VOLCANOLOGICAL OBSERVATIONS IN EAST AFRICA.

II.—KILIMANJARO: KIBO'S FUMAROLIC ACTIVITY IN 1942-43.

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Contents.

1. Introduction.

Kibo, the highest, the youngest and best preserved volcanic cone of Kilimanjaro (Fig. 1) of which Shira and Mawensi (Fig. 2) represent the older main vents, contains, sunk in its white shining glaciers, a two-kilometre-wide caldera caused by subsidence, inside which is a secondary eruption cone, with its own small crater.

While in the past, attempts to conquer the summit of Kibo, Kaiser Wilhelm Point, about 5,950 m. high (Klute's figure) were numerous, mountaineers rarely tried to descend into the caldera and visit the crater. Mostertz (1930), in his list of ascents of Kibo, records, since H. Meyer with L. Purtscheller first reached the top in 1889, up to 1928, 47, of which 15 were successful, but does not mention any visit to the crater itself. The amount of energy and the time required to climb the highest point, form the main reasons for this apparent forgetfulness.

From the summit, only a faint black line, situated in the northern part of the caldera, the crater rim, about 500 m. wide and the northern upward inner slopes, are seen above a rather flatshaped broad cone, just below the great northern ice barrier or eastern extension leading to the Credner, Drygalski and Penck glaciers (Fig. 3 and map).

Until recently, Kibo was considered extinct.

Three short expeditions to the caldera of Kibo were carried out by the author. The first, on August 29th, 1942, made together with a friend, Mr. A. Cooke, his son and Flying-Officer B. Hawson, led to the top, Kaiser Wilhelm Point, and the south and south-east parts of the caldera. The afternoon of the 9th of October, 1942, was spent in examining its eastern side. After a cold night under a rockshelter near Gilman's Point (Fig. 4) together with guides, Thoma and Johane, the next day was employed in investigating the central and northern part of the caldera, and a descent into the northern crater was made. On the 1st of February, 1943, a second short visit was made to the crater, while my companions, Dr. L. Stevens and Lieut. P. C. Spink, were making for the summit. These two last visits to the crater gave me a clear demonstration that this East African volcano was dormant rather than extinct.

While expounding in the following pages on the theme of Kibo's activity, only where essential and in so far as the caldera and the crater are concerned, the long list of literature on Kilimanjaro will be mentioned.*

*A complete list of literature of Kilimanjaro, up to 1932, is to be found in C. Gillman's compilation in *The Ice Cap*, No. 1 (1932), pages 67-71.

In this connexion, I am especially grateful to Mr. C. Gillman. When in Dar es Salaam, in February, 1943, I had the privilege of consulting his extensive library, failing which a narrative on the history of Kibo could not have been written.

2. The Caldera of Kibo and its Eruption Cone in the Past, According to the Literature.

On turning to the literature on Kibo of the last fifty-four years to find instances of early activity of the crater one discovers little information. This lack of references is due mainly to the fact that efforts to reach the crater in the past were often frustrated, as they are sometimes today, by the bad state of the ice and snow. Other adverse factors are the meteorological difficulties encountered, in the form of blizzards, and the climatic and physiological troubles of high altitudes, namely, mountain sickness or physical exhaustion. In addition to the time required for investigations, a definite kind of ill fate attended many attempts to conquer Kibo's true crater in the past.

H. Meyer's earliest statements, contained in three letters to Professor Ratzel, 9th October (pp. 15-17), 25th October (pp. 20-21), and 5th December, 1889, published in Petermann's Mitteilungen, Vol. 36 (1890), do not contain any specific indications as to whether or not the central cone, which is first mentioned on page 16, was still active. In his first letter of the 9th of October, one finds the earliest mention of its existence. The upper half was then free from snow, while the lower was armoured with a strong ice belt. A sketch, Tafel 2, of the cone shows a small crater on its top. H. Meyer, on his second exploration of Kilimanjaro when he reached the summit with E. Purtscheller on the 5th October, 1889, and named it Kaiser Wilhelm Spitze, attempted a little later on the 18th, to visit the central cone. After reaching the breach in the ice, called later H. Meyer Notch, he and Purtscheller started on their way across the caldera. In *Across East African Glaciers,* (English edition, 1890, p. 83), the attempt is commented on as follows: ". . . everything seemed to promise such easy progress that Purtscheller gave it as his opinion that we should reach the cone at the bottom in an hour . . . A little experience of the 'nieve Penitente' surface of the ice ahead soon caused us to modify our sanguine expectations . . . we became involved in a chaos of ruts and rents and jagged points amid which it was nearly impossible to find a footing . . . , the brittle crust gave way beneath us and we found ourselves up to the armpits struggling to extricate ourselves from the jaws of the crevasses." On page 184, H. Meyer mentions fissured ice-sheets lying between them and the brown lavas and ashes of the central parasitic cone. In his second letter to Professor Ratzel (*loc. cit.* p. 20), H. Meyer came to the conclusion that the plan was irrealisable.

On the question of activity, H. Meyer (1891, p. 307) states: "the activity of Kilimanjaro is now a thing of the past, there is no trace even of fumaroles." In his magistral work, *Kilimanjaro,* (German edition, 1900), after his fourth ascent to Kibo nine years later, H. Meyer is more definite still. On page 144, he writes: "In 1889, I was dubious as to whether a relic of volcanic life still animated the crater of Kibo, now, I could see plainly that there was nothing in the cauldron to indicate formation of steam, nowhere were there visible hot springs, fumaroles, solfatares or mofettes. In addition the ice-layers *on* the eruption cone itself show that this holds no remnants of heat. The volcano is to be considered as completely extinct." In another reference to the cone on page 317 of the same work it is stated: "the eruption cone has produced outflows of lava, flat and broad, apparently without forming a crater." In another of his works, H. Meyer (1909, p. 228) wrote: "since the extinction of the volcanic fire, which took place in the early diluvial, the mountain has known no further great volcanic catastrophy," while on page 335 of *Kilimanjaro* 1900, we find: "The last eruptions took place at 4,400 m. on the west where the 'Lenthügel' are found. These eruptions occurred in late Pleistocene times"

The statement (1900, p. 352) that in 1889, mighty ice-masses from the northern side reached over and across the eruption cone together with the two other statements, on pages 144 and 317 (see above), are somewhat in contradiction with H. Meyer's earlier statements of 1889, and the sketch mentioned. In a panorama (19th October, 1889), as seen from slightly south of the East Notch, the central cone is free of ice and its rim is indicated by the mention of two angles, 312° and 334° giving its extreme points (roughly west and east). The northern glacier is at an angle of 345° i.e., 11° distant. It is difficult to believe that these figures were merely imagination. Mention was made above of H. Meyer's earliest references to the central cone. In *Across East African Glaciers,* page 155, there appears a plate executed by E. T. Compton after a photograph by H. Meyer in which "the main features of the mountain scenery are reproduced with remarkable fidelity" (H. Meyer, Preface, p. XII). This plate shows the upper parts of the cone free of ice. In another reference to the cone, *ibid.,* page 183, it says: "The ice-sheet stretched in a compact mass *to the foot* of the small central cone." The only explanation, and this is quite to the credit of H. Meyer's integrity, is that from the lower point (H. Meyer Notch) where he stood nine years later, and from where the crater cannot be distinguished (Fig. 6), H. Meyer came to doubt whether his presumptions of 1889 were correct. From the summit and from the south rim of the caldera the outlines of the cone and crater, when covered with snow, are not always clearly seen even today (see Fig. 2).

Dr. C. Uhlig on September 30th, 1901, and again in 1904, with Dr. Fr. Jaeger (who made a further attempt with E. Oehler in 1906-07), explored the north and south parts of Kibo as well as the western, so-called, "Great Barranco." They reached Johannes Notch and continued about 200 yards beyond it to the south, but were forced to abandon an attempt to reach the top by the jagged ice and soft snow in which they sank up to their knees. Exhaustion and lack of time did the rest.

And so, with more or less successful attempts, the story of Kibo continues.

In 1912, E. Oehler and Fr. Klute, proceeding from the west *via* the Drygalski Glacier, reached the north-west edge of Kibo, but they were too exhausted to climb to the summit, and returned by the Great Barranco to their camp under Penck Glacier.

In their publications neither Uhlig (1904) nor Oehler (1915) give new information about the true crater.

Jaeger (1909, p. 135) mentions the "ashcone" in the caldera, and on page 169, expresses the view that "it is not impossible that in addition to solar action, volcanic heat from the crater has led to the strong melting of the former glacier, which possibly, to a variable depth, covered the whole bottom of the caldera." While H. Meyer and C. Uhlig failed to discern the smallest trace of volcanic activity, "the absence of this," says Jaeger, "does not exclude the possibility that there may still be some internal heat escaping from the crater." It is difficult, however, to decide what factors in the first instance, have contributed to the deficiency of the ice in the caldera, a fact which seems at variance with the favourable altitude and orographic conditions.

