SBORNÍK ČESKOSLOVENSKÉ SPOLEČNOSTI ZEMĚPISNÉ
Ročník 1976 • Číslo 4 • Svazek 81

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RECENT VOLCANOLOGICAL OBSERVATIONS ON MT. KILIMANJARO

Introduction

In January 1976, the University of Dar es Salaam received an urgent request for some of its staff to proceed to Kilimanjaro and study a recent rise in the seismic activity of that region. Dr. P. B. Vitta, the Dean of the Faculty of Science, then asked Dr. V. Cílek and Dr. H. Duyverman, both of whom are UNESCO experts in the Faculty's Department of Geology, as well as Mr. A. A. Foum, their local counterpart, to set off on this expedition. The main objectives of the expemition were:

1. To collect data on recent volcanic tremours in Kilimanjaro.
2. To climb up to the Kibo crater of Mt. Kilimanjaro, and there study the present activity of Kibo's fumaroles (gas-emitting vents).
3. To compare the results of the observations in 1 and 2 above with previous data on this subject.
4. To make whatever recommendations which 1, 2 and 3 may suggest.

The expedition began on February 2nd and ended on February 11th, 1976. This period was not long enough to permit high-altitude acclimatization of the members of the expedition — all of whem were accustomed to the sealevel conditions of Dar es Salaam. As a result, only one of them, V. Cílek, was able to reach the Kibo crater on February 7th and make on-the-spot observations. He was at the crater for four hours (between 7 and 11 p. m.). During this time he took photographs of the area and made a sketch of the crater indicating the locations of the new main fumaroles. He also made temperature measurements at the site. Finally, he took a sample of the gas, as well as some specimens of the chemical sediments, emitted from the fumaroles for subsequent analysis upon his return to the University. Physical extertion was extremely difficult at the crater owing to the prevailing low-pressure conditions. The author was, therefore, unable to make a more systematic set of observations during his short stay at the crater. Later, at lower altitudes, he and his colleagues listened to oral reports by residents of the region. Much useful information was gained in this way from especially one Kilimanjaro resident, Mrs. Erica Lány, the proprietress of the Marangu Hotel. The graph showing tremour incidence and intensity over the past several months which is included in this report (Fig. 4), is based on Mrs. Lány's records.

