VOLCANOLOGICAL OBSERVATIONS IN EAST AFRICA

III THE ERUPTION OF KITURO NYEFUNZI NEAR LAKE KIVU IN 1948

by J. J. Richard

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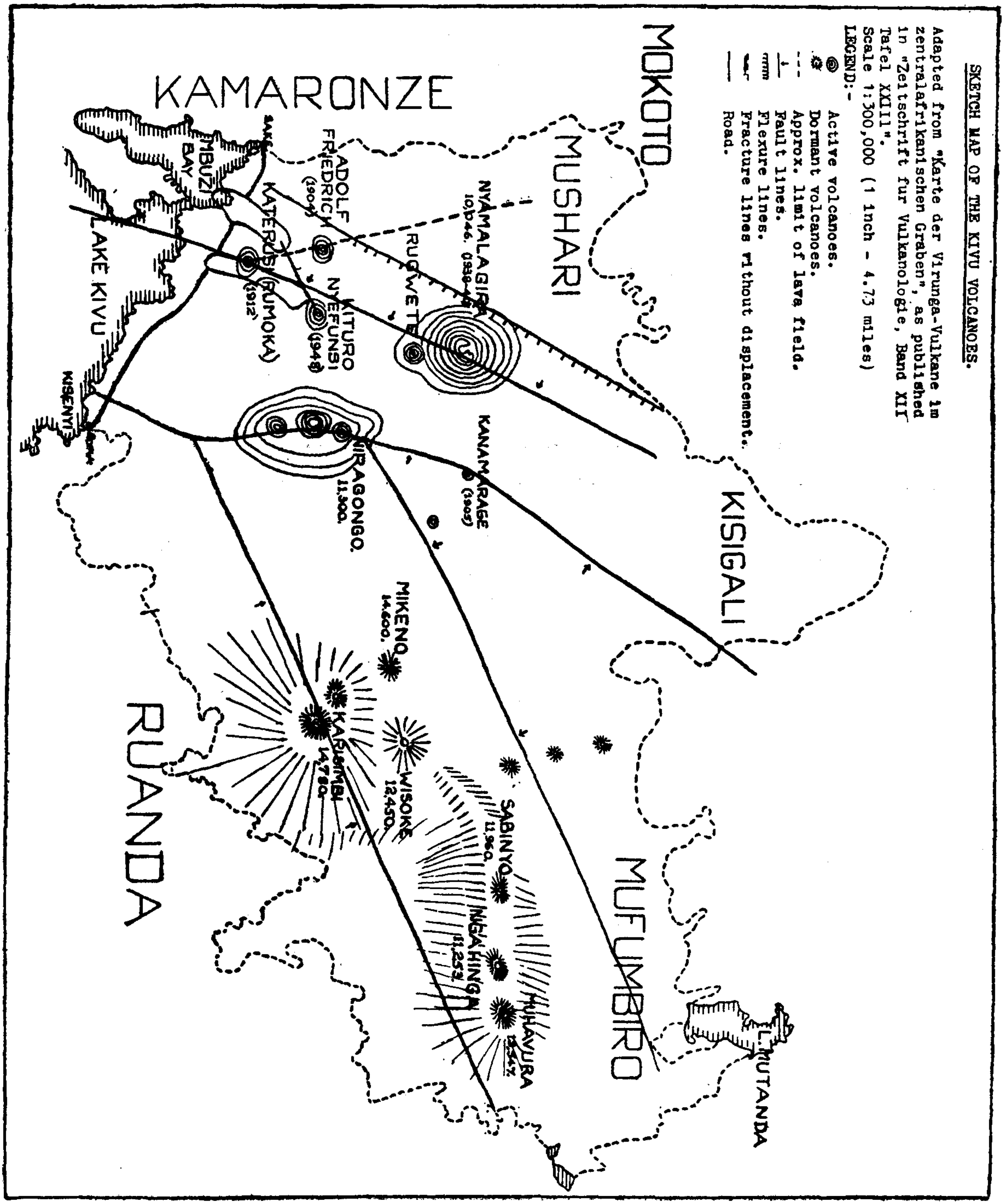
1. Introduction

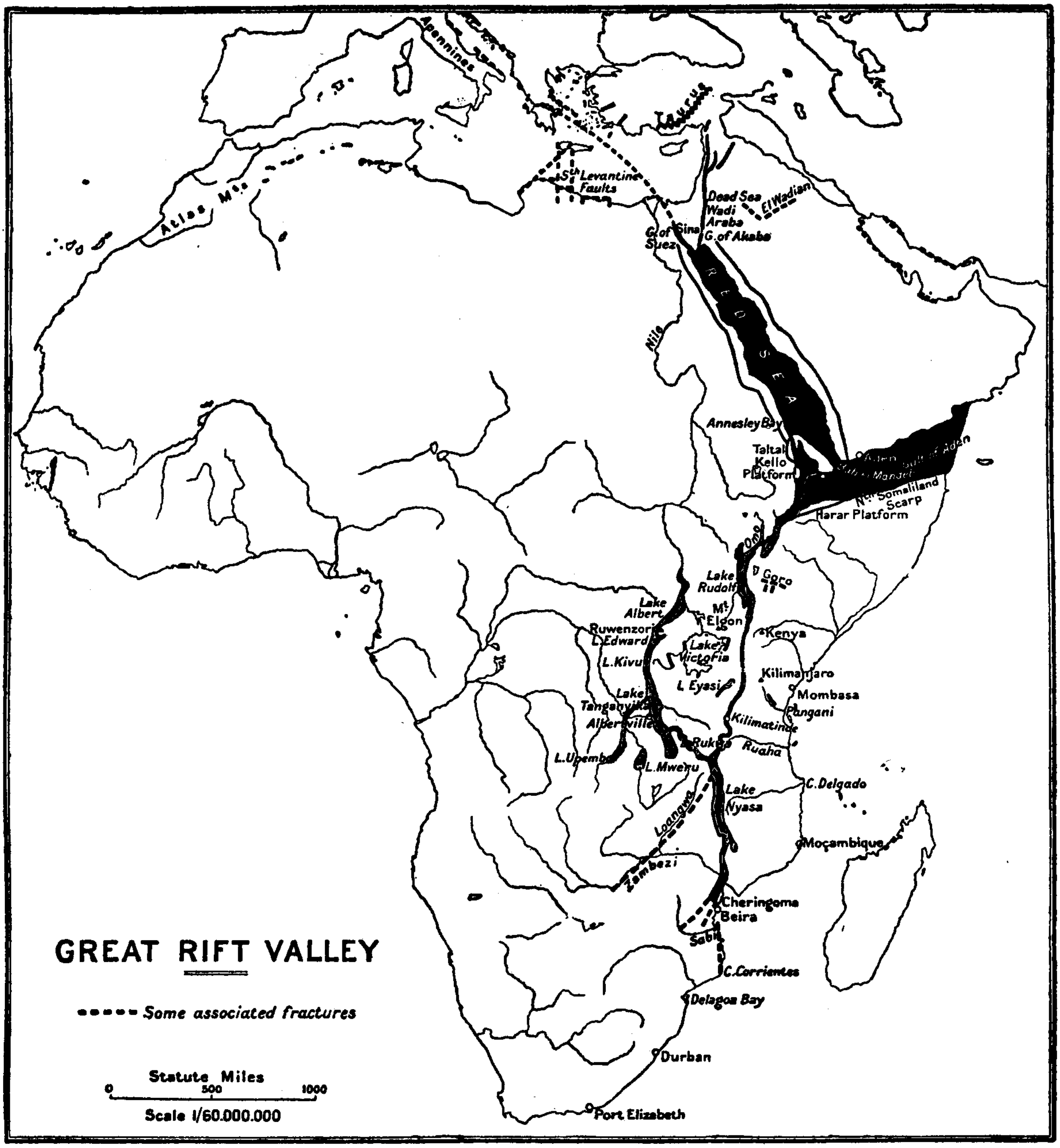
The Birunga volcanic area of Uganda and the Belgian Congo, although situated in Central rather than in East Africa, is geologically sufficiently related to the Great Rift system to allow us to include its renewed activity in this series of articles. The volcanoes are located north-east and north of Lake Kivu, about midway of the Western Rift Valley. The latter branches off from the Great Rift Valley, north of Lake Nyasa, and extends in a wide arc for over 1,000 miles, first in a north-westerly, thence in a north and north-easterly direction towards the Sudan. (Map 1.)

Lake Kivu is a drowned valley, which, before it was dammed up by the Birunga volcanoes, used to discharge its waters to the north in the direction of Lake Edward and the Nile. Today Lake Kivu has its outflow to the South by way of the Ruzizi river into LakeTanganyika and forms one of the sources of the River Congo.