Klute (1920, p. 70) mentioning the caldera, writes: "no crater exists," and on page 86: "The eruption cone with its faded-out configuration, shows no crater opening and is but a ridge stretching approximately N.E.-S.W." This statement is confirmed by Klute and Oehler's map, in which no crater is indicated on the summit of the central cone. See also Reck (1922, pp. 201 and 204). Thus we see that most of the early authors are unanimous in declaring Kibo as being extinct and deny even the existence of a crater. After a break between 1914 and 1921 a new period of explorations of Kilimanjaro was opened when in the latter year C. Gillman in company with P. Nason reached Johannes Notch. C. Gillman (1923) pointed to the great regression of the ice cap since former investigations, and brought up a boiling point thermometer and determined the altitude of Johannes Notch (at the foot of the then protruding rock) as 5,880 m. This figure, used later for the determination of the height of the summit of Kibo, gives for the latter a height of 5,965 m. (19,570 ft.). See *Ice Cap,* p. 102, footnote.

Mostertz (*ibid.,* p. 304) referring to the holes in the horizontally stratified ice (1/3/1927) of the caldera bottom, expressed the view that melting might be due to local persistence of post-volcanic activity.

Nillson, who took the first panoramic photograph from Kaiser Wilhelm Point, showing clearly the eruption cone (13/1/1928) in a pamphlet (1929) and in his thesis (1932), was mainly concerned with the quaternary glaciations and their correlation with pluvial epochs. He refers to the recent retreat of the glaciers of Kibo in general, and mentions on page 76, without entering into details, volcanic activity in the dry period of the Gamblian.

Dr. Reusch, after reaching the summit of Kibo on the 26/9/1926, climbed it twice again in the following year and has, up to now, some forty ascents of Kilimanjaro to his credit. We owe to him the discovery of the crater on the central cone on the 17th of July, 1927. Mr. C. Gillman handed to me an unpublished paper bearing on this discovery, and having been given permission to make use of it I reproduce here the following comment:—

> "In a letter written by H. Meyer on 1/3/1929, shortly before his death, to the Rev. R. Reusch of Marangu—in reply to the latter's announcement that he had discovered a crater in the central cone I find this remarkable confession: 'Enclosed you will find my sketch of the crater. I have inserted on it the ash cone which at the time was inaccessible to me owing to the magnitude of the covering ice-masses. I have made this sketch in 1889 (obviously a copy of the one in Pet. Mitt., C.G.). I was greatly interested to hear that you have discovered a crater on the same. This seems to be much larger than one might have anticipated. I suspected its existence but was very doubtful whether it existed (*sic!* C.G.). You will recognise it as a quite small hole on my sketch. *It was, however, a mere assumption of mine that it existed.* Your news confirms that my assumption was correct and throws fresh light on the origin of this mountain.'
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> " 'These statements make it clear,' writes C. Gillman, 'that Professor Meyer cannot be credited with the discovery of the "pit" '."

Two years later, on the 5/1/1929, N. Rice reached the top of Kibo and we owe to him, in addition to a panorama taken from the summit, the first correct 1:10.000 map of the caldera of Kibo, with the true position and aspect of the eruption cone and crater (1932). The survey, I understand from a letter written to me by Dr. Reusch, was undertaken in 1932. Mr. Rice reached the central cone and built a beacon on its top. In a letter N. R. Rice states that, at the time of his visit, he did not notice any steam jets or fumes in the crater.

W. Mittelholzer (1930) flew over the crater. Some splendid airviews are reproduced in his book, the first photographs of Kibo crater from the air.

C. Fluckiger, according to a verbal communication of C. Gillman, visited the eruption cone in December, 1932. He has not, however, published an account of his findings.

W. Geilinger (1936) in a clear *exposé* on the retreat of the glaciers and the changes at Kibo since Fr. Jaeger's time, wrote on page 16: "certainly no traces of still existing volcanic activity have been observed." His last ascent of Kibo took place on the 23rd of February, 1934, when he reached Kaiser Wilhelm Point.

Shortly before, however, W. H. Tilman, according to a note in the Kibo hut-book, reported his visit to the north crater, on August the 21st, 1933, where he "noticed sulphur fumes discharging from the outer rim on the south side." The Rev. R. Reusch, who read this statement on the 6th September, 1933, replied: "I was surprised to read in Mr. Tilman's record that he had seen sulphur fumes in the northern part of the crater. I looked for these today but could not find any traces of them. I am afraid Mr. Tilman must have mistaken a certain kind of whirling, little clouds resembling smoke for the sulphur fumes."

Dr. P. Julien (Dutch Itoeri Expedition) writes in the Kibo hut-book on the 11th of October, 1933, that he saw no smoke but only clouds in the crater.

W. H. Tilman in his book, published in 1937, stated on page 41, that Kilimanjaro is an extinct volcano and on page 48: "on top of Kilimanjaro is a great flat-bottomed crater possibly a mile across at its longest diameter, filled up with ice and snow." On page 175, Tilman wrote further: "I walked across to the north side of the crater to inspect a secondary and very perfectly formed crater. At the top the diameter was about 400 yards across, at the bottom 200 yards." In contradiction to these statements he said on page 48: "sulphurous fumes rose from the lip and pieces of sulphur lay about . . ."

While nothing shows that Dr. Julien "walked over" to the true crater, it is certain that Dr. Reusch, who knew the crater well, noticed nothing unusual at the place mentioned in the hut-book by Tilman. Does this mean that in a short space of time alternating phases of rest and activity of the crater have taken place? Insufficient evidence of this is available, for the reports are too vague.

The above quotations from the literature show that during the last fifty-three years (between 1937 and 1942 no data are yet available), there has been little or no evidence of activity of Kibo.

Incidentally, some points in one of the ancient legends of the Wachagga, related by Dr. B. Gutmann (1909, p. 2), and mentioned in a slightly different way by Dundas (1924) and by Dr. R. Reusch (1928), suggest that the Wachagga based their tradition on volcanic activity in past ages. In primitive countries, legends *after appropriate interpretation,* have often proved to contain some truth. The legend, mentioned here as a curiosity, says in short that Mawensi, Kibo's older brother, twice borrowed embers from Kibo's hearth, thereby disturbing the latter in its occupation of stamping dried bananas (possibly an allusion to rumbling noises from the then active Kibo, R.). Each time, the fire went out on the way to Mawensi (possible reference to the last lava streams rolling down at night on Kibo's eastern flank, or the glowing fire of the then, perhaps, active, red hills situated roughly between Kibo and Mawensi, as viewed from below by people, who did not venture far into these high, hostile regions). The third time, Kibo in an access of great fury, gave Mawensi a shattering blow with its heavy pestle (doubtless an allusion to the eruption cloud which often takes the form of such an implement: subsequently, this cloud could have enveloped both mountains, while a great eruption with earthquakes from which Mawensi's crumbling edifice emerged in a still more shattered and jagged condition, developed*).

So much for evidence in the past.

3. Kibo's Fumarolic Activity in 1942-43.

In a letter to the editor of the *East African Standard* of the 17th July, 1942, P. J. Sinclair of Moshi suggested on the basis of reports received by mountaineers who had climbed Kilimanjaro recently "that Kilimanjaro is not altogether extinct, but still retains a modicum of activity in the crater proper . . ." "A very unpleasant and nauseous smell had been noticed when a descent was made into the crater, and an intermittent steamjet noticed in a fissure about 30 feet under the top of the inner slope of the crater . . ."

This statement was made after A. J. Firmin's visit to the northern crater on the 1st of July, 1942, on which occasion some very good panoramic photographs were taken which were on display in November, 1942, in the Coryndon Museum, Nairobi.

These interesting facts decided my first visit to Kibo. On August 28th, 1942, following so many others, I had the privilege of reaching the highest point along the south-east and south ridge, Kaiser Wilhelm Point, which, apart from the immediate view of the caldera, is devoid of interest. On the way up, shortly after having passed Stella Point, a familiar noise, which seemed to come from the steep caldera wall under H. Meyer Point (Fig. 5) and recalled distinctly the typical hissing noise of steam fumaroles, made me investigate this part of the caldera. Soon it was plain that the noise of a strong wind moving round from south to east along the caldera wall, running through holes and against rocks, was the cause of this phenomenon. When descending from Kaiser Wilhelm Point into the caldera bottom about 600 feet below, the absence of any fumaroles in this part of the caldera which I crossed from south to east became unmistakably clear. Passing near the so-called "Ice Dome" or "Eisburg" (Ice Castle) of the old German maps, it was evident to me that this block of residual ice had suffered from further intensive melting since Geilinger's visit in 1935 (Gelinger, 1936, p. 18). It was greatly reduced in size, most of the lower, eastern part as well as the western part having vanished. Two small, isolated fragments of ice on the east and a series of ice-needles in the west, indicated the places where these parts of the glacier ended, only seven years ago (Figs. 4 and 6).