1. Previous Observations

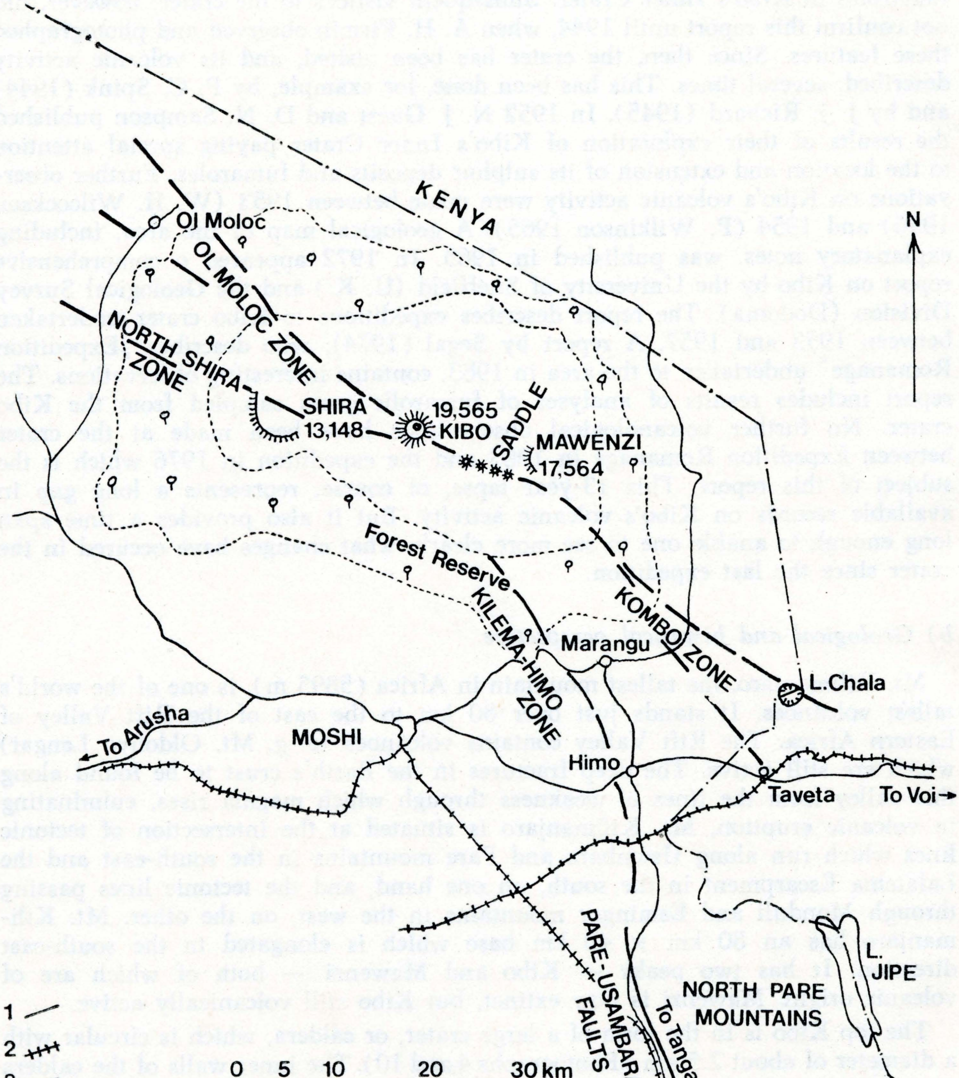
a) Previous expeditions

In 1889, H. Meyer and L. Purtschiller climbed Mt. Kilimanjaro and reached its Kibo crater. They observed no volcanic activity at the crater. To explain why, in the absence of volcanic activity, the snow at the crater had not turned into glaciers, as expected, Meyer postulated the existence of some mechanism of heat transfer to the snow from deep below. Later in 1933, H. W. Tilman (see D. N. Simpson 1971) reported for the first time the existence of sulphur deposits and fumaroles in Kibo's Inner Crater. Subsequent visitors to the crater, however, did not confirm this report until 1944, when A. H. Firmin observed and photographed these features. Since then, the crater has been visited, and its volcanic activity described several times. This has been done, for example, by P. C. Spink (1944) and by J. J. Richard (1945). In 1952 N. J. Guest and D. N. Sampson published the results of their exploration of Kibo's Inner Crater paying special attention to the location and extension of its sulphur deposits and fumaroles. Further observations on Kibo's volcanic activity were made between 1953 (W. H. Wilcockson 1956) and 1954 (P. Wilkinson 1965). A geological map of the area, including explanatory notes, was published in 1965. In 1972 appeared o comprehensive report on Kibo by the University of Sheffield (U. K.) and the Geological Survey Division (Dodoma). The report describes expeditions to Kibo crater undertaken between 1953 and 1957. A report by Segal (1974), who describes „Expedition Romanage" undertaken to the area in 1963, contains interesting observations. The report includes results of analyses of fumarolic gases sampled from the Kibo crater. No further volcanological observations have been made at the crater between Expedition Romanage in 1963 and the expedition in 1976 which is the subject of this report. This 13-year lapse, of course, represents a long gap in available records on Kibo's volcanic activity. But it also provides a time span long enough to anable one to see more clearly what changes have occured in the crater since the last expedition.

b) Geological and historical perspective

Mt. Kilimanjaro, the tallest mountain in Africa (5895 m), is one of the world's tallest volcanoes. It stands just over 80 km to the east of the Rift Valley of Eastern Africa. The Rift Valley contains volcanoes (e. g. Mt. Oldonyo Lengai[1]) which are still active. The deep fractures in the Earth's crust to be found along this valley from the lines of weakness through which magma rises, culminating in volcanic eruption, Mt. Kilimanjaro is situated at the intersection of tectonic lines which run along Usambara and Pare mountains in the south-east and the Lalatema Escarpment in the south, on one hand, and the tectonic lines passing through Monduli and Esmingor mountains in the west, on the other. Mt. Kilimanjaro has an 80 km × 40 km base which is elongated in the south-east direction. It has two peaks — Kibo and Mawenzi — both of which are of volcanic origin. Mawenzi is now extinct, but Kibo still volcanically active.

The top Kibo is in the form of a large crater, or caldera, which is circular with a diameter of about 2.5 km (Photographs 4 and 10). The inner walls of the caldera are as high as 180 m on the southern side (Fig. 2). Inside the caldera (Fig. 3) is the Inner Cone, rising to within 60 m of the summit height. The Inner Cone is situated excentrically n the northern part of the caldera. The top of the Inner Cone is also in the form of a crater, called the Inner (or Reusch) Crater, with a diameter of 820 m and a floor between 30 and 50 m below its rim. In the centre of the Inner Crater is a minor cone, the Ash Cone, which has in its centre a circular vent, the Ash Pit, which is 340 m in diameter and 130 m in depth (Photographs 4—6). Fumarolic activity has been observed in the Inner Crater, along the subsidiary scarp within the Inner Crater, which flanks the western side of the Inner Crater to form a „terrace". Some fumaroles have also been observed in the steep scarp of the Ash Pit itself.



1. Map of Kilimanjaro area showing the main volcanic and tectonic zones (1 — roads; 2 — railway; 3 zones of volcanic cones and faults).

The past volcanic history of Mt. Kilimanjaro may be divided into three stages. First, *Shira,* on the north-western side of the mountain, went through a phase during which it produced undersaturated lavas and nephelinites, culminating in a short period of explosive activity. Then, in the *Mawenzi stage,* the lavas became more alkaline. Both Mawenzi and Kibo were producing trachyandesitic lavas, with Kibo continuing to do so long after the last eruption of Mawenzi. Finally, during the *Kibo stage* at the end of the Lower Pleistocene, volcanic activity of the main centres was confined to Kibo — though many minor parasitic eruptions also took place elsewhere. At the end of the Middle Pleistocene, caldera faults developed around Kibo, with eruption of small porphyry groups of lavas. During the Upper Pleistocene, a crater, possibly a caldera, was formed. But volcanic activity had now become sporadic. The last eruption of Kibo, after the Wurm Glaciation, formed Kibo's present caldera and its Ash Pit. This may have coincided with the carbonatic-gas explosion by which Lake Chala was formed.

