O	0,27	0,44	0,34	K	0,03	0,05	0,04
CO_2	0,00	0,00	0,85	O	14,19	14,03	14,23
H_2O^+	0,14	0,08	0,21				
H_2O^-	0,05	0,06	0,05				
Total	99,80	99,82	99,88				
	28	29	31	mol. % Alkali melilite	$NaCaAlSi_2O_7$		
	56	52	58	Åkermanite	$Ca_2MgSi_2O_7$		
	12	14	2	Iron åkermanite	$Ca_2MgSi_2O_7$		
	3	4	2	Gehlenite	$Ca_2Al_2SiO_7$		
	1	1	7	Iron gehlenite	$Ca_2Fe_2SiO_7$		
Sp. gr.	3,019	3,002	3,016 (**)				
ε	1,632	1,634	1,642				
ω	1,637	1,639	1,647				
a_0 (Å)	7,784	7,783	7,772	± 0,003 Å			
c_0 (Å)	5,019	5,019	5,025	± 0,003 Å			
Volume (Å³) ...	304	304	304				

(*) Neglecting $CaCO_3$ and H_2O.
(**) Corrected for 2 % $CaCO_3$.

TABLE VI. — **Chemical analysis of leucite from olivine-leucitite (specimen FEAE No. 85). Leucite flows. Km point 232 on the Goma-Rutshuru road.**

Analyst : PENTTI OJANPERÄ, 1953.

	Weight %		Cation %
SiO_2	54,80	Si	49,68
TiO_2	0,19	Ti	0,13
Al_2O_3	23,34	Al	24,94
Fe_2O_3	0,53	Fe^{3+}	0,36
FeO	0,14	Fe^{2+}	0,10
MnO	0,00	Mn	—
MgO	0,04	Mg	0,05
CaO	0,09	Ca	0,09
Na_2O	0,95	Na	1,67
K_2O	19,87	K	22,98
CO_2	0,00		
H_2O^+	0,34		
H_2O^-	0,00		
Total	100,29	Total	100,00
n = 1,509			

TABLE VII. — **Chemical analysis, optical and unit cell data for apatite from kalsilite-bearing olivine-melilite-nephelinite (specimen S. 96 = VM. 355). Fallen block from the NW breach of Baruta.**

Analyst : PENTTI OJANPERÄ, 1956.

	Weight %	Physical data
SiO_2	1,34	Sp. gr. = 3,214
TiO_2	0,02	ε = 1,635
Al_2O_3	0,55	ω = 1,639
Fe_2O_3 (*)	0,40	
MnO	0,02	Unit cell :
MgO	0,23	a_0 = 9,379 Å
CaO	53,75	c_0 = 6,888
Na_2O	0,38	
K_2O	0,00	
P_2O_5	40,56	
CO_2	0,28	
Cl..	0,12	
F	3,57	
H_2O^+	0,10	
H_2O^-	0,00	
	101,32	
— O	1,53	
Total	99,79	

(*) Total iron.

TABLE VIII. — **Refractive indices and birefringence of a nepheline crystal from specimen FEAE No. 87. Nepheline Aggregate lava.**

Wave length mμ	ω		ε		ω — ε
	Measured	Smoothed	Measured	Smoothed	Smoothed
450	1,5518	1,5518	1,5489	1,5488	0,0030
475	1,5498	1,5499	1,5466	1,5467	0,0032
500	1,5483	1,5482	1,5445	1,5449	0,0033
525	1,5468	1,5468	1,5435	1,5435	0,0033
550	1,5457	1,5455	1,5423	1,5422	0,0033
575	1,5443	1,5443	1,5408	1,5411	0,0032
600	1,5433	1,5433	1,5401	1,5401	0,0032
625	1,5423	1,5422	1,5391	1,5390	0,0032
650	1,5417	1,5415	1,5382	1,5383	0,0032
675	1,5407	1,5408	1,5376	1,5375	0,0033
700	1,5401	1,5401	1,5366	1,5367	0,0034
725	1,5395	1,5395	1,5360	1,5359	0,0036
750	1,5389	1,5389	1,5352	1,5352	0,0037

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PLATE I

EXPLANATION OF PLATE I.