Elsewhere in the caldera the damage done by time was less evident as freshly fallen snow, frozen hard, still covered the ground. Denudation on the low side of the south-east caldera wall had become somewhat greater, and marked erosion had occurred on the eastern ridge of the northern ice barrier, near the most northerly notch.

These changes which had developed since 1935 seemed to me to have been due principally to meteorological causes, that is to say: a predominance of solar radiation and sublimation over precipitation during recent years. As mentioned above, no signs of volcanic activity were found anywhere.

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*The genealogical tables of Chagga chieftaincy (Eva Stuart Watt and Dundas) and the principal events of Chagga history show that they have not occupied the slopes of Kilimanjaro for more than 300 to 400 years.

It was 1 p.m., when Johannes Notch was reached again. Porters who were supposed to bring up a sleeping bag and food failed to reach Gillman's Point and it was considered inadvisable to spend the night without shelter in these icy regions. The temperature, which during the morning was round about 32° F., fell quickly to 5° F. below freezing point as soon as the clouds gathered. Time being too short for a crossing to the northern eruption cone, further exploration had to be put off to a later date.

A little more than a month later, on October 9th, I climbed the toilsome screes above Kibo hut once more (Fig. 7) with three willing porters marching in front this time, instead of behind.

The lava outcrops on both sides of the scree consist of trachydolerite, and are subject today predominantly to strong erosion through frost, as can be seen by the neatly separated crystals of anorthoclase lying about. It seems, when examining a rock sample, that the melting water infiltrating between the phenocrysts and the matrix functions as a wedge when refreezing takes place. It is possible also that owing to differences in hardness and elasticity, the glassy or obsidian-like matrix of some of the rocks, and the phenocrysts, respond in different ways to the repeated changes of temperature and in this way the peculiar disintegration is facilitated. Where the slopes are sufficiently steep, the loose material of the screes seems to move slowly down through the alternate freezing and melting of water and snow.*

No distinct striae, similar to those exposed so beautifully one hour above Peter's hut at about 13,000 feet (Fig. 8), were noticed on neighbouring lava streams. They have probably disappeared through weathering. The whole of the eastern flank of Kibo was once covered with glaciers; a number of boulders, resembling erratic blocks are scattered widely on the saddle-plateau (Figs. 9 and 10). Glacial valleys and ancient moraines have been altered by subsequent desert erosion. In the past struggles between the ice and fire of Kibo and the mud-flows which must have occurred along its flanks have contributed, together with the erosion products of Mawensi, the ejecta from the fairly recent red hills south-west of Kibo, and the still downhill-creeping stone-wastes, to fill up the once much deeper valley between the two mountains.

Johanes Notch was reached in four and a half hours, and a camping place found under some overhanging rocks beneath Gillman's Point (Fig. 4).

There is no doubt that the cauldron or caldera of Kibo has been caused by subsidence. Klute's argument (Klute, 1920, pp. 69-70) that the lavas of the outer slopes could not have flowed upwards from the lower level of the actual cauldron is clear and needs no confirmation. During a great eruption, which may have left a mass defect in the reservoir of magma, possibly due to an exhaustive emission, the formerly higher top sank and disappeared. If the caldera had been formed by the mountain top blowing up (this is how certain authors explain the formation of calderas), thick layers of debris would be found on the actual caldera rim or in its neighbourhood, and this is not the case on Kibo.

The caldera has sunk somewhat in the northern quadrant of the former summit. Its rim is highest in the south and east, lowest in the west where the great barrance is found. The caldera bottom is uneven, the lowest parts are in the east and south, the highest in the north-west quadrant where the eruption cone is situated. The lower parts are not flat but show an irregular surface, the results of the latest eruptions.

*A petrographical description of the rocks of Kibo did not materialize owing to the difficulty of obtaining the necessary slides and chemical analyses and has been postponed.

It occurred to me on the afternoon of the 9th October, 1942, when examining some of the holes and depressions south-west of Johanes Notch mentioned by Mostertz (Figs. 4 and 6), that some of the deepest holes may be remnants of old secondary ephemeral craterlets, partly filled with debris of later eruptions and by subsequent erosion.

Ancient fissures may have re-opened or new ones appeared under the influence of greater activity of tectonic or magmatic origin. Such fissures may have initiated the formation of cavities in the past or assisted in the unequal melting of the ice through the heat that escaped from them. Manifestations of this kind, however, were *definitely absent* in October, 1942* When situated on impervious ground, these hollows contained frozen pools, but over porous layers the melting water was absorbed during the day before re-freezing of the surface took place in the evening.

Local wind currents and snowdrifts, related to the irregularities of the caldera rim and its inner topography, have also, to some extent, contributed to the variable thickness of snow and ice deposits. On both visits, October, 1942, and February, 1943, while the prevailing breeze blew from the north-east, it appeared to come from the west. Snow gauges or better, "Mougin" totalisators as used in the Swiss Alps, put up at different points across the caldera could give indications as to the precipitation on the higher parts of Kibo.†

The thermic influence of the bare, dark and heat absorbant spots, once these have appeared, as emphasised by Jaeger and Geilinger, cannot be underrated. They form a strong melting agent, for their radiations have an important effect on the surrounding ice.

On the night of the 9th to 10th October, the temperature went down to 22° F. Not so much hardship was caused by cold as by the fact that on account of the high altitude very little food, only glucose and water, could be kept down. On the 10th, an early start was made in the direction of the northern crater. The snow-fields in the caldera, which a month before were level and provided easy walking, had undergone a great change and nearly the same fate as had overtaken H. Meyer befell me. The frozen and brittle slabs of ice, 1 to 2 inches broad and separated by ½ to 1 foot wide and in many places 3 feet deep, S.-N. ruts, the "Nieve penitente" (Fig. 12), made the going very difficult. To avoid wedging, a zigzag course was taken, first to the west, then to the east and north, choosing when possible the few bare places. After three hours of tortuous steering in the direction of the crater, which is only three-quarters of a mile away, without (unfortunately) encountering any melting due to volcanic activity, the cone was reached at last.

The east and north-east side of the half-bare surface of the outer slope of the cone was curiously marked with terrace-like undulations, more or less parallel with the contour lines. Stones had collected to form irregular alignments or garlands, while between, in the depressions, only fine material was found. These reticulated figures are due probably to the alternate pushing and contracting of freezing and defreezing whereby separation of the material according to size takes place. They are different

*Stress is laid upon this point because of some misleading statements of Huxley in a letter of 28th December, 1942, in the *London Times*, reproduced also in the *Illustrated News* of 16th January, 1943, where a photograph taken near Johannes Notch is described as being one of the crater which obviously was never visited.

†These instruments being unavailable at the time, on the second ascent after having consulted Group-Captain A. Walter, B.E.A.M.S., Nairobi, I took up and installed four ordinary totalisators at respectively 7,200, 9,200, 12,500 and about 16,000 feet (Kibo hut) (Fig. 11) to obtain a general idea of the precipitation on Kilimanjaro's southern flank.

from the "polygonal" figures of the saddle plateau, described by O. Fluckiger (1934, p. 358); but due to similar causes and are known from arctic countries.

The last, somewhat steeper, outer slope on the south-east side was slowly traversed in a mood of scepticism as to what the crater would reveal. However, the reward for the past struggle was immediate as soon as the top (about 400 feet higher than Leopard Point according to my aneroid) of the outer crater rim was reached.

The crater practically free of snow lay before me in all its splendour (Fig. 13).

The first and highest rim, on which I stood, was circular in shape, and gave a clear view of the second semi-complete ring-wall from south to north-west, and the third, central, inner rim encircling the crater pit: a morphology in strict conformity with the gradually-diminishing activity of Kibo. Close by, on the side of the first inner slope, four solfataras were sending noiseless fumes into the air. A sulfurous smell hung about.

The first inner slope in its eastern part consists mainly of fine material, scoriae, lapilli and ashes with but a few volcanic bombs. No figures, as noticed on the outer slope of the cone, occur here. After descending to the first level, soft, warm spots with some sulphur deposits were passed (Fig. 14) near a lava stream of prismatic structure (Fig. 15). Leaving on the left the second wall which stretches from the south and turns to the north-north-west, indicating a shifting of the eruption point to the north-east not long before the last eruption, I climbed a small slope which led to the inner pit or vent. This orifice, a nearly-perfect, round funnel about 300 feet wide and 200 feet deep showed in its northern upper part, remnants of lava from one of the last eruptions. From this lava-mass a "gendarme" or lava pinnacle about 30 to 50 feet high (Figs. 16 and 17) protruded on the crater-side.