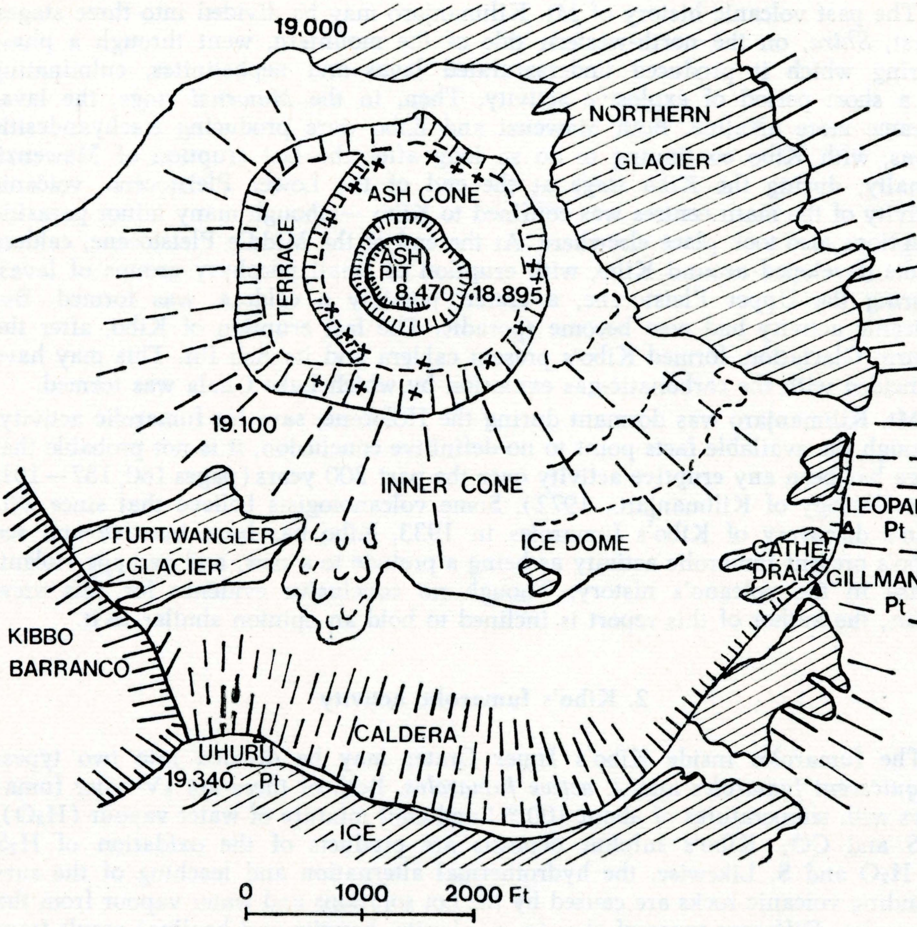
Mt. Kilimanjaro was dormant during the Holocene, save for fumarolic activity. Though the available facts point to no definitive conclusion, it is not probable that there has been any eruptive activity over the past 200 years (pages 180, 187—191, The Geology of Kilimanjaro, 1972). Some volcanologists believe that since Tilman's discovery of Kibo's fumaroles in 1933, Kibo has been inactive and see Kibo's present fumarolic activity as being a prelude to a new, and perhaps violent, phase in the volcano's history. Though no conclusive evidence for this view exists, the author of this report is inclined to hold an opinion similar to it.

2. Kibo's fumarolic activity

The fumaroles inside Kibo's Inner Crater may be divided into two types: 1. *quiescent fumaroles* and 2. *active fumaroles*. Both of these are IV-order fumaroles with temperatures of about 100 °C and emit mixture of water vapour (H_2O), H_2S and CO_2. Kibo's sulphur deposits are products of the oxidation of H_2S by H_2O and S. Likewise, the hydrothermal alternation and leaching of the surrounding volcanic rocks are caused by the hot solutions and water vapour from the fumaroles. Different types of clay (e. g. alunite, bauxite and kaoline) result from this process. Quiescent fumaroles are characteristic of exhalationes of low-pressure steam and gases. In places where quiescent fumarolic activity lasts for several years, the fumaroles are often partially, or completely, covered by chemical deposits and hot fumes do not escape to the surface. On the other hand, active fumaroles emit high-pressure exhalations. Their fissures and vents are well exposed, and visible clouds of vapour come out of them.

The steam emitted by Kibo's fumaroles and the rate at which it is emitted may be influenced by the presence and condition of the snow in the area. It is possible, for example, that some of the steam originates from water which has percolated downwards following the melting of snow under solar heating. The present author, however, does not believe that all of the steam emitted by Kibo's fumaroles can be fully accounted for in this way. The author suspects that a part of this steam is of volcanic origin.