The eastern Birunga volcanoes: Muhavura, well-known as a sanctuary for gorillas; Mgahinga, Sabinjo, Visoke, Mikeno and Karisimbi, between 11,400 and 14,780 feet high, are now dormant or extinct. (1933.) Two of the Birunga volcanoes, north of Lake Kivu are active (Map 2). Niragongo, an impressive cone 11,386 feet high, holds an active lava lake in a sink of its nearly 4,000 feet wide crater, the like of which is only to be found in Hawaii. This lava lake discharges clouds of gaseous matter almost continuously and shows a red glow at night. The crater was entered for the first time by H. Tazieff and Mr. Tondeur in June 1948. Nyamlagira, a flat topped mountain, 10,048 feet high, situated about eight miles north-west of Niragongo, contains a 6,000 feet wide "caldeira" or cauldron, whose behaviour since the beginning of this century and the flank eruption of 1938-1940 are well-known through the earlier publications mentioned at the end of this article (Literature.)

Apart from these main features of the landscape, numerous lesser cones made their appearance in the past, which gave to this area its typical topography. In the last forty-eight years, four of these cones emerged around Niragongo and Nyamlagira. Adolf Friedrich appeared in 1904, Kanamaharage in 1905, Katerusi or Rumoka in 1912. Finally, during the night of 1st and 2nd March 1948, a new eruption began in the plain


SKETCH MAP OF THE KIVU VOLCANOES.
Adapted from "Karte der Virunga-Vulkane im zentralafrikanischen Graben", as published in "Zeitschrift fur Vulkanologie, Band XII Tafel XXIII".
Scale 1:300,000 (1 inch - 4.73 miles)
LEGEND:-
Active volcanoes.
Dormant volcanoes.
Approx. limit of lava field.
Fault lines.
Flexure lines.
Fracture lines without displacement.
Road.
MOKOTO
MUSHARI
KAMARONZE
KISIGALI
MUFUMBIRO
RUANDA
LAKE KIVU
MBUZI BAY
SAKE
ADOLF FRIEDRICH (1904)
NYAMALAGIRA 10,046.
RUGWETE
KATERUSI (RUMOKA) (1912)
KITURO NYEFUNSI (1948)
NIRAGONGO 11,300.
KANAMARAGE (1905)
KISENYI
MIKENO 14,600.
KARISIMBI 14,780.
WISOKE 12,450.
SABINYO 11,960.
NGAHINGA 11,253.
MUHAVURA 13,547
L. MUTANDA


GREAT RIFT VALLEY
Some associated fractures
Statute Miles
0 500 1000
Scale 1/60.000.000
Apennines
Taurus
Atlas Mts
Levantine Faults
Dead Sea
Wadi Araba
El Wadian
G. of Suez
Sinai
G. of Akaba
RED SEA
Nile
Annesley Bay
Taltal
Kello Platform
Aden
Gulf of Aden
N. Somaliland Scarp
Harar Platform
Omo
Lake Rudolf
Goro
Lake Albert
Mt. Elgon
Ruwenzori
L. Edward
Kenya
Lake Victoria
L. Kivu
L. Eyasi
Kilimanjaro
Mombasa
Pangani
Lake Tanganyika
Albertville
Kilimatinde
Rukwa
Ruaha
L. Upemba
L. Mweru
Lake Nyasa
C. Delgado
Loangwa
Moçambique
Zambezi
Cheringoma
Beira
Sabi
C. Corrientes
Delagoa Bay
Durban
Port Elizabeth

south of Nyamlagira and the new cone in the north eastern (S. lat. 1° 32′ E. long. 29° 10′) sector of the eruption area was named Kituro Nyefunzi. * The activity of all these little cones was short-lived and Kituro was no exception, the eruptive phenomena lasting only for about six months. All these eruptions produced abundant lava streams, however, several of which reached Lake Kivu.

I flew† to the new eruptive area and stayed there between 6th and 9th April, returning for a longer visit between 1st and 11th May 1948. New information was gained during these visits, together with numerous photographs and a coloured film bearing witness of this very interesting eruption.

I express here warm thanks to M. and Madame de Munck of Buheno for their charming hospitality, to Dr. H. Tazieff, the geologist who studied the eruption and whom I was privileged to accompany during some of his investigations, and last but not least to Major van Coole the Conservator of the Parc National Albert, who gave me the necessary permits and the use of comfortable camps " en route."

2. The 1948 eruption

(a) The beginning of the eruption

On 29th February 1948 and the next day, the inhabitants of the agglomerations of Goma and Kisenji near Lake Kivu were given warning that something was amiss. Earth tremors were felt; subterranean noises were heard from a westerly direction, heralding the new eruption. During the night of 1st to 2nd March, thunderous explosions followed. Mr. and Mrs. de Munck, who live on the shore of Lake Kivu, a few miles south of the scene of eruption, told me that they were woken up during the small hours of the night by what sounded like an artillery barrage. Frightened natives were making for the hills. The sky was lit up by bright red clouds, while tremendous detonations, almost continuous, could be heard for the rest of the night. Curtains of smoke were passing by (*fig.* 1). The following day report came that a four-mile long fissure, direction N. 120° W., had opened up from three to ten feet wide, in the wooded plain between Niragongo and Nyamlagira, MAP 2, (*fig.* 2). At its eastern end, at an altitude of 1,000 feet above the level of Lake Kivu, a volcanic cone, elliptical E. W. at first, was growing up steadily. It threw up flames and gases, bright orange coloured lava fountains and red hot bombs, some of which were hurled up a thousand feet high. Light scoriæ fell on the surrounding country for about two to three miles. Ashes carried by an easterly wind blew to a distance of about thirty miles west of the new volcano, while very fine dust (I was told by Mr. Tazieff ½ (for microw) in size) was thrown up to a height of several miles, producing a marked halo around the sun.

After a month the elongated main vent near the eastern end of the fissure was replaced by a series of smaller vents in alignment with the fissure. A single cone in this part became the major point of issue of the projections.

In the early days of the eruption, incandescent, ropy dermolithic (pahoehoe) lavas flowed from the cone southwards (*fig.* 3, 4). After nine days the lava crossed the Costermansville-Sake-Goma road at Km. 192, west of the " Lac Vert " (a crater lake), over a front of about 300 feet and forming a chaotic wall ten feet high of clastolithic lava blocks. Mr. Tazieff, who was investigating in the area was nearly trapped with his car in the meandering lava streams. Mr. Tazieff had a narrow escape himself when, with his porters, he had to cut his way out of the heavy bush to avoid being caught up by an advancing lava wall fifty feet high. The car was rescued in time, driven towards the lake and taken away by lighter. These lava streams did not reach Lake Kivu.

* Kituro=cone; Nyefunzi=pygmea name for a waterhole.

† With P Arnal in a chartered Leopard Moth piloted by Capt Fielden of Caspar Air Charters, Nairobi.

PLATE XIX

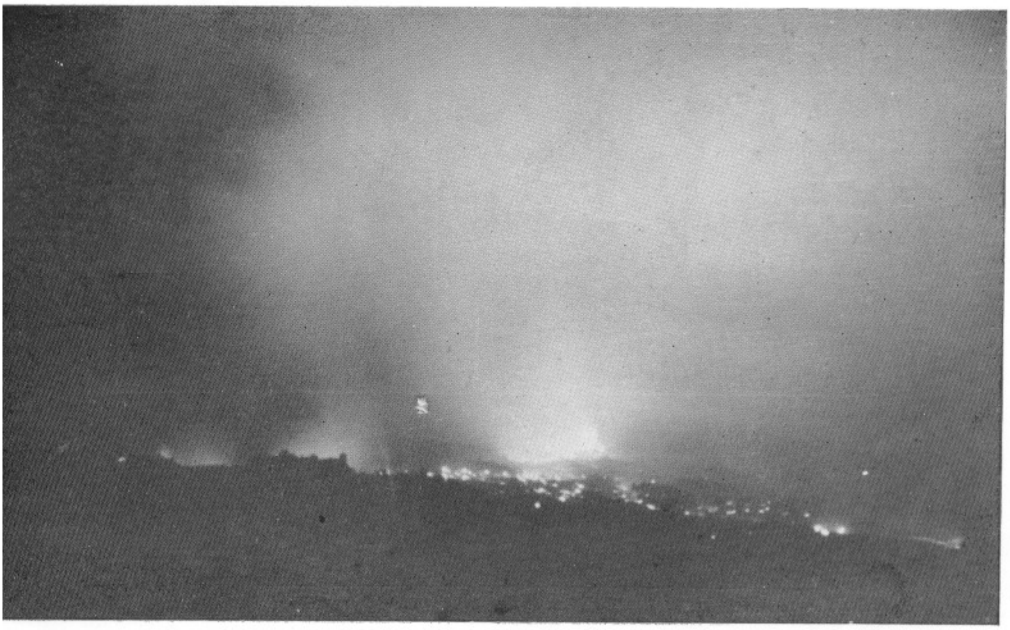


Fig. 1 (*Photo Vermeezsch*)

Fig. 2 (*Photo Tazieff*)