The last eruption, of Strombolian type, consisted of explosions scattering the solidified lava which at intervals filled the crater, possibly forming lava lakes, followed by subsidence due to receding of the magmatic column, as is shown by the regular, horizontal strata of lava about 10 to 15 feet thick which form part of the inner walls of the pit. Similar layers of lava alternating with tuffs are visible in the first ring-wall on the west side, the north side and near the eastern fumaroles. The young eruption cone, as well as Kibo itself, built up alternatively of clastic ejecta due to explosions and lavas, but predominently of the latter, is a cone of the mixed type or typical *strato Volcan* (Sketch 1).

Though it is perhaps possible with some difficulty to descend into the pit from the east side, this aspect does not present so much interest as the bottom, which consisting of loose material, can be seen clearly from the rim.

The whole titanic landscape is one of striking freshness. It is possible that the caldera was once covered by an icecap but it is doubtful if it has spread over the whole crater since the last eruption. An ice-cover would, only up to a certain point, have played a protective role on the configuration; it would, also, by its movements have worn down the slopes by abrasion. No sharp rims of soft material could have resisted its obliterating influence. The lava peak in the crater, obviously a body injected between older lavas and owing its growth to subsequent erosion of the surrounding lavas, would have been torn away to the depth of the crater if grinding ice-masses had descended along the slope behind it.

The abrupt ending of the northern ice-wall, the gaps and chunks in the neighbourhood of the crater, the horizontally-banded ice, may arouse the suspicion that the ice melted *a posteriori* (Jaeger, p. 169); the sudden drop of the frontal part of the glaciers, however, is the criterion on Kibo. This drop is due to the combined actions of the strong solar radiation, of the bare rock in front of the glaciers, and of the protective snow-cover at their apex (Jaeger, p. 185). Fig. 18 shows these features as they occur along the northern ice-wall from beneath which Fig. 19 was taken.

As for the crater, we can only point out that no evidence that ice has covered the whole of it exists today. Nowhere is alteration caused by ice visible. This leads one to suppose (all the more easily now that the potential activity of the crater has been demonstrated) that, ever since the last eruptions, the cone has been under the influence of a high geothermic gradient, preventing, at least over the greater part of it, persistence of ice or snow. Naturally, the effect of the sun and the sheltered position of the crater are additional, contributory factors.

The fumaroles.—The four eastern fumaroles, already mentioned (Sketch 2⥉●) were found in curiously shaped, semi-elliptical, dark, damp spots. The fumes consisted mainly of steam with some SO_2, and issued from several small fissures in the old underlying lava. They showed a temperature from north to south of 85°, 102°, 94° and 83° C. respectively. Firmin assured me, and his photographs prove, that in July, they were absent.

The small steam-jet seen by Firmin in July, somewhat to the right of the pinnacle's foot, was still active in October, when thin vapour was seen escaping from a fissure.

The soft, warm spots mentioned as present at the bottom of the first slope, where crystalline sulphur was found, showed a temperature only 55° C.

Two other fumaroles were seen on the north side, one, a few hundred feet to the left of a small lava peak on the highest ridge, the other near its bottom.

Yellow, sulphur deposits, in which temperatures varying between 55° and 60° C., were found occurred to the west along the second ring-wall as well as to the south along the same wall. This sulphur was deposited several years ago, as it is to be seen just above some snow in Mittelholzer's photograph No. 119 taken in 1930.

No gases of suffocating character such as CO_2 or H_2S, which often accompany the low temperatures of volcanoes in the solfatara stage, were noticed. There was some suspicion that CO_2 might have been responsible for the dizziness felt when measuring temperatures in the lower part of the first rim; but its presence could not be confirmed by a candle test, and the indisposition was probably caused by fatigue and altitude. This gas, which has caught unawares not only people ignorant of its existence, but also experienced surveyors working on volcanoes in Java and elsewhere should never be overlooked. It appears now here, now there, sometimes in well-known places where it has not been found before, but usually in depressions, ravines and at the bottom of craters where it may reach heights, varying up to several metres.

On the 2nd February, 1943, on a second but shorter visit to the crater *via* Leopard Point (Fig. 20), the caldera was found practically free from neveglacier and provided an easy crossing. Instead of a few fumaroles working in different parts of the crater there were whole groups of them. On the inner, south flank, from the second terrace to the top, two-thirds of the slope was alive with fumes (Sketch 2). Four main groups of fumaroles consisting mostly of small solfatares could be discerned. They are called here 6, 7, 8 and 9, while from west to north on the second rim another two groups occurred: 10 and 11 (see Sketch No. 2♂).

In addition to the main fumaroles mentioned above, the southern groups contained a quantity of additional, smaller areas, where emanations of steam and sulphurous fumes escaped from various and variable small cracks. The temperatures usually were about 60° C.

Groups 10 and 11 on the second rim were more or less in a line, and situated near or in older sulphur deposits.

The fumaroles 1-5, of my previous visit were still there. Nowhere in the crater could really-high temperatures be found.

So we see, that a definite increase of thermal activity took place between October, 1942, and February, 1943, the activity being more marked along the limits of the older crater walls. This indicates that, after the lava plug of the central chimney had cooled off to a certain depth, the gases found an easier outlet at its periphery along the boundary lines of the former craters. It is not impossible that further fumaroles occur in the older, semi-buried, south and west ring-walls, which I did not visit.

4. Conclusion.

When the existence of older solfataras (as proved by the south and west, second rim, sulphur deposits), is taken into account the slight activity of Kibo in 1942-43, does not enable one to decide whether this activity indicates a reawakening of Kibo, or is merely an aftermath, a final post-volcanic convulsion. Only future observations will show which interpretation is correct.

H. Meyer (1900, p. 335-338) wrote the following on Kibo: "occurrences of intratelluric events of dying volcanism in relation to small hearths of second or third order and their remnants of magma, will find enough internal spaces and refrain from breaking through to the surface." H. Meyer thus circumscribed the life of Kibo to the occurrence of an injection of magma of long ago.

The problem is, however, not merely in relation to a local magma intrusion in the past, and the reactions deriving from its evolution and crystallisation processes. According to Krenkel's (1922) volcano-tectonic map, Kibo lies not far from the centre of the eastern negative zone of gravity anomaly, uncompensated isostatically (−100). Ultimate isostatic adjustments may still play a role in the future, the dominant feature is, however, Kilimanjaro's situation on a tectonic zone of weakness and faulting. Roughly situated on a line east-west *via* "dormant" Meru, Mondul, Burko and Essimingor, it lies at a right angle to the north-south stretching Great Western Rift which, in its depression north of lake Manyara bears the volcanoes: Gelei, Kerimasi, Kitumbene and active Oldonyo Lengai.

Apart from the more ancient tectonic features: Tschatschame scarp to the south, Pangani rift in the south-west, which are formations due to similar causes as the younger Great Rift Valley, several secondary younger fault-fissures or fracture lines radiate from Kilimanjaro's east-west axis, marked by subsidiary outlets or epigones—south-east and south the volcanic subgroups of the so-called Rombo and Kirua-Kilema zones, etc. They all point to the complicated tectonics of this region.

Thus, the life of Kibo, though characterised by a certain amount of individuality, is primarily and foremost contingent on the behaviour of the great earth movements and tectonic disturbances of which ultimately volcanoes are one of the outer manifestations. The fate of Kibo and a departure from its customary attitude depend on what is happening deep in the earth's events. Taphrogenic manifestations, dislocations or readjustments due to tangential crustal tension resulting in volcanism, can however, occur elsewhere.

In the last three months of 1942, according to Group-Captain A. Walter, Chief Meteorological Officer, Nairobi, the seismograph at Entebbe registered more tremors of local origin than in the last three years. In the Masai District, not far from Mondul, seismic unrest followed by landslides causing dustclouds occurred at intervals from November, 1942, to January, 1943. It is not possible that the events on Kibo are remotely connected with the increase of seismic disturbances.

The effects of an eruption of Kibo, without going so far as to predict in the near future such an occurrence for which indications such as premonitory volcanic tremors, sharp rise in fumarolic temperatures, etc., are still absent, are largely dependent on several factors: character and strength of the eruption, position of the vents (either in the old crater or situated on the flank of the main cone) as well as other features such as the presence of glaciers, the morphology of the surroundings, the river systems, etc., on which we shall not insist here.

The solution of some of these problems will be found in the further close study of the bewildering features, only partly disclosed, of the Great Mountain.

NAKURU,
23*rd* July, 1943.