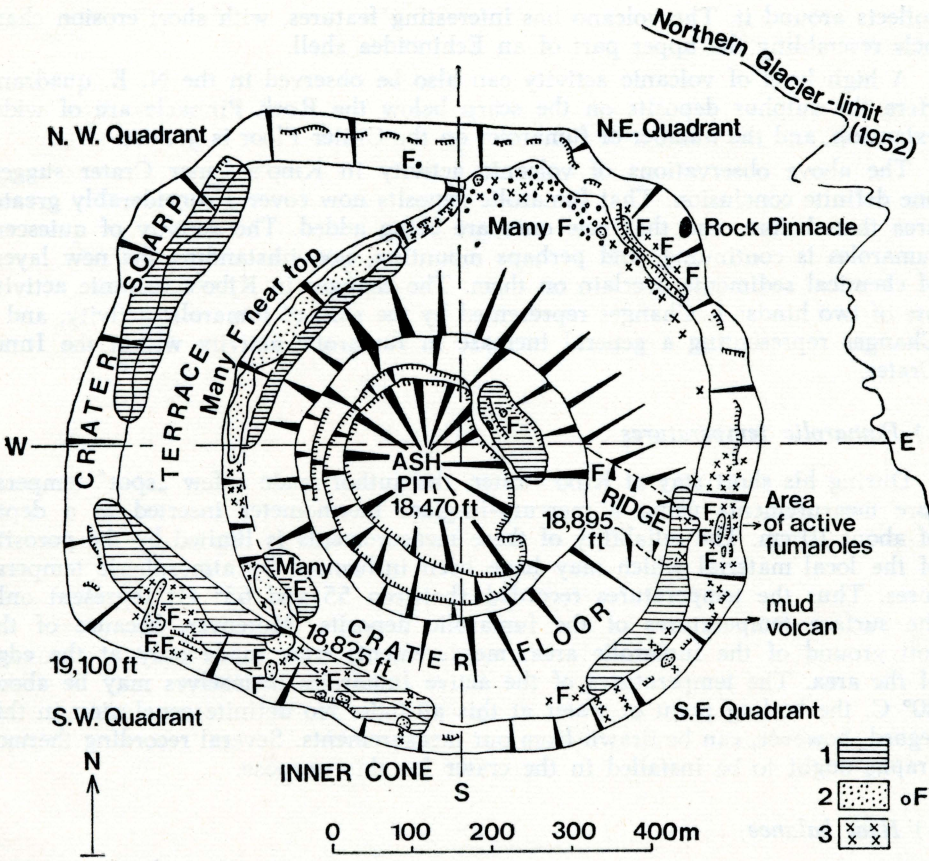
Comparison may be made between present author's observations of Kibo's fumarolic activity with similar observations by other authors. The author observed that Kibo's fumaroles and fumarolic products spread in three quadrants (the N. E. quadrant having none). This agrees with the observations made by D. N. Sampson and G. P. Leedal (1952). There is a difference, however, in the N. W.



2. Map of the Caldera area of Kibo, showing the sites of fumarclic activity (x) and the main topographic features (after Downie — Wilkinson 1972).

quadrant, where P. C. Spink shows sulphur beds and areas of fumarolic activity along the base of the crater scarp and the outer margin of the terrace (Fig. 3). On Sampson and Leedal's map, fumaroles and sulphur deposits are distinguished from each other. The main group of fumaroles is shown to be in part of the S. W. quadrant, in the whole of the N. W. quadrant, and in the northern corner of the N. E. quadrant. Only a few fumaroles are shown in the S. E. quadrant. This was the picture in 1952. In comparison with this, one sees that in 1976 the picture has changed. In general, the area of fumarolic activity has extended. Sulphur deposits produced during the last few years now cover large parts of the crater, especially in the S. W. quadrant on the crater scarp and on the northern and southern ends of the terrace scarp. In this area, quiescent fumarolic activity now prevails. The author is of the opinion that this area contains subsurface fumarolic vents which are obscured from view by new layers of chemical deposits, or are perhaps covered by altered-slope debris along the scarp.

At the time of the author's visit, Kibo's most active fumaroles were in the S. E.



3. Map of Kibo Crater — Kilimanjaro (partly after Sampson-Leedal 1952). Explanation to show the development of fumarolic activity: 1 — Sulphur beds and fumaroles (Spink 1943); 2 — Sulphur beds and fumaroles (Sampson — Leedal 1952); 3 — Sulphur beds and fumaroles (Cílek 1976).

quadrant. The fumaroles pierce through recent deposits of sulphur and other substances over a distance of about 100 m on the steep slope in the crater's eastern side. Water vapour, with perhaps only small traces of H_2S, cover the whole of this slope (Photograps 7 and 8). Rock temperature in this area is considerably high and one cannot collect rock samples using one's bare hands. The chemicals deposits overlying this area are soft ind porous (Photograph 8). One's legs sink into them deeper as one walks inwards from the edge. For this reason, the centre of this area is inaccessible. The chemical deposits consist of alternate layers of sulphur and clay.

The southern part of this quadrant contains about 12 quiescent fumaroles, situated both on the scarp and on the floor. A small „mud volcano" was observed by the author in the depression between the Ridge (Fig. 3) and the Crater Floor. It is about 5 m in diameter, and has a regular cone built from only partially altered reddish volcanic material. Rock temperature is about 50°C. It would appear that volcano erupts intermittently, starting when water from melting snow collects around it. The volcano has interesting features, with short erosion channels resembling the upper part of an Echinoidea shell.