FIG. 1. — General view of the Nyiragongo massif and the surrounding lava plains, taken from S.E. To the left of the central cone, the Shaheru is partly hidden by clouds; on the right, the Baruta. The northern slope of Nyamuragira appears behind the Baruta. The dark country in the foreground is covered by flows from the Karisimbi and it's satellites. The leucite flows form the plain at the foot of the Nyiragongo and cover the sunlit patch to the left.

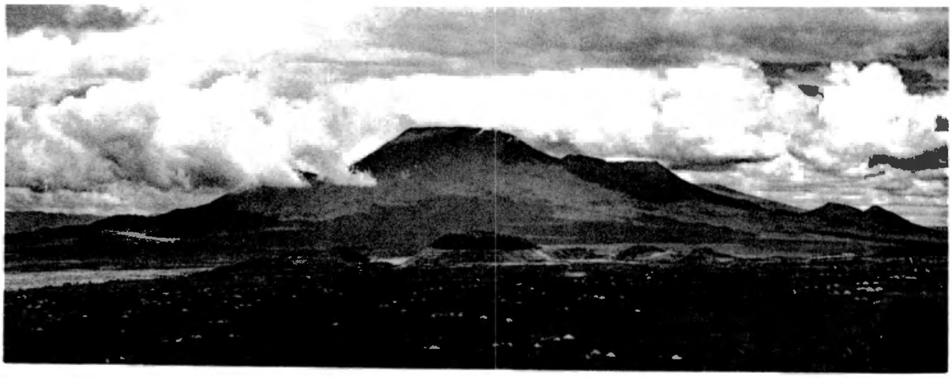
(Photo: R. BOURGEOIS. 12.614/504 — C.I.D.)

FIG. 2. — The Nyiragongo seen from the south. In the left background, the Nyamuragira with the steam of the Shabubembe eruption. Photograph taken in November 1951.

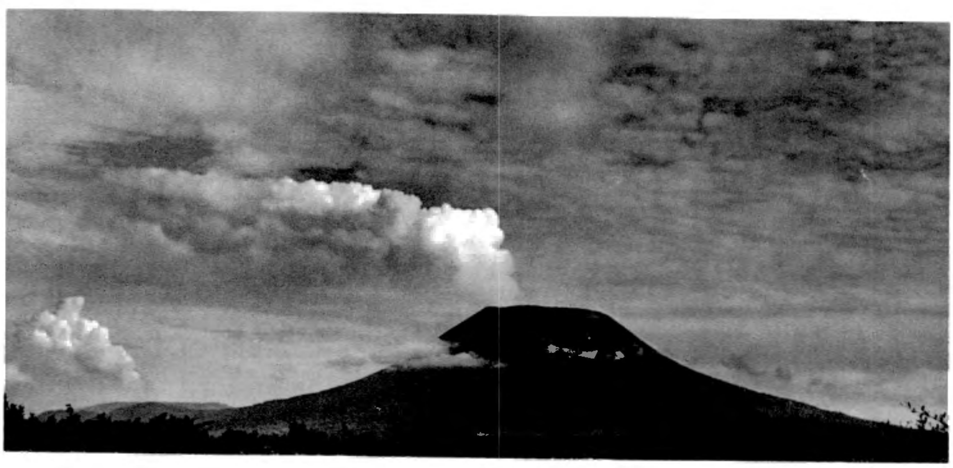
(Photo: C. LAMOTE. 12.614/225 — C.I.D.)

FIG. 3. — The crater of the Nyiragongo in July 1918. The two pits visible during the period 1894-1911 have formed one single sink the outline of which has undergone no major changes since.

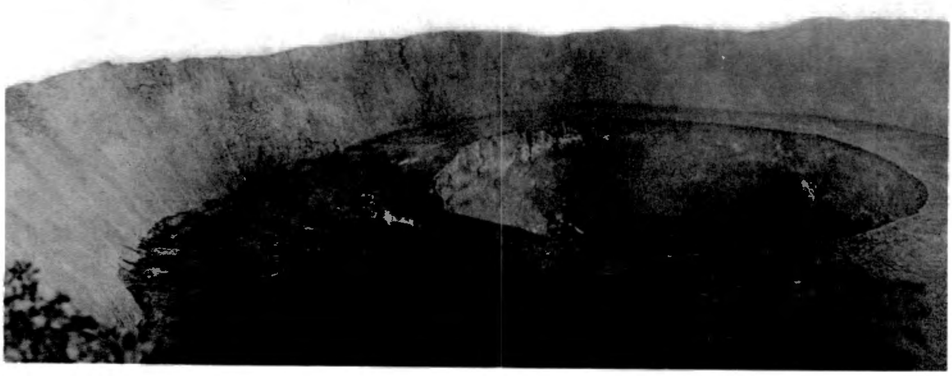
(Photo: X. DIERCKX.)