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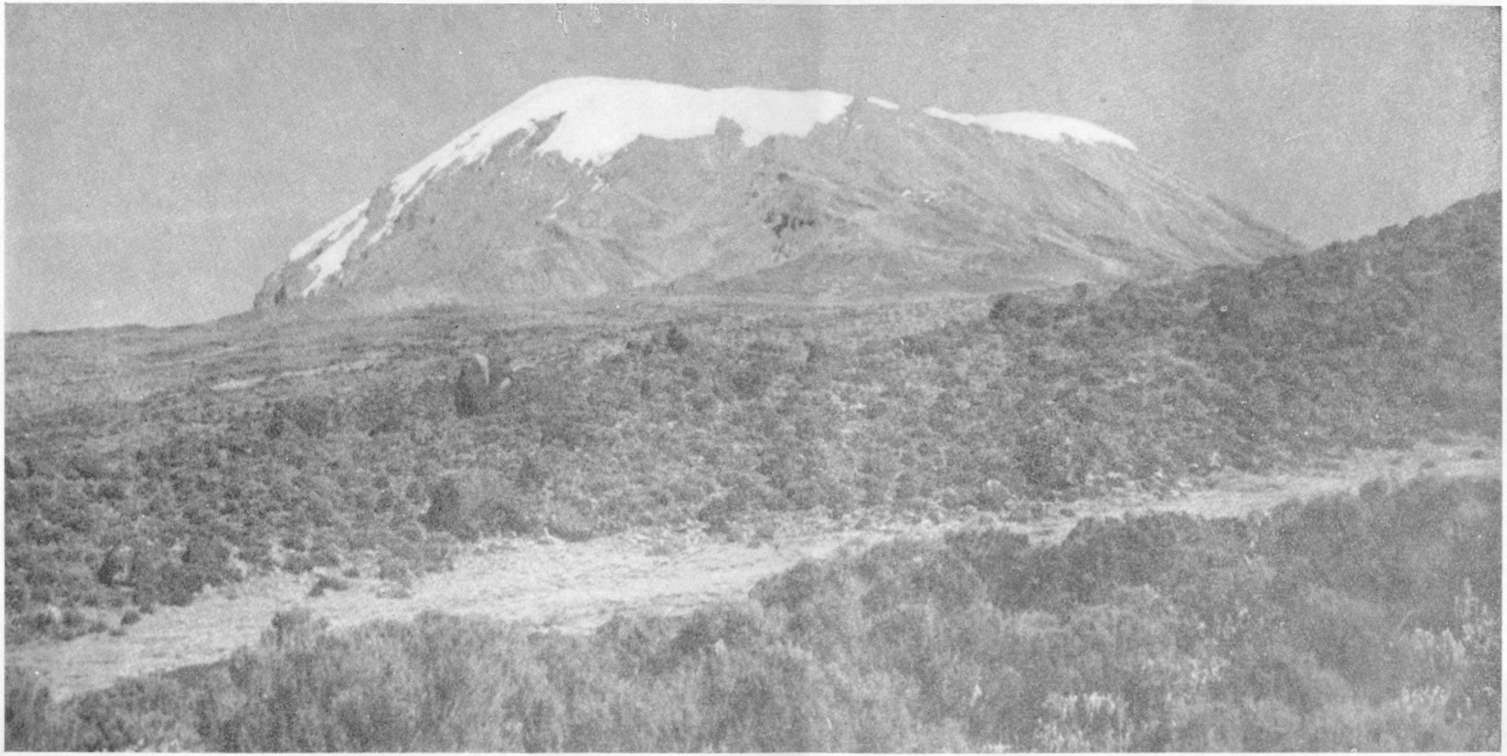


Fig. 1. Kibo from near Peters Hut, 12,500 feet.
7 October, 1942.

Fig. 1a. Kibo the morning after a snowstorm, from saddle. Camp place Spink and author.
30 January, 1943.

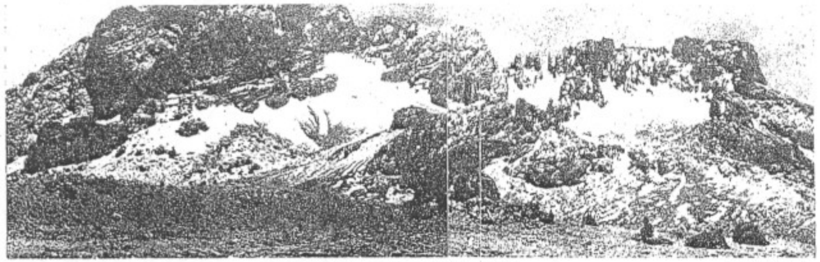


Fig. 2. The massif of Mawensi from the saddle. 31 January, 1943.

Fig. 3. Panorama from the summit of Kibo. On the left the active cone with (as a black line) the true centre of Kibo.
29 August, 1942.

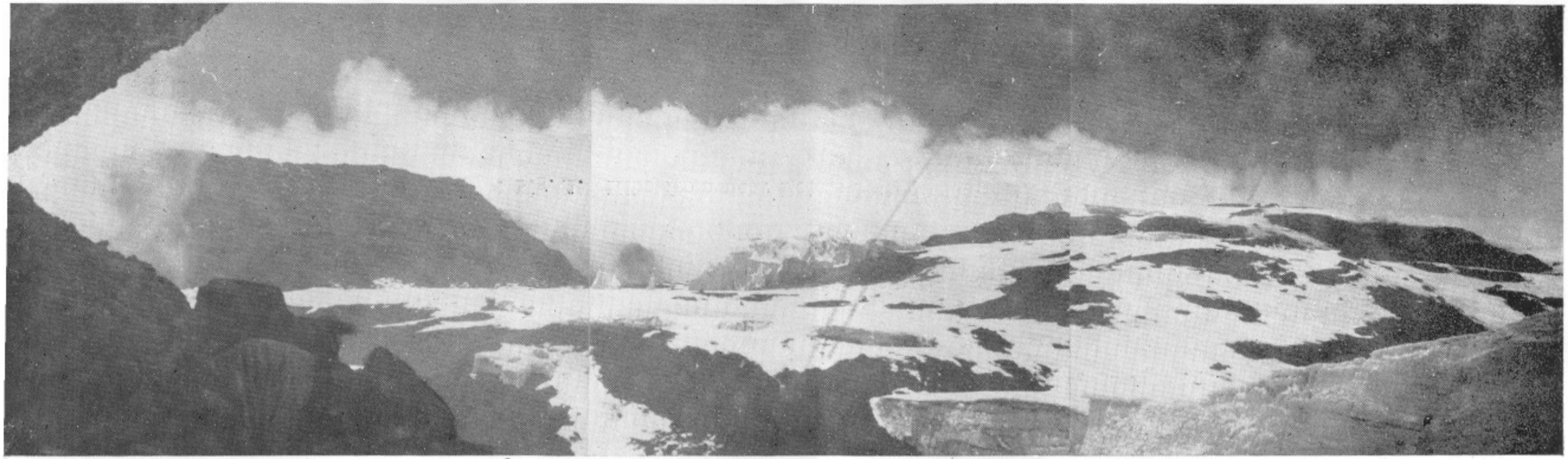


Fig. 4. The Caldera of Kibo from under Gillman's Point.
K.W.P. on the left. Ice dome in middle.
9 October, 1943.

Fig. 5.
Rock and ice formations on the Caldera edge near H. Meyer Point.
29 August, 1942.

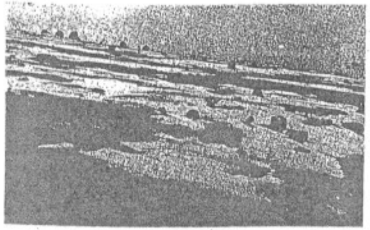


Fig. 9. Boulders on saddle plateau.
8 October, 1942, and 31 January, 1943.

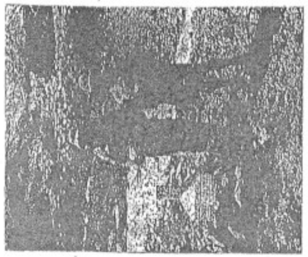


Fig. 11. The "Totalisator" near Kibo Hut at about 14,500 feet altitude, Dr. Sturveas (right) and the writer.
31 January, 1943.

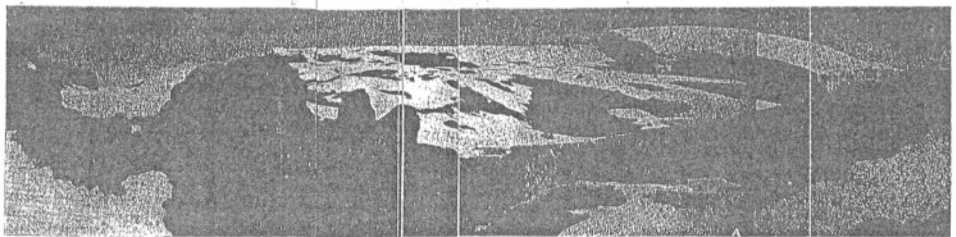


Fig. 8. View of the Caldera near Gillman's Point. Ice dome on the left. Eruption dome in the middle (crater not visible) northern ice barrier to the right ending in the most northerly notch.
28 August, 1942.