A high level of volcanic activity can also be observed in the N. E. quadrant. Here the sulphur deposits on the scarp below the Rock Pinnacle are of wider extension, and the number of fumaroles on the Crater Floor is greater.

The above observations of volcanic activity in Kibo's Inner Crater suggest one definite conclusion: That fumarolic deposits now cover a considerably greater area than before, and that new ones are being added. The activity of quiescent fumaroles is continuing, and perhaps mounting, notwithstanding the new layers of chemical sediments overlain on them. The changes in Kibo's volcanic activity are of two hinds: 1. Changes represented by the shift of fumarolic activity, and 2 Changes representing a general increase in fumarolic activity within the Inner Crater.

a) Fumarolic temperatures

During his short stay at Kibo Crater, the author made a few „spot" temperature measurements using a mercury-in-glass thermometer inserted to a depth of about 10 cm. The reliability of these measurements is limited by the porosity of the local material which may have been influenced by atmospheric temperatures. Thus the temperatures recorded (between 55 and 65° C) represent only the surface temperatures of the fumarolic deposits. Moreover, because of the soft ground of the fumarolic area, measurements were made only at the edge of the area. The temperatures of the active fumaroles themselves may be above 80° C, the boiling point of water at this altitude. No definite conclusion in this regard, however, can be drawn from our measurements. Several recording thermographs ought to be installed in the crater for this purpose.

b) Heat balance

As early, as 1909, F. Jaeger suggested that the observed melting of ice masses in the Kibo Caldera might be due to volcanic heat flow. P. Wilkinson (1954) tested this hypothesis on a detached ice mass, choosing the „Ice Dome" on the slopes of the Inner Cone for the purpose. The result was that „the required heat flux was found to be of the order of only 5% of the theoretical annual solar energy receipt, and an abnormal geothermal gradient was an unnecessary hypothesis" (Geology of Kilimanjaro, page 186, 1972).

During the author's ascent to Kibo, excellent climatic conditions prevailed, with a clear sky and warm and dry weather, which were ideal for observations at the crater. There was only a thin cover of ice and snow on slope of Uhuru Peak and along the caldera scarp towards Gillmans's point. The Inner Cone was completely bare (Photograph 9), and small patches of snow were found only on the scarp of the Reusch Crater on the southern side. Very striking is the deglaciation both on the rim and inside the caldera. The „Ice Dome" has been reduced to small relicts of ice. (Photograph 10). The glaciers „Cathedral" and „Battleship", near Gillman's and Leopard points, also have diminished by more than one-third, and what remains of them are only parts protected by the caldera. The height of the glaciers is small and in the case of „Battleship", the whole middle part has vanished. The Northern Glacier which in 1952 covered the slopes of the Inner Cone, about 100 m from the crater rim, has now receded to about 400—500 m from the rim. This comparison of past and present glaciation, though perfunctory, leaves no doubt whatsoever that striking changes are occuring at the Kibo Crater. The deglaciation and defrostation is proceeding fairly rapidly. The author is of the view that even in future years of snowfall this process will probably not be reversed. He suspects that this glacial retreat is not solely due to recent global ablation and a general warming-up of the atmosphere alone. He believes that a considerable part of this may be the result of changes in the internal levels of heat.

c) Fumarolic gases

The author took a sample of the fumarolic gas from the active fumaroles of the S. E. quadrant. This was done by means of a glass cylinder with two tapes, having at one end a rubber tube with a funnel. The funnel was put directly over the fumarolic vent and the cylinder was then opened to let in the fumarolic exhalations under natural pressure. These exhalations were later analyzed. The analysis indicated presence of oxygen, nitrogen and water — which means that the exhalations consist primarily of steam. No sulphuric gases were detected. The absence of sulphuric gases may be due to the condensation, and later precipitation, of them out of the exhalations in the deeper layers of the chemical deposits, so that only water vapour reaches the surface. Nevertheless, in certain places at the crater, the author had smelled sulphuric gases.

The author also collected three samples of chemical deposits around fumaroles. The first sample, taken from an area of active fumaroles in the S. E. quadrant, contains sulphur as a volcanic sublimate (78 % by weight) and some impurities. The crystals of this sulphur is of an α type. β — type sulphur is usually found deep below (at temperatures above 95.6°C). The second sample was collected from a great fumarole in the N. E. quadrant on the Crater Floor. It consists of whitish material, most probably kaolin and alunite, and represents the complete decomposition of volcanic rock by steam. The third sample, taken from the „mud volcano“, is of reddish colour, perhaps owing to partial alternation. Both of the last two samples contain large amounts of aluminium, silica and iron.

d) Seismicity

The publication of Sheffield University doesn't deal with seismicity despite the introduction of this paragraph on the page 181.