PLATE XX

Fig. 3

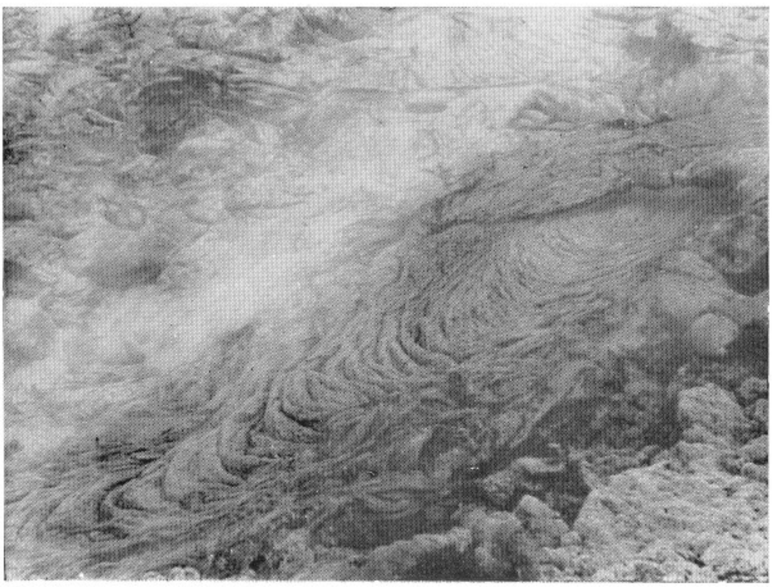


Fig. 4

PLATE XXI

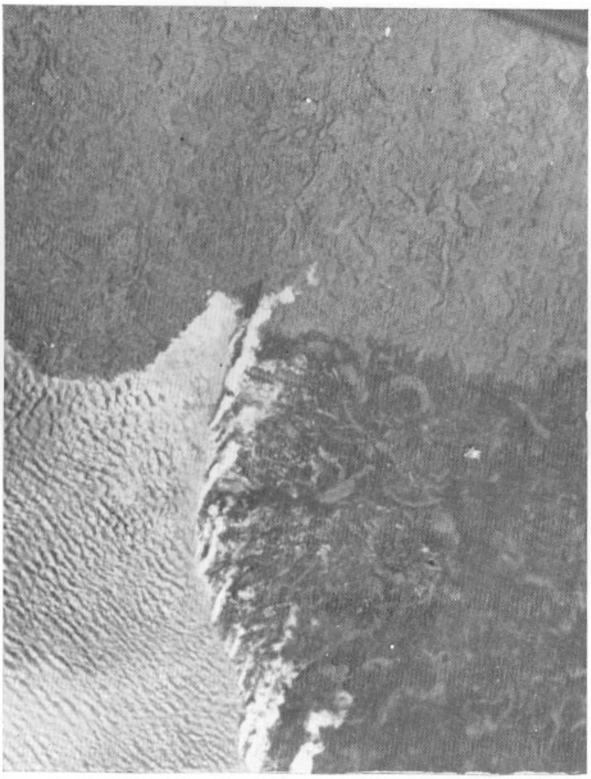


Fig. 5

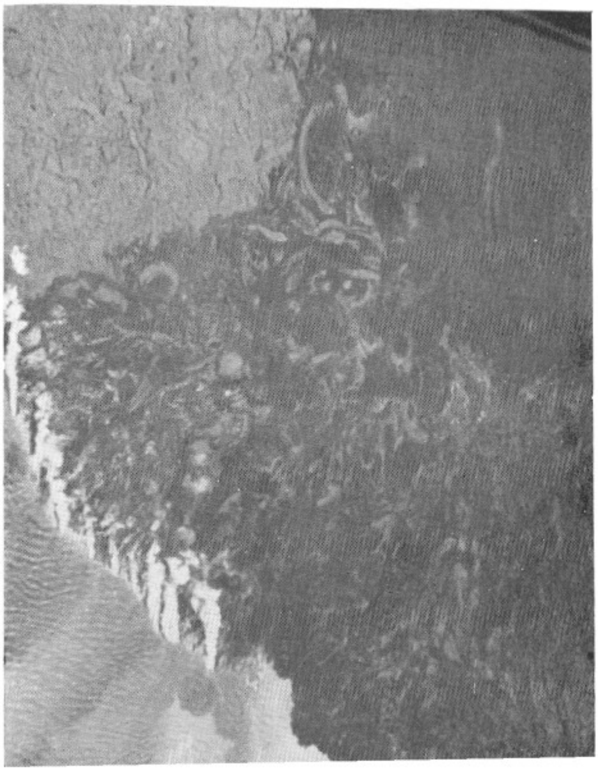


Fig. 6

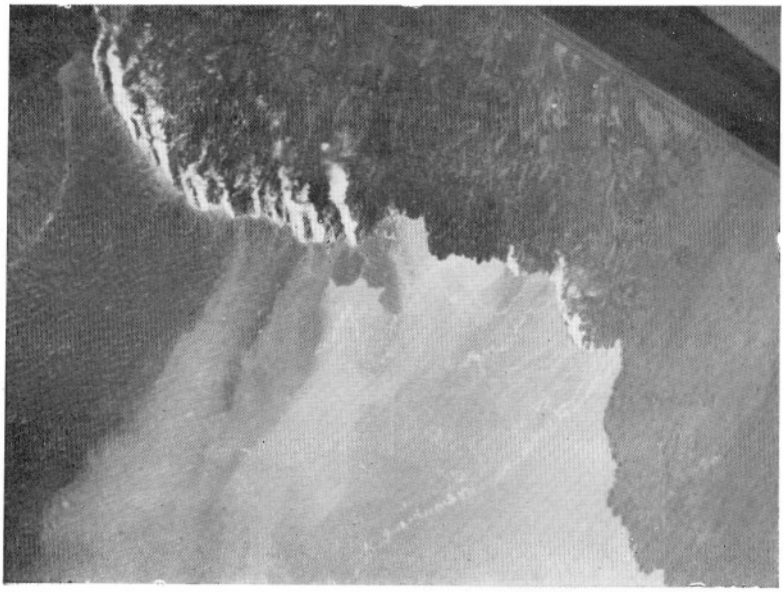


Fig 7

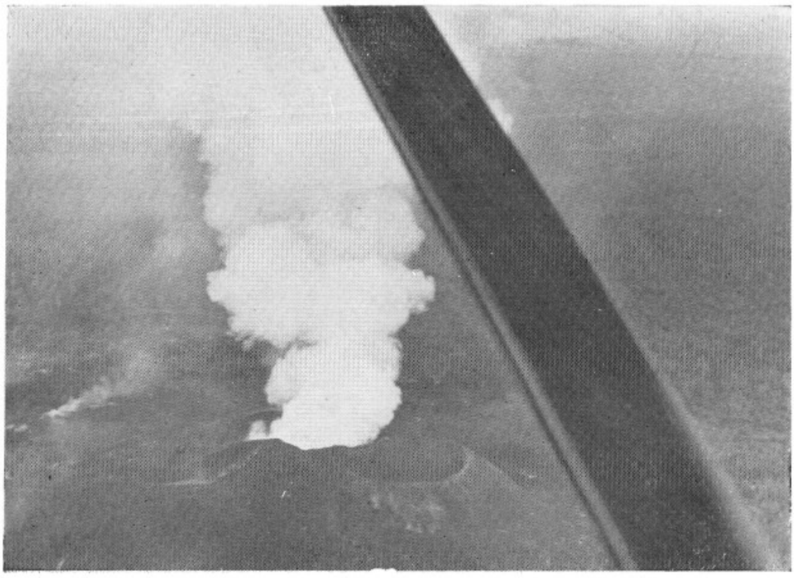


Fig. 8

PLATE XXIII

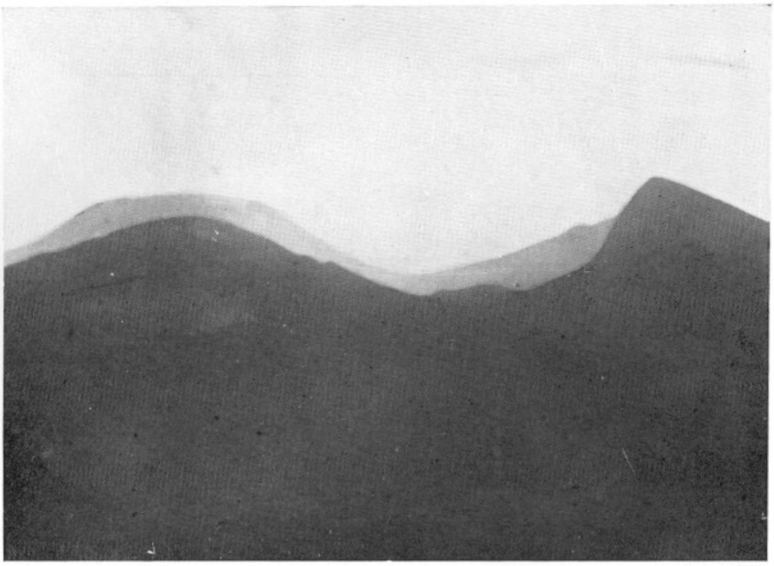


Fig. 9

Fig. 10

Fig. 11 (*Photo Tazieff*)