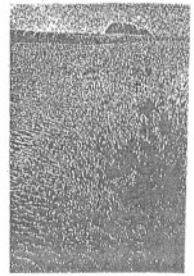


Fig. 12. Nieve Penitente.
10 October, 1

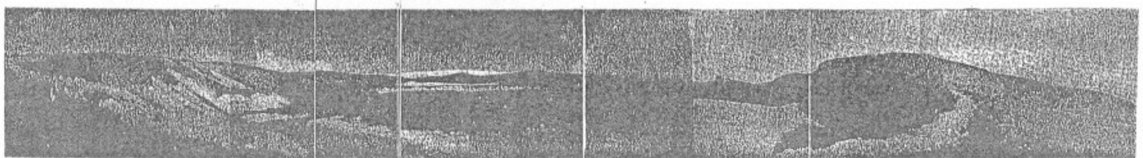


Fig. 10. The crater of Kibo. Fumaroles of Group No. 2 are visible on the inner flank to the right.
18 October, 1942.

Fig. 7. Porters on the scree above Kibo Hut.
9 October, 1942.

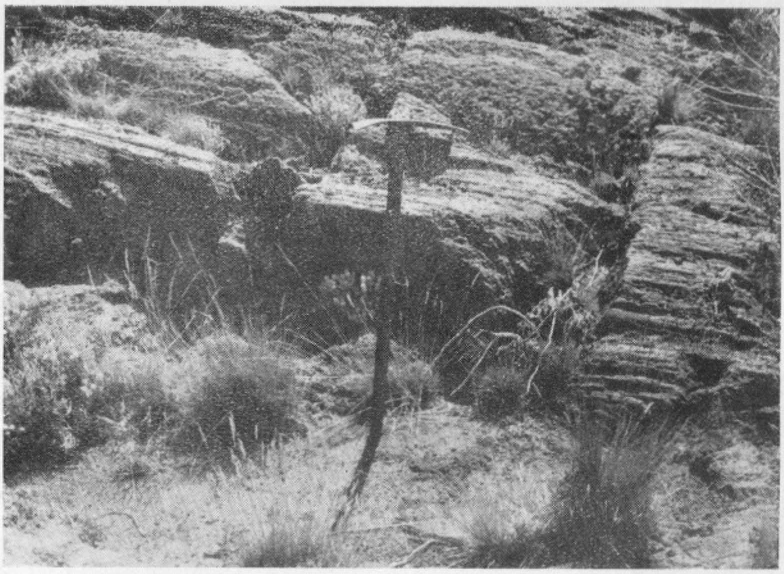


Fig. 8. Glacial striae at about 13,000 feet altitude.
8th October, 1942.

Fig. 9. Boulders on saddle plateau.
8 October, 1942, and 31 January, 1943.

Fig. 11. The "Totalisator" near Kibo Hut at about 14,500 feet altitude, Dr. Stevens (right) and the writer.
31 January, 1943.

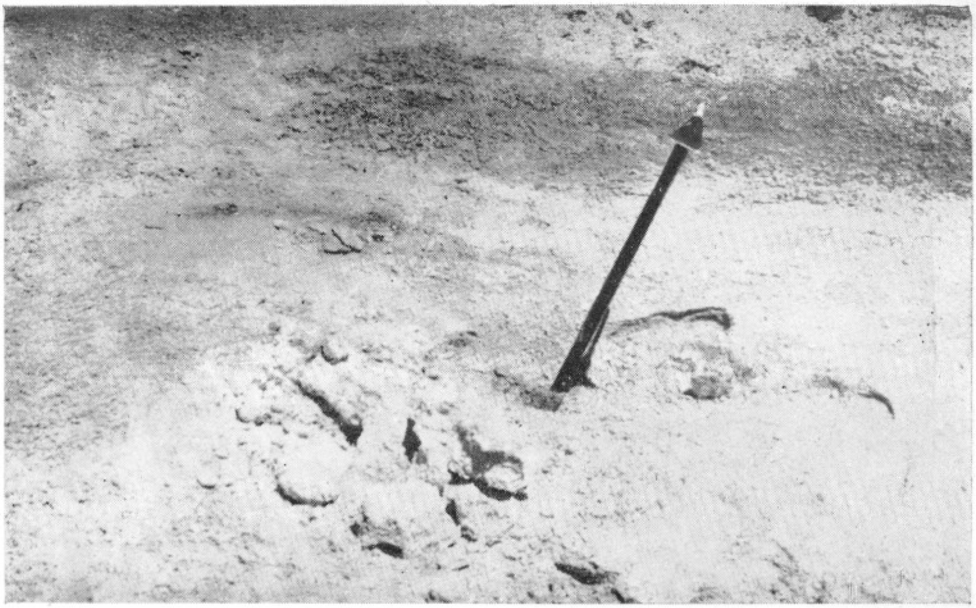


Fig. 14. Sulphur deposits, fumarole No. 3.
10 October, 1942.

Fig. 15. Prismatic lava, first floor.
10 October, 1942.

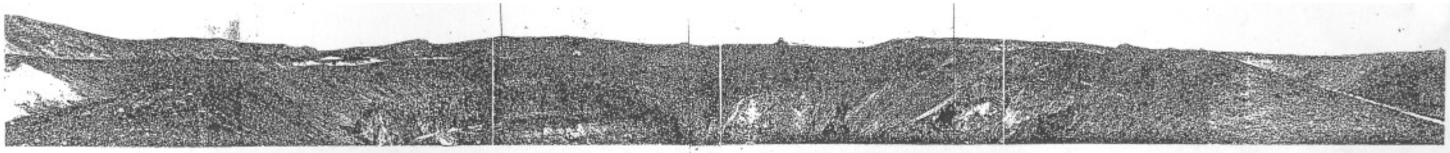


Fig. 16 Upper part of the inner crater taken from the south with protruding lava "gendarme" in the middle.
10 October, 1942.

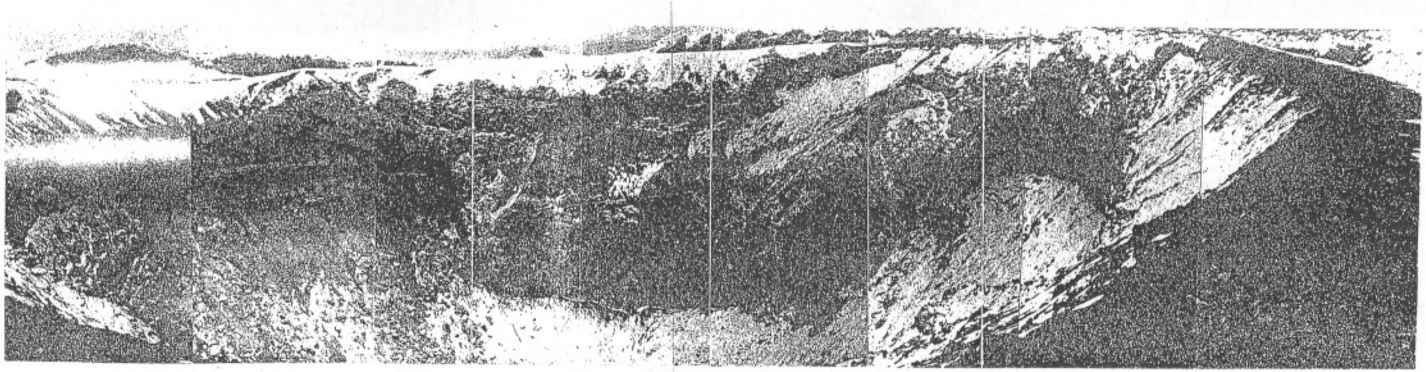


Fig. 18. Kibo Crater.
1 February, 1943.