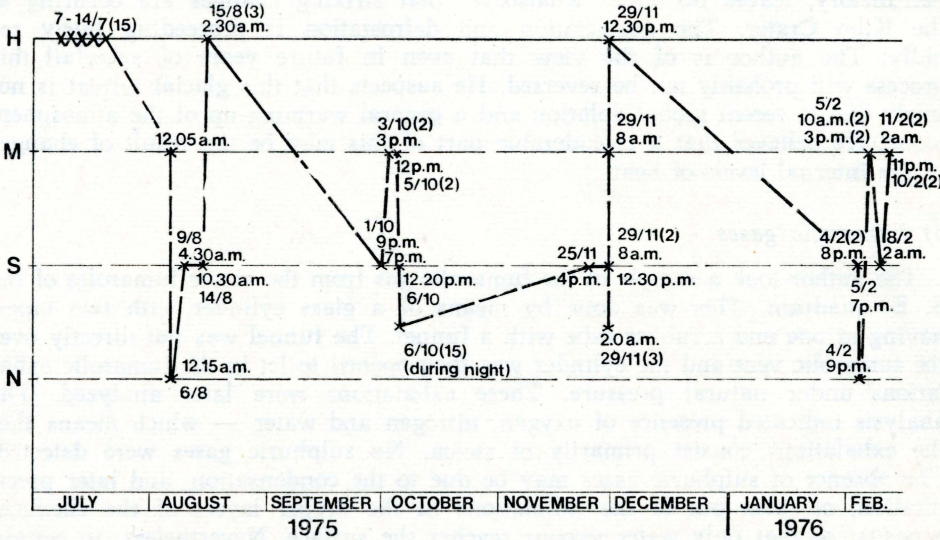
The geological map of Kilimanjaro shows the evidence of distinctive tectonic lines represented by zones of parasitic cones and subsidiary centres. Outside Kilimanjaro volcanic area these zones continue as normal faults of regional importance.

These are the zones of seismicity (see Fig. 1):

i) Rombo Zone is developed in two branches; first Branch extending from Lake Chala towards Kibo; second branch from Taveta joins the first zone near Marangu and continues along the slopes of Mawenzi to the Saddle, across Kibo Crater towards the northwestern slopes of Kilimanjaro to Ol Moloc.

ii) Kilema — Himo Zone follows the Kilema Ridge and continues towards south-east along the escarpment of Pare — Usambara Mts. (Pangani Faults); towards north—west this zone cuts the Kibo Peak and may join the North Shira Zone.

Along these lines movement of blocks may occur causing drift and instability of magma deep in the crust. These tectonic lines are intersected by other seismic zones coming here from Lalatema Escarpment block and from area of Rift Valley.



4. Tremours at Marangu Hotel (Rombo District), Kilimanjaro Region; recorded by Mrs. E. Lány 1975—76.

Seismic tremours occur rather frequently in the Kilimanjaro Region — generally, about once in every 3—5 years. The last great earthquake occured in 1970, when several houses and a church were damaged in the Kilema area. No further tremour occured until 1975 when the present wave of seismic activity started. This activity began in July 1975 and, in the first instance, lasted 7 days. Since then tremours of different magnitude occur almost daily. Some informants told members of this expedition that tremours usually occur at night, proceeding from east to west. The areas most affected by this activity are Rombo, Kilema, Old Moshi and Machame.

Mrs. Lány, the proprietress of Marangu Hotel, told the author that since July 1975, more than 150 tremours, of different amplitudes, have occured. Figure 4 shows these tremours to occur regularly, their frequency sometimes increasing, but their amplitudes so far always being insufficient to destroy houses. Nevertheless several houses between Rombo and Old Moshi have cracked walls as a result of these tremours. The strike of the cracks is mostly in a direction of 30—70 ° NE (only in one case did measurement indicate a direction of strike of 30° NW). Although the tremours are concentrated in Rombo area mostly, earthquake is often recorded in North Pare Mts. and as far as Usambara Mts. in the vicinity of Lushoto. It could be supposed that seismic acivity follows the main tectonic line along the southern escarpment of Usambara and Pare Mts. towards Kilimanjaro.

Very little is known about earthquakes following the lines along Rift Valley and from here to Meru volcano and Kilimanjaro. There is also a lot of uncertainty about the renewed activity at Oldonyo Lengai volcano, the only active volcanic centre within the area. The piecemeal release of seismic energy developed by tensile stresses between blocks, which is represented by these tremours, is definitely of advantage. But in the absence of scientific data one cannot say for how much longer this will continue, or w h e n t h e s e t e c t o n i c e a r t h q u a k e s w i l l t r i g g e r v o l c a n i c a c t i v i t y a t K i b o C r a t e r.

3. Conclusions

Some observers of Kibo are of the opinion that its activity is increasing. Others accept that new fumaroles have been formed, but feel that the claim of greater fumarolic activity is unproved. The author's opinion, based on the observations which have been described above, is that volcanic activity within the crater is increasing. In his view the present wave of seismic activity offers proof of this. No direct connection can be demonstrated between the tremours on the sides of Mt. Kilimanjaro and the volcanic activity of the Kibo Crater. Delayed reaction to the seismic activity in the form of volcanic activity at the crater is, however, possible.