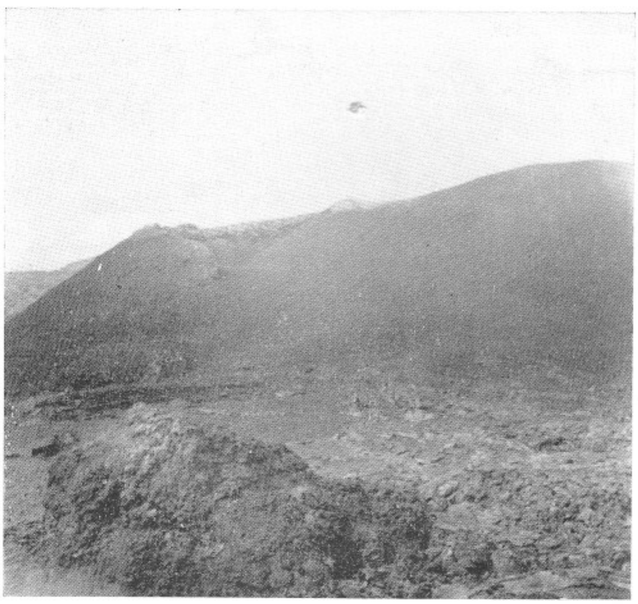


Fig. 12 (*Photo Taziff*)