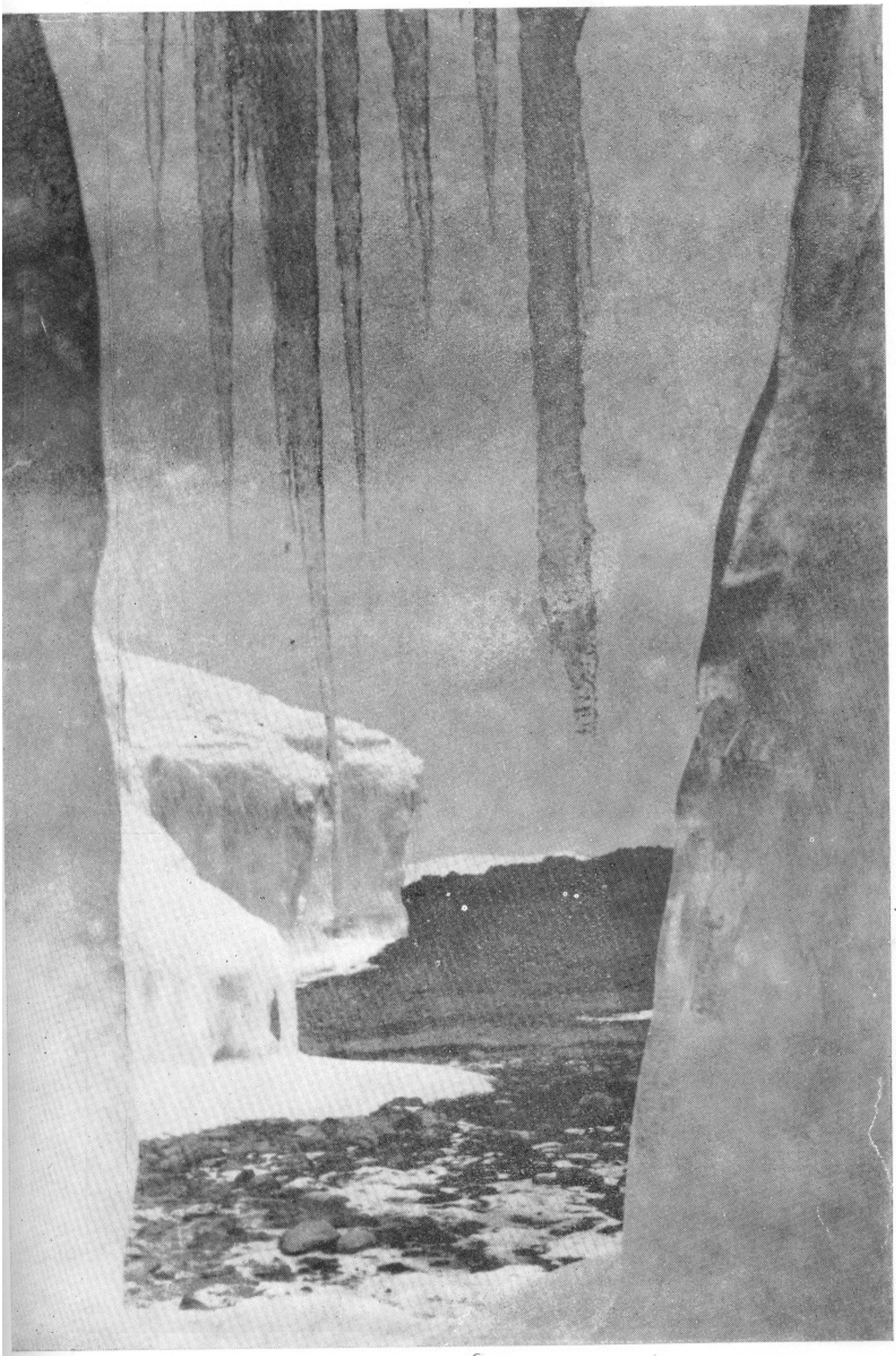


Fig. 19. Ice formations on Kibo along the Northern Ice Wall.

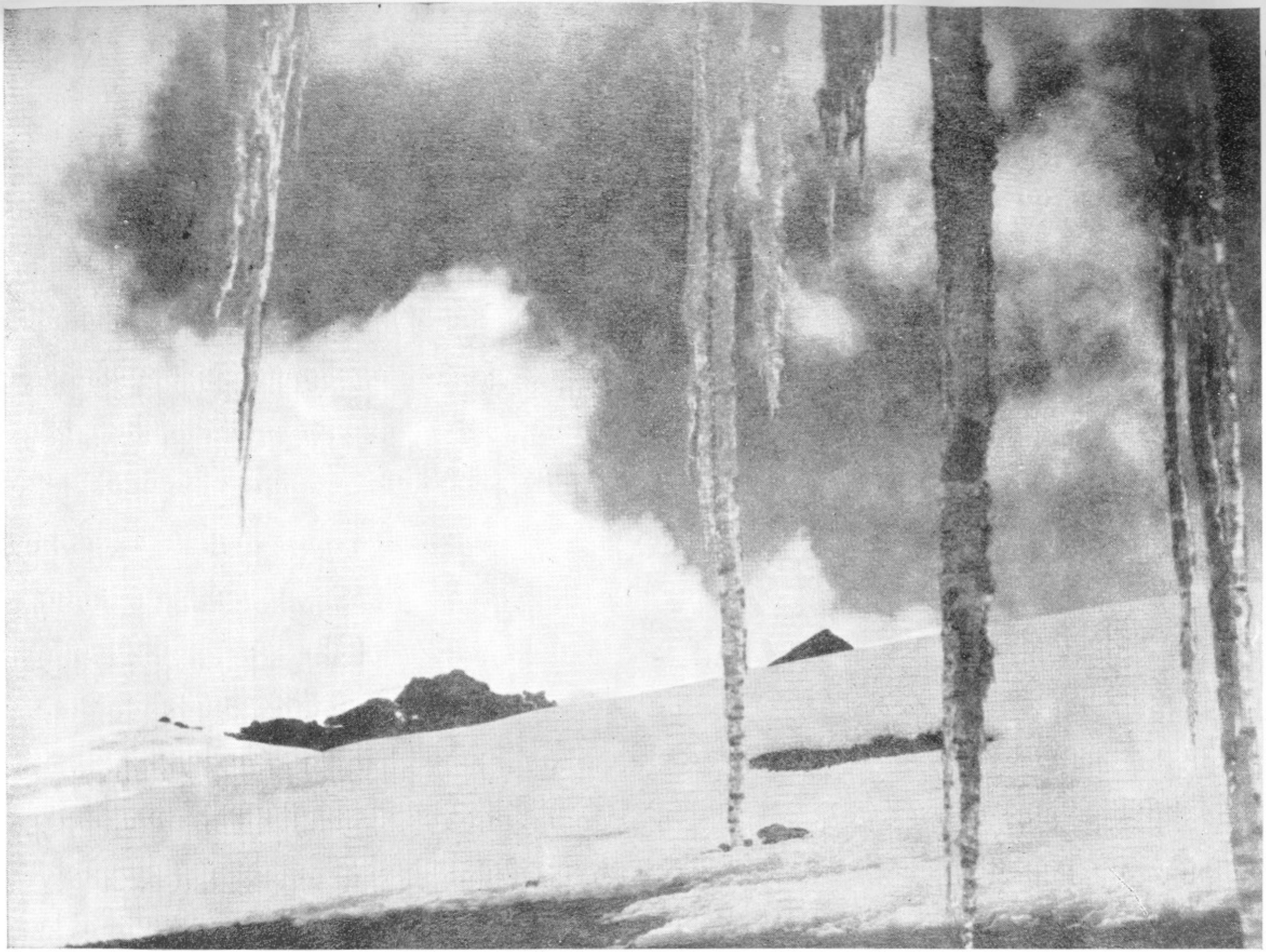
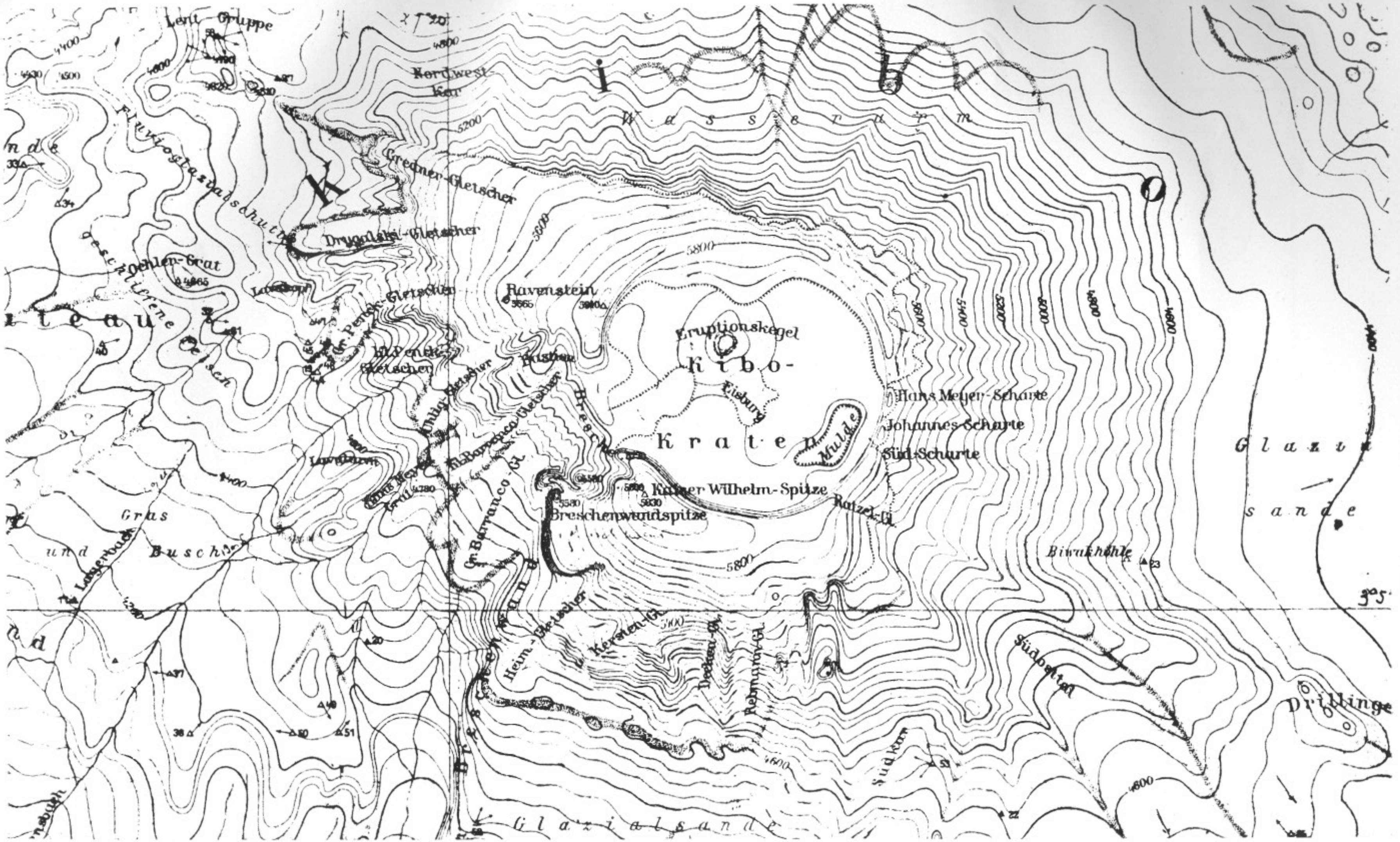
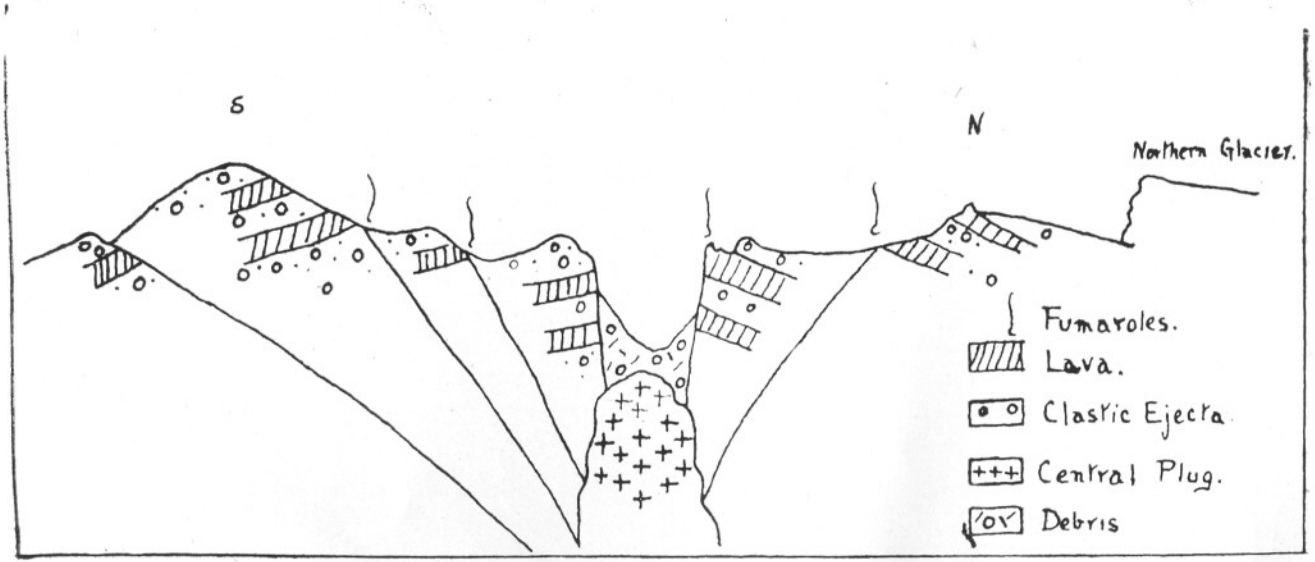