The following conclusions can be drawn from what has been said above:

1. The increase in seismic activity may proceed along the known tectonic zones.
2. The increase in volcanic activity is probably a secondary process, which could be accelareted by continuing tremours.
3. The seismic activity on the sides of Mt. Kilimanjaro may have its origin in tectonic movements in the Rift Valley.
4. The possibility of greater volcanic activity coming as a consequence of tectonic earthquakes cannot be excluded.

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Resumé

VULKANOLOGICKÁ POZOROVÁNÍ NA KILIMANDŽÁRU

Autor, který působí jako československý expert UNESCO na univerzitě v Dar es Salaamu vystoupil v únoru 1976 na vrchol Kilimandžára, dosáhl Gillman's Point (5635 m), sestoupil do kaldery a odtud vystoupil na okraj vnitřního vulkanického kužele Kibo. Na jeho vnitřních svazích provedl geologická a vulkanologická pozorování: hrubé zamě-

ření fumarol, měření teploty fumarol, odběr plynu, chemických produktů z okolí kráteru a dosáhl okraje polovyhaslého jícnu zv. Ash Pit, který je 130 m hluboký a jeho stěny jsou téměř svislé. Sestup do jícnu byl neuskutečnitelný.

Důvodem vyslání expedice, jíž se kromě autora zúčastnili další dva geologové (A. Foum, Tanzanie a H. Duyverman, Nizozemí) a 15 domorodých pomocníků, byla žádost tanzanské vlády zjistit příčiny častých zemětřesení v oblasti masívu Kilimandžára. Největší bylo v r. 1970, kdy bylo na úpatí Kilimandžára zničeno několik domů a kostel. Další zemětřesná činnost začala v r. 1975. Od července 1975 do konce ledna 1976 bylo zde pozorováno přes 150 otřesů, zatím jen slabší intenzity. Dochází k nim hlavně v noci a postupují směrem od V k Z. Nejvíce postiženými místy jsou Rombo, Kilema, Old Moshi a Machame.

Protože jedna z hlavních seismických linií v oblasti probíhá přes kráter Kibo (vyšší z obou vrcholků Kilimandžára), který byl činný ještě asi před 200 lety, rozhodl se autor začít výzkumy porovnáním současného stavu vulkanické aktivity Kiba s výsledky pozorování předcházejících jiných expedic.

Popsaná autorova pozorování v kráteru byla omezena na dobu několika hodin, jež v této nadmořské výšce bylo možné bez patřičné aklimatizace strávit. Ostatní účastníci expedice dna kráteru nedosáhli pro naprosté fyzické vyčerpání.

Odběr vzorků hornin (povahy andezitových láv), plynů i minerálů sublimujících z fumarol byl velmi obtížný. Povrchová teplota horninového materiálu kolísá kolem 50 °C a teplota fumarol na okrajích kolem 55—65 °C. V jejich středu může přesahovat 80 °C, což v této nadmořské výšce znamená bod varu. Pro vysoký obsah H_2S a CO_2 jsou výrony par těžko dýchatelné. Pohyb na velmi svažitém terénu je ztížen mocnými uloženinami sopečného popele a sypkého zvětralinového materiálu, do něhož se hluboko zapadá a jehož vířením se ještě více omezuje možnost dýchání. Při občasném úplném bezvětří bylo ovzduší v kráteru poblíž fumarol naprosto nedýchatelné.

Výskyt nových fumarol zaznamenal autor do mapky (viz obr. 3). Nejvíce aktivních fumarol zjistil v jihovýchodním kvadrantu. V depresi mezi okrajem a dnem kráteru pozoroval dokonce jednu menší bahenní sopku — pravý sopečný kužel s kráterem o průměru 5 m. Je v činnosti pravděpodobně jen občas v době, kdy do něho stéká voda z odtávajícího sněhu a ledu.

Větší sopečnou aktivitu lze pozorovat též v severovýchodním kvadrantu. Ve srovnání s údaji předchozích expedic se zvýšil počet fumarol na dně a také mocnost uloženin čisté síry se zvětšila.

V souvislosti se vzrůstem počtu fumarol, s jejich teplotou a s teplotou hornin v jejich okolí dochází k celkovému oteplování mikroklimatu v prostoru nejen vnitřního kužele, ale i celé kaldery. Severní ledovec v kaldeře ustoupil nejméně o 300 m ve srovnání se stavem, který zaznamenali Sampsal a Leedon v roce 1952. Rovněž na vrcholu Kibo je rozsah ledovců nyní menší.

Přímá závislost mezi vzrůstající vulkanickou činností a zemětřeseními na úpatí Kilimandžára zatím nebyla prokázána. Vulkanická činnost je zde druhotným procesem. Zemětřesení probíhající na úpatí vulkanického masívu Kilimandžára (jeho rozloha je přibližně 80 × 40 km) sleduje známé zlomové linie (viz obr. 1) a má svůj původ v tektonicky nestabilní oblasti na okrajích Východoafrického příkopu (Rift Valley). Nelze ovšem vyloučit, že déletrvající otřesy by mohly podnítit novou vulkanickou aktivitu v dosud nevyhaslé sopce.