PLATE XXV

Fig. 13

Fig. 14

PLATE XXVI

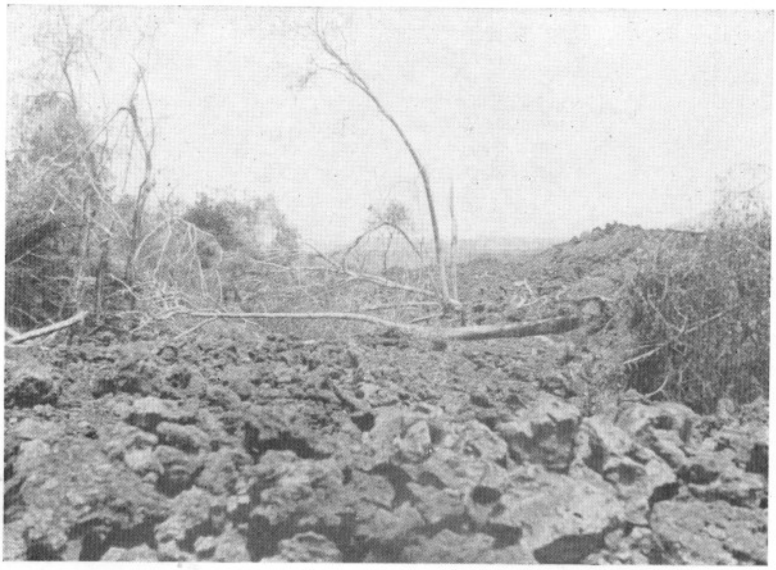


Fig. 15

Fig 16

PLATE XXVII

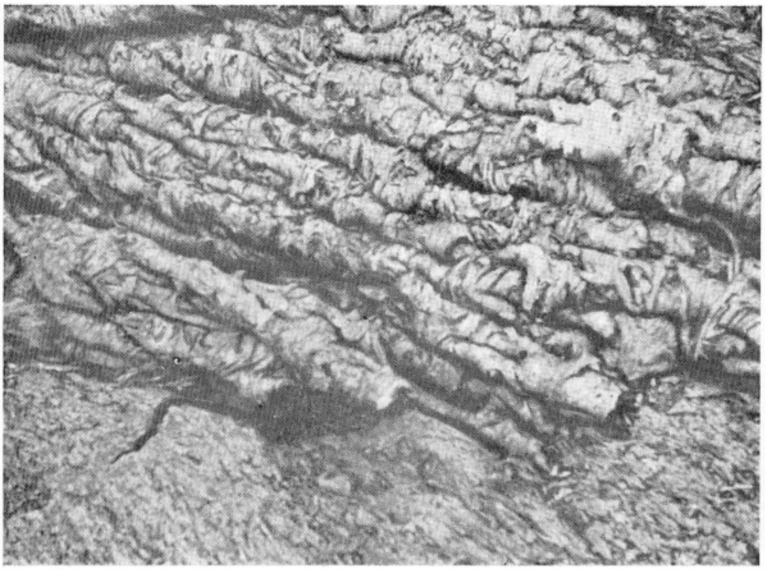


Fig. 17

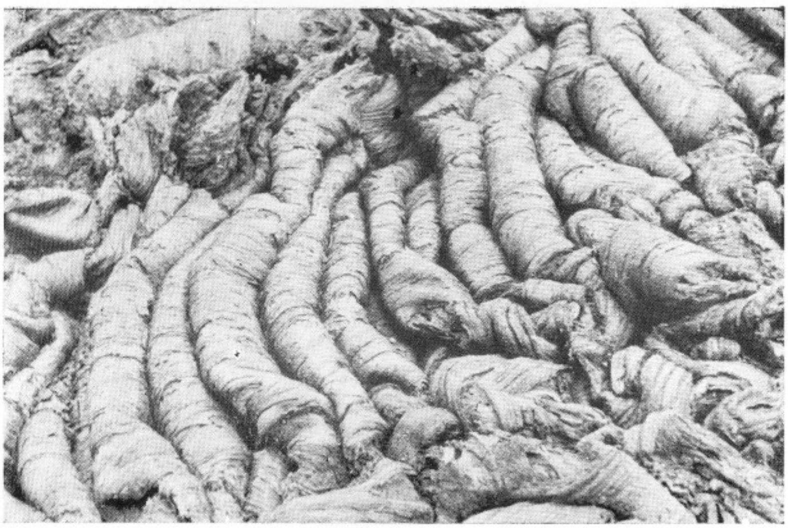


Fig. 18

Fig. 19

Fig. 20

Fig. 21

Fig. 22

PLATE XXX

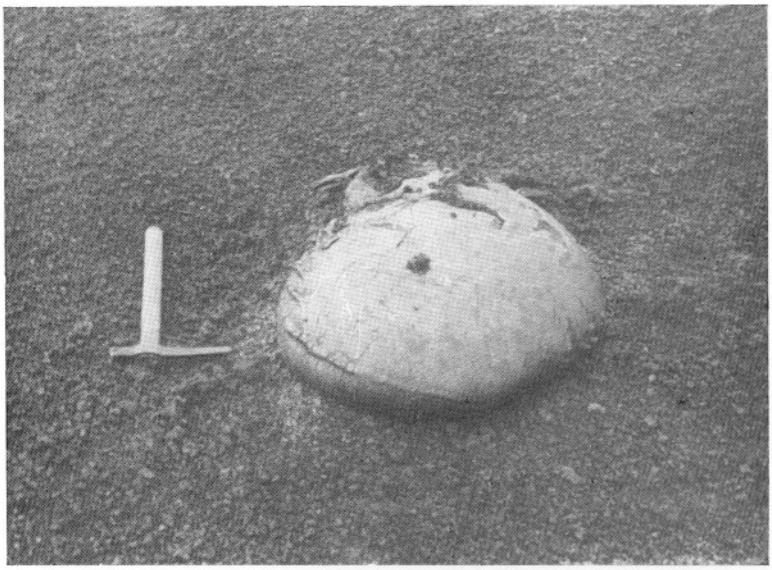


Fig. 23

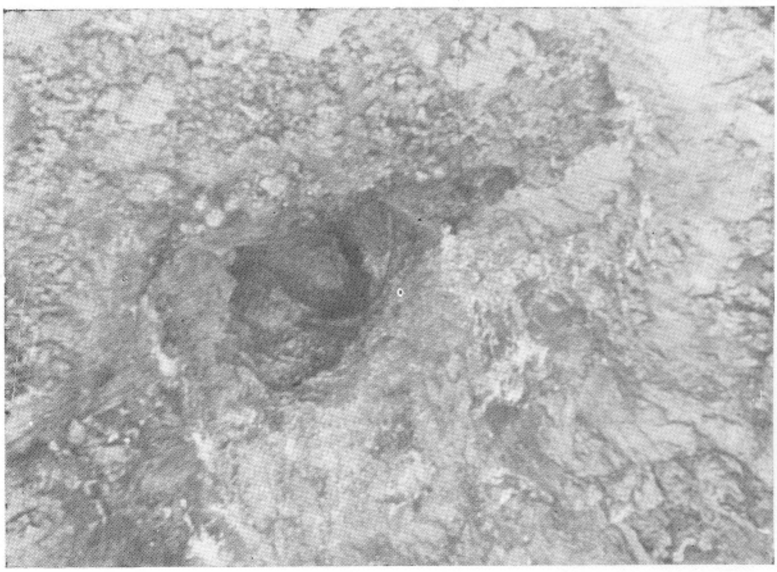


Fig 24

PLATE XXXI

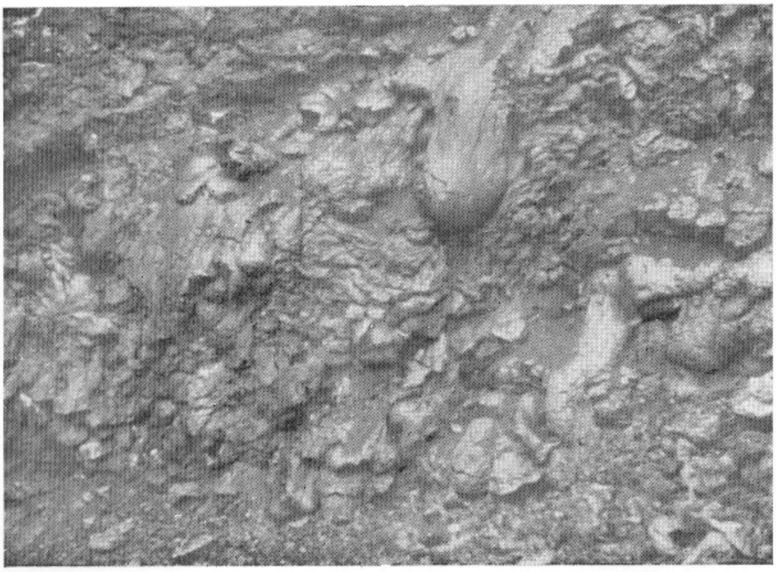


Fig 25

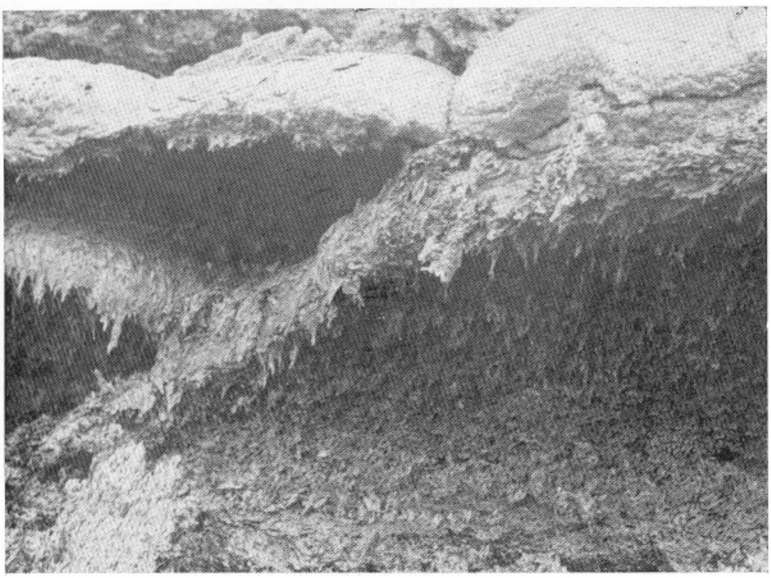


Fig. 26

PLATE XXXII

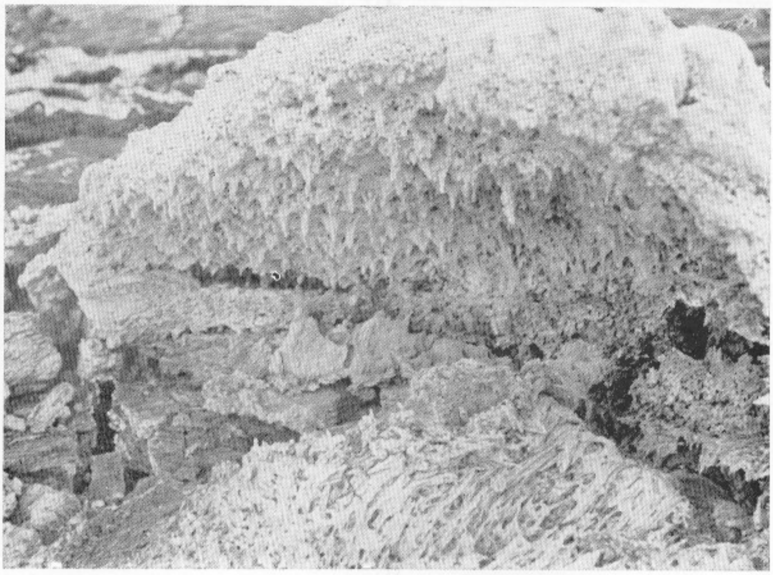


Fig 27

Fig. 28

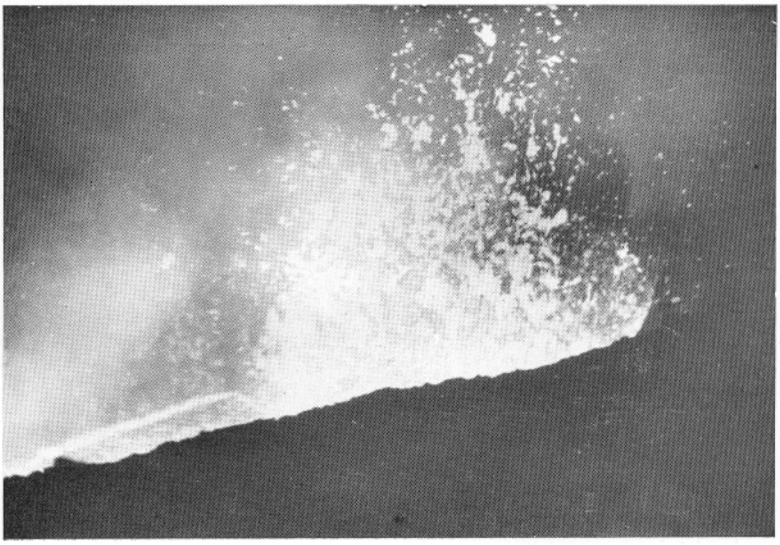


Fig. 29

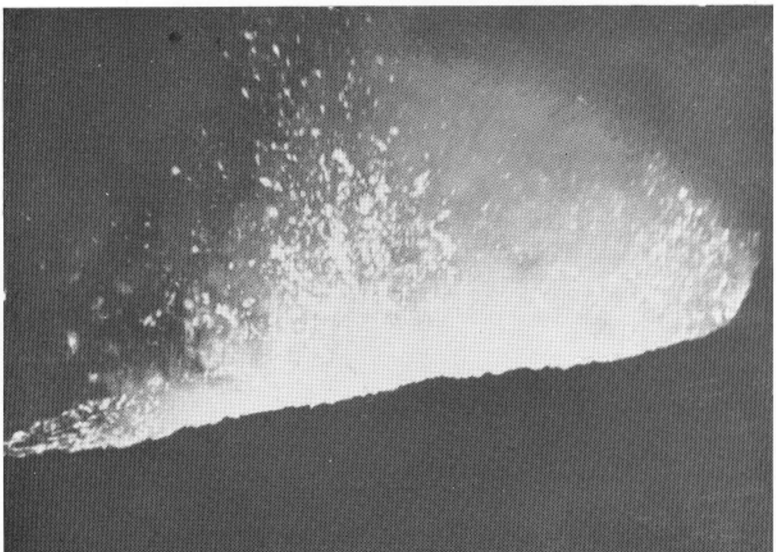


Fig. 30

Meanwhile, a second series of lava streams (MAP 3) issuing at the beginning of March from the west end of the great fissure between Shove and the little volcano Rumoka of 1912, flowed in a south-westerly direction, crossed the Costermansville-Sake-Goma road at Km. 185 and reached the bay of Sake in a few hours, travelling at times at the rate of over twelve yards a minute. Swift lava torrents with a temperature of 1,100- C. rushed through the thick jungle, burning everything in their way.

(*b*) *The conditions in early April* 1948

When I flew over the area on 7th April lava was still pouring into the bay of Sake over a broad front (ab. 3,000 feet). Huge geyser-like columns of steam marked the edge of the lake (*fig.* 5, 6). The waters showed streaks of yellow as well as greenish colourations, due to the sublimation of the gases issuing from the lava while it cooled off. The fissure was marked by several little spattercones in the region of Shove. From six to ten feet high, they were spitting up red coloured lava cakes. The enormous lava fields with their dark red tongues where forest had been before, was indeed a fantastic sight from the air.

When arriving near the volcano (*fig.* 7), the incandescent lava, churning and boiling heavily in its cauldron was clearly seen. Every few seconds, preceded by strong upwellings, gases escaped, throwing up bombs and scoriæ.

The next day, after one hour's walk from the main road along a newly made bushpath, Parc Albert was entered. Soon scoriæ up to two inches in size, thrown up during the first weeks of the eruption, were crunching under the feet. These scoriæ were cold when they had fallen: dark grey in colour, bluish in fresh breaks and were more numerous nearer the volcano. From the observation camp established south-east of Kituro near the edge of the lava field surrounding it, a full view of the new volcano 500 yards distant, about 250 feet high with a base from 800 to 1,000 feet wide, was obtained. (*fig.* 8, 9).

An explosion took place every few seconds with a noise comparable to heavy breakers on a shingle beach. Viscous lava cakes amidst showers of scoriæ and lapilli, after having been hurled through the air, were sometimes seen to alter in shape or break up in mid-air. They fell back together with smaller fragments, partly in the crater or on the outer slopes of the cone mainly to east and north. Volcanic bombs were seen falling and rolling for several dozen yards down the cinder slope, throwing up small dust clouds and leaving a trail behind (*fig.* 10).