1. General view of the Nyiragongo massif.



2. The Nyiragongo seen from the south.



3. The crater of the Nyiragongo.

Phototypie A. Dohmen, Bruxelles

PLATE II

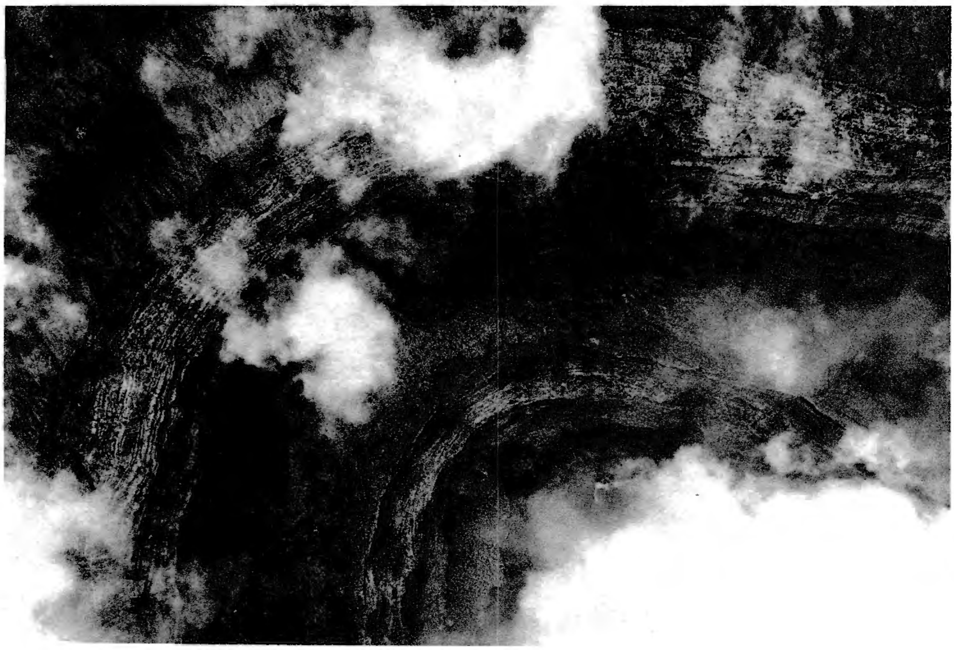
EXPLANATION OF PLATE II.

FIG. 1. — Aerial photograph of the N.E. part of the Nyiragongo crater. Interrupted flow channels can be identified on the outer slope. Splatches of glassy lava on the inner wall, to the right of the upper cloud. Steam hides the lava lake.

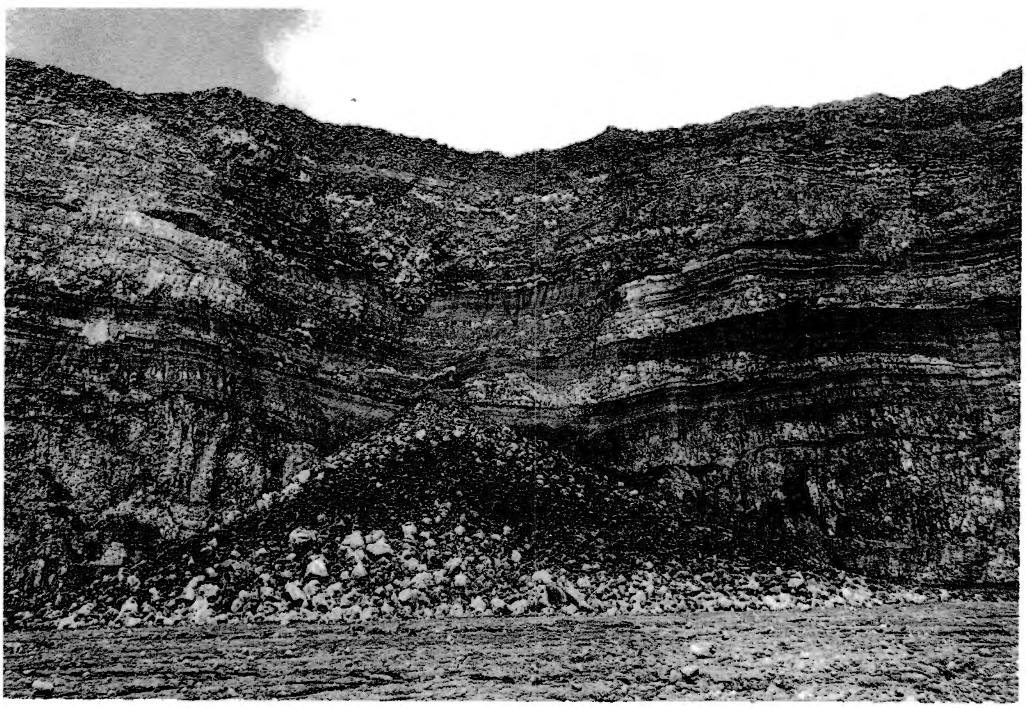
(Photo: INSTITUT GÉOGRAPHIQUE DU CONGO BELGE.)