Fig. 20. Icicles from an ice cave on the Northern Ice Wall.

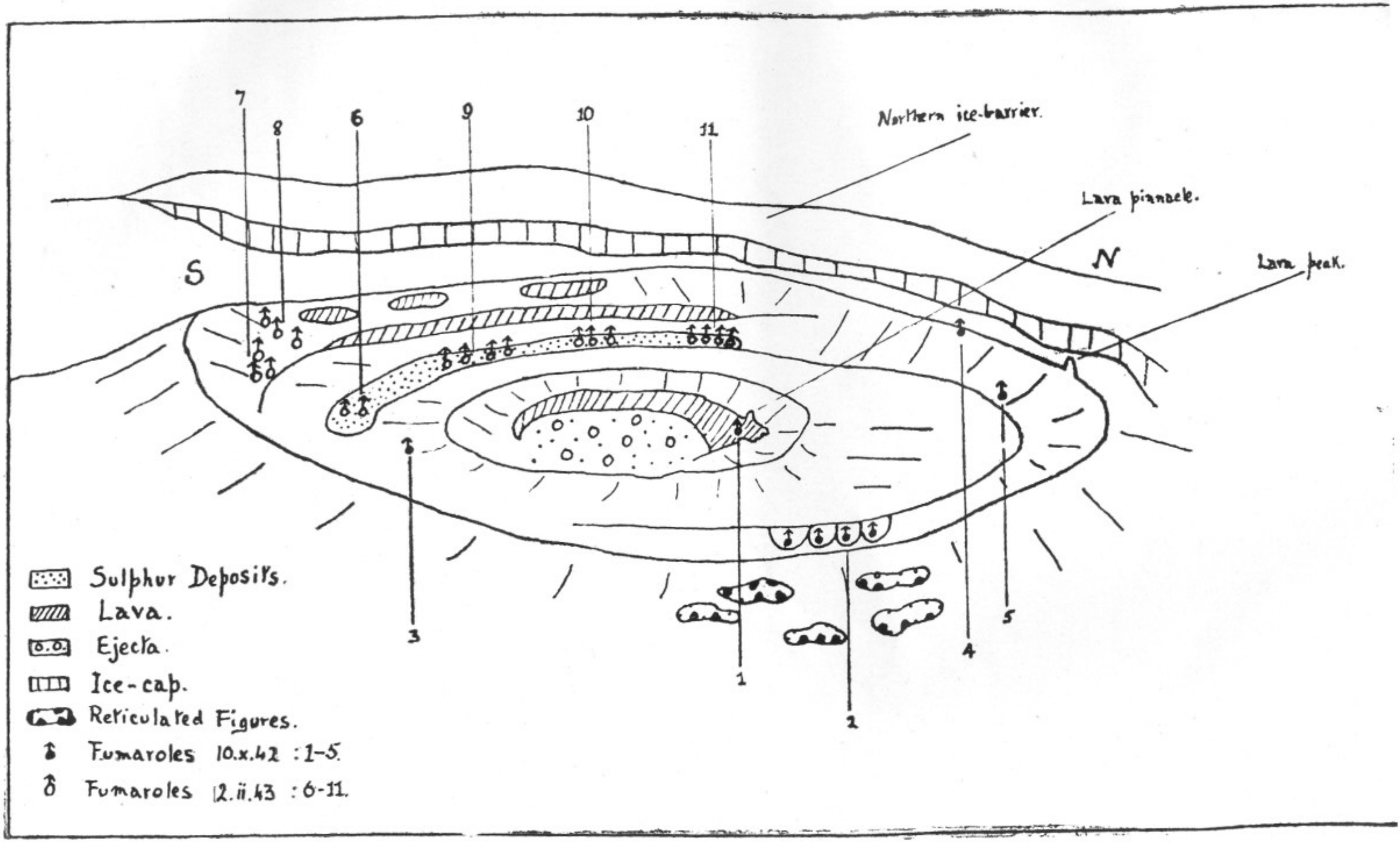
Fig. 21. Dr. Reusch's Leopard after which the notch is named.
10 October, 1942.



Map of Kibo. Reproduced from Ochler (1920). Scale 1:50,000.



Sketch 1. Schematic profile S.-N. of the eruption cone of Kibo. Scale about 1,5,000.



Sketch 2. Scale about 1:3,500.