Within a few minutes walking distance to the east, the major fissure was reached. It was a few feet wide and extended for about 500 yards in an easterly direction from the volcano. Here and there small streams of ropy lava had flowed out of it. Lava clots lay scattered on both its sides. The most striking feature however, was that where trees had been left standing along the fissure, black cakes of lava were found hanging in the forks and amongst the branches. They give some indication of the force with which the gases had been escaping from the fissure during the initial stages of its formation or shortly after. They must have been flung up in a molten state, but had only partly burnt the outer bark of the trees. Often both ends of these lava cakes, bending towards each other, had been fused together before solidifying. In this area, many trees had been uprooted presumably by the violent escape of gaseous matter from the fissure.

The gaping fissure (*fig.* 11), leading west to the volcano, was followed for about 200 yards. Hot gases were still escaping from it. Coloured sublimates were discernible on its edges, yellow sulphur, red crusts of iron oxide together with white salts were prominent. When the brink of the arena of lava encircling Kituro was reached, an attempt to cross the fantastically shaped lava battleground, to approach nearer to the cone, 200 yards away, was frustrated. The lava, though hardened, was still too hot to be crossed, with fumes and steam emanating from cracks everywhere.

The cone was breached on its eastern and western sides and had been extruding mainly to the north which showed a rounded slope in contrary to the southern flank which was steeper and possessed a ringwall of older debris to its south-east (*fig.* 12).

The rhythm of the explosions that day was not abating. Cherry-coloured lava fountains, hawaiian-strombolian in type, as they passed over the edge of the crater, reached a height of over thirty or forty yards, sometimes solo, often in pairs. The eruption tempo seemed to increase in intensity as the evening was proceeding. The billowing smoke screens, the fireworks, followed closely by the hissing noise, as from crashing trees, were breath-taking to watch.

And so it had been going on, day and night; the eruption was in its fifth week and did not seem to have decreased much, although it had somewhat changed in character.

The huge amount of gas produced during the first three weeks or so, mainly at the eastern end of the fissure, had given way to great masses of lava which from Shove, at the lower western end of the fissure were still pouring out over the plains towards Lake Kivu. The volume of lava had now reached approximately over half a million tons.

On my second visit, a little over three weeks later, the lava was still flowing out near Shove from the western end of the fissure. It was diminishing, however. The spectacular steam columns of April, when the lava was entering the waters of the bay, had much decreased.

The little volcano as seen from the observation camp on 3rd May had not increased much in height, its crater was narrowing as the explosions diminished in strength. Two weeks before, Mr. Tazieff, with some precautions had been able to climb the cone and to take photographs from the crater-edge.

The afternoon of 3rd May, a small party of us, including my eleven-year-old daughter Jocelyne, spent the afternoon on a tour of Kituro to examine it more closely (*fig.* 13, 14). It was rough going at first, where ropy lava had been broken up into chunks and blocks over large areas (*fig.* 15). Bulging or swollen lava crusts, tumuli (schollendome) due to pressure (*fig.* 16) demanded careful walking. Well preserved ropy surfaces were seen before reaching the foot of the cone (*fig.* 17, 18). Fumes and gas emanations were few, occasional cracks showing a red glow two feet below were passed. Nearer the cone the lava bombs, some with extraordinary shapes, were more numerous (*fig.* 19-23).

The scoracious slopes of the cone displayed beautifully coloured sulphur crusts, clustering along fissures and coating wide surfaces.

Proceeding from a westerly direction along the W. E. fissure line, the several minor vents, now dying, were passed. Warm gases still escaped from them slowly. Their inner walls were coated with lava projections which, when still in a semi liquid state, had stuck to their walls. (*fig.* 24, 25). The western breach in the main crater nearby, allowed a quick glance between two explosions of the boiling interior; one photograph and a hasty retreat, as molten scoriæ were flying around. Proceeding to the northern. side of the cone, a twenty yards high hornito belonging to a former eruption was examined, Baked quartzites were collected. Lava caves hung with lava stalactites (*fig.* 26, 27 and 28) a dead antelope choked by the gases, its feet burnt, were passed, and camp was reached by nightfall.

For hours we sat outside the tents, watching the display of fireworks from the explosions into the red glowing eruption cloud lit up by the lava. Then Mr. Tazieff and I decided to try and climb the cone at night, to reach the very summit on the South side and secure photographs. After crossing the lavafield at the foot of the cone with much stumbling and nearly losing our way twice, we climbed the cone along its southern flank. The steep slope consisting of loose boulders, lava lumps, then fist-like lava clots, took some time to overcome. Cracks with a red glow were carefully crossed and at the top of the Southern ringwall a halt was called to observe the direction the projectiles above us were taking. The chances seemed good and a final rush along the edge brought us to the top of the cone. We looked directly into the fiery seething mass only a hundred feet distant. The noisy lava fountains seen from this point offered a fantastic sight above description. *Fig.* 29, 30.

Photographs give only a vague idea of what was really happening. A coloured film is more truthful, but even this could not really convey the deafening sounds and the immensity of the explosions, without some comparative objects in the foreground. We found the ridge too small, the ground too hot, and time too short to achieve this. When at the opposite edge the chilled crust broke off and a small avalanche took place, we realised better that under a thin crust, the material forming the cone under our feet was still red hot.

Explosions followed each other with a few seconds interval. Sometimes the upswellings in the lava pool formed waves battering the sides of the cauldron. Masses of molten lava lumps were thrown up. Some plastered the inside walls, stuck to it or dropped back into the molten mass. Above us, the extraordinary fireworks against the blue smokescreens, the clattering sound from the material falling on to the outside slopes. Totally indescribable, the primeval-shaping-of-things; the labouring-Earth . . . Those who have seen an eruption at close quarters will understand.

(d) The conditions on and around Nyamlagira between 6th to 9th May 1948

In the early days of May it was reported that in the region North of Kituro, towards Nyamlagira, a new kind of activity had started in the form a of series of little active vents appearing in the middle of the forested region. I was able to visit Nyamlagira and this region accompanying Mr. Tazieff and Assistant Conservator de Wilde.

Leaving Mushangabo on the 7th of May, we reached that afternoon the camp on the northern flank of Nyamlagira, where Dr. Verhoogen had undertaken his laboratory studies of the 1938-1940 eruption. The following morning at 9 a.m. the caldeira of Nyamlagira was entered via the Western breach. An examination of the caldeira showed no signs of fresh activity. Fumaroles emitting mainly steam were blazing in the central part but no recent alterations could be detected in the elliptical southern depression due to engulfment, which before 1938 contained some lavapools, nor in the 450 feet deep crater in the eastern sector or near the little cone or stack which Dr Combe regards as a remnant from the top of the old floor, before the collapse. A smell of sulphuretted hydrogen was noticed in the NW. part. The southern fracture, formed in 1938, through which the lava pools were drained, showed no change, apart from fumarolic action in its lower part. A descent was made to Tshambene, the scene of the flank-eruption of 1938-1940. Solfatara were still active in the fissure, but here also and around the spattercones of the 1938 eruption, no signs of recent activity were present. Of the fumarolic activity it is, of course, difficult to ascertain that no alterations have taken place lately as the region was not revisited by geologists since 1940. There is no permanent volcanological survey in existence: this is to be deplored, as with such great objects as Nyamlagira and Niragongo, volcanological data and surprising events of great interest may go by unnoticed.

On 10th May, the plain south of the adventive cone of Rugwete, just south of Nyamlagira was visited. This is the area where a week or so before, the new activity was observed. Mr. de Wilde told us that this region had been recently deserted by elephants. They had crossed the road towards Mikeno in great numbers as was proved when sixty to seventy droppings over a 500 yards stretch of road were found. We passed first a blow-hole about six yards in diameter in old lava covered by forest. It was due to a gas explosion. Blocks of old lava had been projected sideways for a distance of about twenty feet. There was a curious smell suggesting a combination of sulphur and chlorine, but its true origin could not be ascertained.

Several new vents were encountered, where in an old lava field already covered with some vegetation (1938 and pre-1938), volcanic gases were burning. At some places the red hot lava blocks looked like coke fires. At one spot where, during an earlier eruption, a tree stump had left a deep hole after having been burnt out, a flame was blowing with fair pressure to a height of about two or three feet. These mysterious fires appeared also in many places in the middle of the forest. The latter being wet as a result of the rains, the burning gases had not set fire to it yet. Evidence of shifting of these fiery foci was met with at places where the vegetation had been withered recently around the now extinct vents. Curious subterranean noises as dull thuds were occuring in the region every few minutes. Was it due to the movement of rising magma under the area? Or was it a result of the search for equilibrium from a thrusting gas-head underneath?

From our camp on the Rugwete that night, one had a good view over the surrounding country. Rugwete is about six or seven miles distant from Kituro Nyefunzi, and between the two cones, numerous little gas fires and some steam columns could be seen. They were in a roughly north-south disposition. Light thumps were still noticed throughout the evening. The next morning, it seemed as if the activity had eased somewhat. About half a mile north of Kituro smoke or steam columns were seen. Two days later, Mr. Tazieff on his return to the cone of Kituro saw a new lava stream which had burst forth near the so-called " Hornito," north of the volcano, where only just a week before we had walked over chilled lava streams and solid ground.