FIG. 2. — The inner wall with the talus on the S.S.E. side. The wall is about 160 m. high. Darker tuff layers alternate with lighter colored lava flows.

(Photo: E. SCHULTHESS-CONZETT & HUBER — « DU ».)



1. Aerial photograph of the N. E. part of the Nyiragongo crater.



2. Part of the inner wall of the Nyiragongo crater.

Phototypie A. Dohmen, Bruxelles

PLATE III

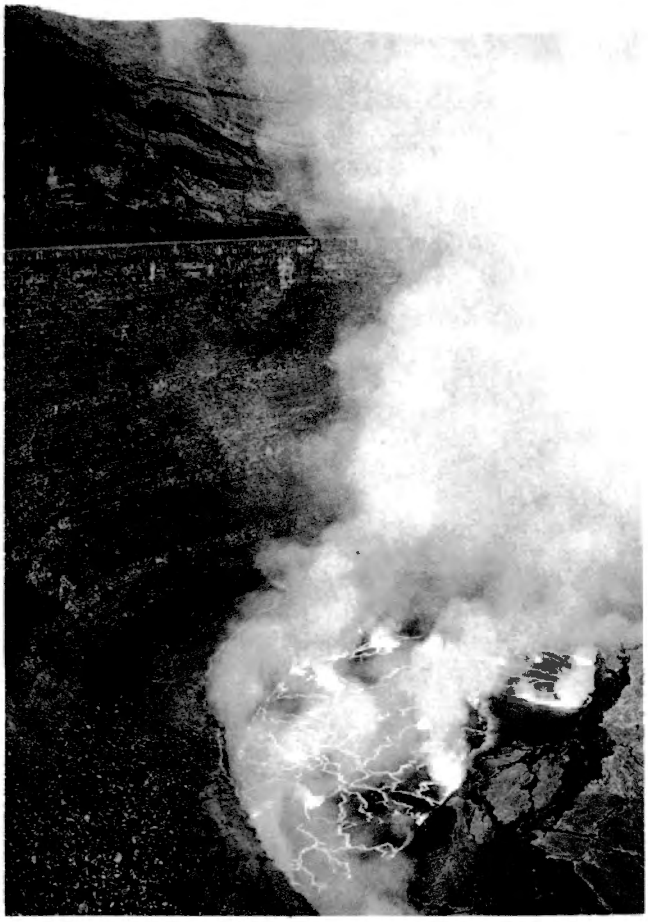
EXPLANATION OF PLATE III.

FIG. 1. — General view of the inner part, taken from the edge of the upper platform towards W.N.W. and showing the crater rim and inner wall with the contact between the tuffs and the overlying lava flows, the regular horizontal flows in the walls of the sink, the lower platform with a talus of fallen blocks, the lava lake and part of the crag.

(Photo: E. SCHULTHESS-CONZETT & HUBER — « DU ».)

FIG. 2. — Some of the leucitite blocks with giant leucites found on the upper platform.

(Photo: E. SCHULTHESS-CONZETT & HUBER — « DU ».)



1. Nyiragongo. General view of the inner part of the crater.

2. Leucitite blocks with giant leucites.

Phototypie A. Dohmen, Bruxelles

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