(*e*) *The end of the eruption*

The situation in the middle of May, according to Mr. Tazieff, was as follows:

After the renewed issue of a small lava stream north of the cone of Kituro, about 400 feet long by 100 feet wide, the explosive activity at the crater was a little stronger than on 3rd May. Explosions followed each other at intervals of one to four seconds, the projectiles reaching a height of about 120 feet.

A small lava pool was formed at the foot of the cone at the end of May. Its surface was shivering and boiling. One did not know at first what to expect from it; was it going to burst into lava fountains? It was impressive to watch, until it merely started to overflow. Near this flow five or six spattercones were working in May.

In June the crater of Kituro was narrowing slowly, its interior terrace of efflata was taking on a conical shape. On the southern end of the major fissure, the little spattercones did not show any further activity.

In August, renewed action of burning gases set fire to the forest on the southern flank of Mt. Rugwete. This happened shortly before the ending of the 1948 eruption. At the end of August, the volcanic activity had ceased altogether and fumaroles only remained, belching fumes into the air.

3. PETOGRAPHY OF THE LAVAS OF THE 1948 ERUPTION

A small collection of the 1948 Kivu rocks has been deposited in the Museum of the Geological and Mining Department Nairobi. Thin sections of the following samples have been retained for examination:

Kivu 1. Sample from blocklava, first stream which cut the Goma-Sake road early in March 1948.
„ 2. Sample from the second (pahoehoe) flow which cut the same road on 13th March 1948.
„ 3. Scoriæ from the beginning of the eruption (March), fallen about 1,000 yards east of the cone of Kituro.
„ 4. Fragment of lava, beginning of eruption, taken from a tree, near fissure, north of Kituro.
„ 5. Lava which had flowed out of the major fissure about 300 yards north of Kituro.
„ 6. Bomb fragment Kituro cone, April 1948.
„ 7. Id.
„ 8. Id.
„ 9. Inclusion in bomb Kituro cone, May 1948.
„ 10. Id.

Dr. W. Pullfrey, Senior Geologist of the Geological and Mining Department, Nairobi, very kindly offered to undertake the petrographical examination of these rocks. Their description follows in full, as it will no doubt prove useful for comparison with earlier and future lavas of Kivu as well as other lavas found in East Africa.

Kivu 1. Olivine hyalobasalt. *Texture* porphyritic with dense base (? weathering) with light patches. *Phenocrysts:Plagioclase* platy crystals and clusters, the latter up to 1 mm across. Some crystals zoned. Approximately An_{63}. A small amount of pericline twinning. *Titanaugite* scattered crystals and groups. Occasional crystals up to ¼ mm. and occasional clusters up to 1¼ mm. across. Some partly enwrap felspars. Slightly brownish or purplish and feebly pleochroic. Z∧C42°. Hour-glass twinning common, and there is occasional poor zoning. *Olivine* much rarer than pyroxene. Colourless. Cf+, 2V large—a magnesian chrysolite. *Matrix:Plagioclase* scattered prisms with indefinite albite twinning Cf. about An_{40}. *Augite* small editions of the phenocrysts. *Olivine* sporadic small grains. *Magnetite* scattered octahedra and grains. *Iron-staining* a considerable amount, and occasional translucent reddish-brown patches. *Glass base* brownish-yellow.

Kivu 2. Olivine hyalobasalt. *Texture* porphyritic, vesicular, glassy base. *Phenocryats:Plagioclase* platy crystals and groups to 0.7 mm. Occasional pericline twinning and feeble zoning. An_{65}. *Titanaugite* slightly purplish, in well-shaped crystals and groups up to 0.45 mm. Hour-glass twins. Dispersion marked. Z∧c38½°. *Olivine.* Rare much-embayed crystals up to 0.4 mm. Colourless, +. *Magnetite.* Rare grains. One 0.4 mm. across, encloses a small felspar. *Matrix:Plagioclase* scattered prisms, Cf. An_{50}. Seriate up to phenocryst size. Also thin platy diamond-shaped crystals up to 0.25 mm. across, often entirely enclosed in the thickness of the slide. *Pyroxene* abundant small crystals resembling the phenocrysts, and seriate in size up to them. *Olivine* colourless ill-defined grains up to 0.15 mm. Occasionally much embayed—one for example is an " atoll " grain with a centre of glass. Occasionally euhedral +. *Magnetite* small octahedra, grains and groups. *Glass base* yellow-brown with numerous crystallites and groups of crystallites. Irregularly cracked. Where weathered much-stained by iron oxides.

Kivu 3. Olivine hyalobasalt. *Texture* highly vesicular. *Phenocrysts:* groups of *Plagioclase* and occasional crystals up to 0.6 mm. About An_{62}. *Titanaugite* slightly purplish, small *e.g.* 0.2 mm. Z∧c47°. *Magnetite* crystals up to 0.2 mm. *Base* light brown glass with crystallites.

A second slide is not so vesicular, but has a stronger development of crystallites. The slide is thick, however, and identification of the crystallites is difficult. This slide also contains one grain of *olivine.*

Kivu 4. Olivine hyalobasalt. *Texture* highly vesicular, porphyritic. *Phenocrysts: Plagioclase.* Mainly synneuses of crystals up to 0.9 mm., but also occasional crystals up to 0.6 mm. An_{65}. *Titanaugite.* Slightly brownish and purplish. Rare groups up to 0.9 mm. across. *Olivine* Rare, up to 0.3 mm. Colourless. Cf. chrysolite. *Magnetite.* Occasional grains up to 0.25 mm. *Matrix:Plagioclase.* Appears to be An_{65}. Some thin diamond-shaped crystals. *Augite* purplish; occasionally stellate groups. *Olivine* small colourless crystals, occasionally sharply idiomorphic. *Magnetite* numerous grains and aggregates. Microlites not identifiable, but ? = felspar. *Base* pale brown glass.

Kivu. 5. Leucite basanite. *Texture:* porphyritic with microlitic matrix. Rare synneuses of olivine, augite and felspar. *Phenocrysts-Olivine.* Few. Occasionally large —2 mm. across, large optic angle, negative—suggests somewhat more iron-rich than in the basalts. *Plagioclase.* Groups up to 1 mm. across. An_{72}, *i.e.*, more basic than in basalts. Occasionally has many inclusions. *Titanaugite* slightly purplish light brown. Occasional single crystals up to 0.3 mm., but most is in groups up to 0.6 mm. across. Hour glass twins. Z∧c49°. *Leucite* scattered trapezohedra up to 0.15 mm. across. Contains prisms of pyroxene, plagioclase and iron ore—the pyroxenes being sometimes orientated more or less parallel with the faces. Isotropic. *Matrix:Plagioclase* abundant prisms sparsely seriate up to phenocryst size, but most are about 0.1 mm. in length. An_{58}. *Augite* small crystals, some idiomorphic. Colour as phenocrysts. *Olivine* scattered grains, much less common than pyroxenes. Occasionally much resorbed. *Magnetite.* Very abundant grains and octahedra. *Base* doubtful. Probably originally glassy: now ironstained, *Kivu* 6. Olivine hyalobasalt. *Texture:* mainly highly vesicular, usually with small round or ovoid vesicles, the largest about 0.6 mm. Porphyritic, with glassy base. *Phenocrysts:Plagioclase* groups and crystals up to 1 mm. An_{59}. Some ophitic towards augite. Some zoned. *Titanaugite.* Rare, up to 0.9 mm. Pale brownish and slightly purplish weakly pleocroic. Also in microphenocrysts up to about 0.3 mm. $Z \wedge c 50^{0}$. Some hour-glass twinning. *Olivine* rare. Colourless. One is 0.25 mm. across, +, 2V large. One crystal is slender prismatic, 0.3 mm. in length. *Magnetite.* Occasional aggregates of octahedra 0.25 mm. across. *Matrix-Plagioclase.* Small prisms, thin diamond -shaped plates, and microlites. *Augite* prisms and microlites. *Olivine* occasional crystals. *Magnetite* octahedra and grains. *Base* brown glass.

Kivu 7. Olivine hyalobasalt. *Texture:* Highly vesicular, with two size-grades of vesicles—large, *e.g.*, 1.7 mm, and small, 0.15 - 0.45 mm., the latter lying between the larger ones. Porphyritic. *Phenocrysts:Felspar.* Plagioclase groups up to 0.6 mm. across. An_{60}. *Titanaugite* slightly purplish and feebly pleochroic. Largest 1 mm. $Z \wedge c 53^{0}$. *Olivine* rare, up to 0.3 mm. Prisms and groups. *Magnetite.* Octahedra groups up to 0.15 mm. *Matrix-Felspar* a few prisms and thin diamond-shaped plates of plagioclase. *Augite* abundant prisms and microl'tes. *Olivine* rare. *Magnetite* abundant grains. *Base* light brown glass.

Kivu 8. Olivine hyalobasalt. *Texture:* highly vesicular with considerable variation of vesicle size. Porphyritic. *Phenocrysts:Plagioclase.* Prisms and occasional groups up to 0.4 mm. An_{65}. Some zoned. Occasional crystals contain many glass inclusions. *Titanaugite* slightly purplish-brown and feebly pleochroic. Prisms e.g. 0.3 mm. length; and groups. $Z \wedge c 50^{0}$. Some hour glass twinning. *Olivine.* Rare—Cf. some xenocrystic, 0.15 mm. across. Also 0.3 mm. prism. Some corroded. *Magnetite.* Occasional irregular grains up to 0.4 mm. *Matrix:Plagioclase* scattered prisms and thin diamond-shaped plates. *Augite* common prisms and microlites. *Olivine* rare small crystals. *Magnetite* numerous small grains. *Base.* Light brown glass.

Kivu 9. Transfused quartzite xenolith (References (1) A. Holmes. Transfusion of quartz xenoliths in alkali basic and ultrabasic lavas, south-west Uganda. Mineral. Mag. XXIV, 1936, 408-421 (2) A. Holmes. The petrology of the volcanic area of Bufumbria. Mem. III, Pt II, G.S. of Uganda. 1937 pp. 145, 148, 253, etc., (3) H. Kazmiteheff. Contribution à l'étude des Roches éruptives et métamorphiques du Kivu. *Mem. Inst. Geol. Univ. Louvain.* IX, VII. 1936, pp. 38-39). *Texture* highly vesicular with remnants of quartz. *Glass* colourless, highly vesicular; no crystalline phase; refractive index between 1.48 and 1.49. *Quartz relics.* Single or composite grains showing weak strain shadows. The glass is eating its way into the grains marginally and along junctions and cracks. *Orthoclase* has developed in the interior of glass veins penetrating the quartz, and in patches when reaction has gone on still further and no quartz remains.

Kivu 10. Transfused quartzite xenolith. Generally similar to nine, but (1) contains numerous prismatic grains of colourless tourmaline, which are presumably derived from the quartzite, and are unaffected by the transfusion (2) contains rare zircon crystals (0.05 mm.) also presumably derived from the quartzite. (3) exhibits small portions of the host rock, there being *no* development of pyroxene at the contact. The refractive index of the glass of the host is considerably greater than that of the inclusion.

This, writes Dr. Pulfrey is a provisional identification in default of a chemical analysis. The slides with quartzite xenoliths indicate that the glass is potash-rich and it is possible that the lavas are in fact of basanitic composition.

What connection do these rocks bear to those of Nyamlagira and Niragongo? Both, these volcanoes started building up in the early part of the Pleistocene. Combe & Simmons 333 p. 120, and consist of rocks which although related, show a striking difference chemically and petrographically.

The lavas of Nyamlagira consist of the more widespread type of medium grained leucite basanites in which porphyritic crystals of Plagioclase, Augite and brownish Olivine are set in a holocrystalline groundmass. Nyamlagira also produced leucite theralite and blocks from the underlying rocks such as baked shales and quarzites which may represent the rocks of the Karagwe-Ankolean system that occur below the floor of the Rift Valley, Combe & Simmons, 327, p. 117. The K_2O content of the basanites is superior to that of Na_2O.

The lavas of Niragongo differ in that they are mainly: nepheline leucitites, leucite nephelinites, melilite nephelinites, melilite basalts, with a content of Na_2O over K_2O. It is not impossible that a degree of assimilation with englobing calcium-rich rocks has taken place (*see* C. & S., 317 p. 113, 114).

The eruptions of the last fifty years produced again different types of lavas. Those of the Adolf Friedrich eruption of 1904 were limburgites. Na_2O over K_2O. The eruption threw up also xenolithic quartzites and granites from the underlying formations. Kanamaharage in 1905, yielded black glassy leucite basanites akin to those of Nyamlagira, with volcanic bombs from a fluid magma similar to those of Kituro in 1948. According to Simmons, this rock is a poorly crystallised trachytic leucite with little felspars, C. & S., 314 p. 112. Rumoka, 1912-13 yielded leucitites. The Nyamlagira flank eruption of 1938 produced leucite basanites. In view of the foregoing, we are inclined to agree with Verhoogen who wrote: "One should hesitate in considering the 1904 and 1912 eruptions as adventive eruptions of Nyamlagira. They came from distinct though temporary volcanoes."

Notwithstanding that the 1948 area of activity was nearer to Niragongo than to Nyamlagira, as the crow flies, and the fissure was directed roughly towards Niragongo, which fact at the time was interpreted by some as if the phenomena were related to this volcano, the character of the lavas issued in 1948, according to the petrographical examination above, are different from those of Niragongo. They differ also from those of the nearby cones of 1904 and 1912. They correspond more to those of Nyamlagira.

The area in which flames from burning gases occurred in May and again in August 1948, North of Kituro, was on roughly South-North lines, directed towards the eastern flank of Nyamlagira. A closer examination of the fault system of the region might give a clearer understanding of the 1948 happenings.

4. CONCLUSION.

The regional tectonics of the eastern Rift Valley north of Lake Kivu are outlined on map 2, after Boutakoff's *fig*. 3 p. 26. The Kivu Rift, continuing towards lake Edward in the north, lies between the western Kivu and the eastern Ruanda tilted peneplains of Miocene age.*

The margins of the Rift consist of scarps due to fault fractures along which, in places, parallel to them, run older flexture lines which were precursory to the breach. The occidental fault fracture or "Faille du Mur" NW. of Lake Kivu which Boutakoff, p.30 regards as a rejuvenated fault, although partly hidden under the young volcanics, merges further North into the Lake Edward fault system. Asselberghs considers, p. 305, that the formation of this fault coincided with the rhyolitic phase south of Kivu of the volcanoe Kahusi, Biega, which followed upon the basaltic sereis from pliocene to middle pleistocene and belongs to the end of the pleistocene.

The lateral Graben or Rift of the Bufumbira, branches off NE. of Lake Kivu in a NNE. direction. Niragongo lies at the intersection of both rifts.

The other Birunga volcanoes are obviously situated on the fracture lines of the northern Rift, Nyamlagira lying exactly west of the "Faille du Mur," Kanamaharage

* I cannot refrain here from mentioning the suggestive figures, 434-435, p. 342, based on experiments undertaken at the Ryksmuseum for Geology and Mineralogy, Leiden, illustrating Leconte, Taber and Cloos's theories on the origin of Rift Valleys, as well as the entire inspiring interpretation on Rift tectonics, chapter XV, part I, p. 339-349 in Prof. B. Escher's Grondslagen der Algemene Geologie, 1948.

on the fault opposite, with three of the five eruptions of the last fifty years occurring between a NNW. fracture and the " Faille du Mur." Rumoka lies on their junction.

This short-lived volcanic activity of the lesser volcanoes and frequent tremors in the region point to movements of blocks, which still persits today. The adjacent downthrown blocks and horsts may offer varying resistance to stresses. The underlying vitreous semi-rigid magma will raise or be squeezed up into zones of weakness. It may form small, individual, shortlived magmabodies in varying localities.

When the upper layers cannot offer further resistance and start yielding a release of pressure in the magma ensues. Gases which were in solution, are allowed to escape (Jagger's hypomagma evoluates into pyromagma). This bursts through and an eruption takes place.

The four miles long fissure of 1948, main feature of the eruption, which, incidentally, cuts east-west partly through the southern triangle of the block formed by the Faille du Mur and the NNW fracture, did not show any vertical displacement or slip on its margins. It was a true fissure bulging out slightly and due apparently to thrusting from below. Little or no lavas issued from the central part. This part may have been blocked or sealed up. As already stated, at Shove, on the lower end of the fissure, altitude approximately 5,200, the lavas (2nd stream), were very fluid and gasarm (dermolithic), in contrast to those originating at the higher level, altitude approximately 6,800 (1st stream) which were aphrolothic, while Kituro still further, provided both lavas, lava-fountaining and gas, the latter being dominant. This may have been due to unequal repartition of gas in the magmabody, due to convection.

It seems according to local reports, that the glow seen in the cloud above Niragongo has not been brighter than usual during the eruption months. The lava-fountaining discovered by Tazieff and Tondeur in June 1948, in its inner crater, may be an unusual feature.

The burning gases and numerous fires situated on north-south fractures between Kituro and the eastern flank of Nyamlagira (Rugwete) may be regarded as a corollary of the 1948 eruption. This may have led to a reviving of the Faille du Mur, on which fault-system Nyamlagira is situated.

The matter at this stage must remain somewhat conjectural. Precise levelling of this lively part of Kivu, the establishment of benchmarks allowing surveys made at regular intervals, would, as they have done in Hawaii or Japan, reveal trends and amplitudes of eventual block movements in future. In conjunction with these observations, seismographs would supply data on local chocks. A regular study of the fumarolic areas, gas analyses, temperature readings at Nyamlagira and Niragongo etc., may lead to a better discerning of the premonitory symptoms of a pending eruption. It may also allow for their prediction, and permit safety measures to be taken in time, in the eventuality of eruptions taking a course different to that we have been accustomed to, in the very short period of our knowledge of the Kivu volcanoes.

5. LITERATURE

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