(Sestavili V. Cílek a J. Rubín)

Vysvětlivky k fotografiím na křídové příloze:

1. Celkový pohled na oblast sedla mezi vrcholy Kibo (5895 m) (vlevo) a Mawenzi (vpravo).
2. Trhliny ve zdích domů jako důsledek zemětřesení na úpatí Kilimandžára mezi Rombo a Old Moshi.
3. Členové expedice na okraji vnitřního kráteru před sestupem.
4. Jižní část vnitřního (Reushova) kráteru s bílými pruhy, které představují chemické produkty fumarol klesajících dolů na dno kráteru. V pozadí kaldery Kibo — tvořený zbytkem valu s nejvyšším vrcholem Kilimandžára — Uhuru Peak (Vrchol Svobody), 5895 m.
5. Pohled na severozápadní kvadrant vnitřního kráteru s ložiskem síry, vyvinutým na severním srázu „terasy“. Vlevo je vidět část sopečného kužele.
6. Pohled na jihozápadní kvadrant vnitřního kráteru s rozsáhlými ložisky síry a s řadou fumarol na srázu kráteru a na jižním okraji „terasy“; na srázu je patrná slabá pokrývka sněhu.

7. Pohled na jihovýchodní kvadrant — oblast činných fumarol, vyvinutých převážně na svahu kráteru. Zřetelně lze vidět vystupující plyny a páru spolu s uloženinami fumarol v okolí. Další fumaroly jsou plyny a páry spolu s uloženinami fumarol v okolí. Další fumaroly jsou na dně kráteru a podél úpatí svahu. V pozadí lávová skalka Rock Pinnacle.
8. Pohled zblízka na činné fumaroly a jejich chemické produkty v jihovýchodním kvadrantu.
9. Pohled na Severní ledovec (Northern Glacier) od Gillmanovy vyvýšeniny. V popředí je vidět vrcholovou část ledovce „Cathedral". Svahy vnitřního kužele Kiba jsou holé a bez sněhu.
10. Pohled na západní část ledovce „Cathedral", který rychle odtává. Ve středu jsou vidět nepatrné zbytky rozsáhlého „Ice Dome" Vrchol Svobody je v pozadí.
11. Pohled na ledovec „Battleship" od vyvýšeniny Leopard. Pozoruhodnou je široká mezera tzv. Northern Notch na J od Severního ledovce, která je ve srovnání s minulostí podstatně rozsáhlejší. Rovněž vnější svah kaldery je bez ledového pokryvu.
12. Jihovýchodní svahy vnitřního sopečného kužele Kiba s ojedinělými zbytky dříve rozsáhlých ledovců.

Vysvětlivky k obrázkům v textu:

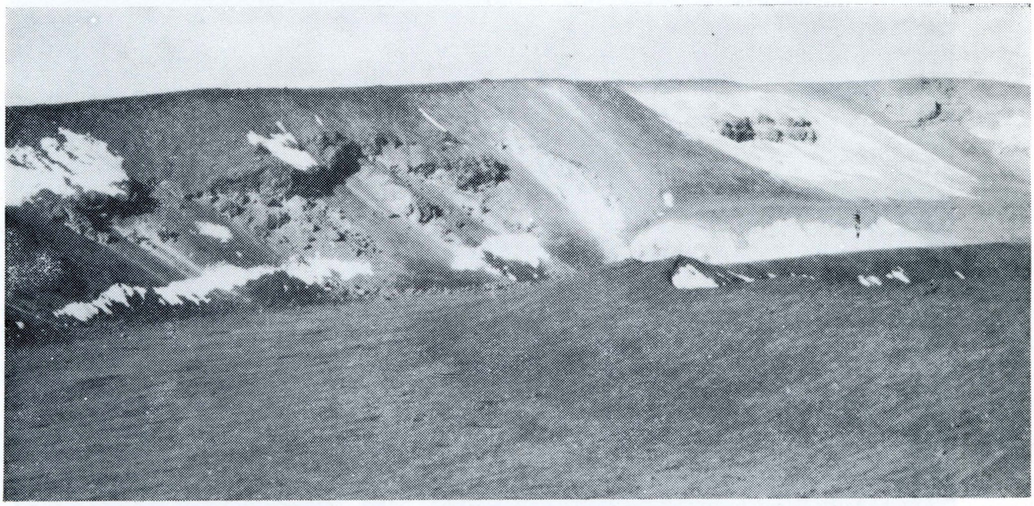
1. Mapa znázorňující hlavní tektonické linie v oblasti Kilimandžára. 1 — sjízdné cesty; 2 — železnice; 3 — zlomy a sopečné linie.
2. Mapka kaldery na Kibu ukazující rozmístění hlavních topografických bodů, ledovců, vnitřního kráteru (Inner Cone), aktivních fumarol a vlastního sopečného jícnu (Ash Pit) uprostřed.
3. Mapka vnitřního kráteru Kilimandžára (na vrcholu Kiba) s výskyty sirných ložisek a fumarol podle posledních tří měření: 1 — měření z r. 1943 (P. C. Spink), 2 — měření z r. 1952 (D. N. Sampson and G. P. Leedal), 3 — měření z r. 1976 (V. Cílek).
4. Zemětřesení v oblasti hotelu Marangu na jv. úpatí Kilimandžára. (Podle záznamů E. Lányové z let 1975 a 1976.)

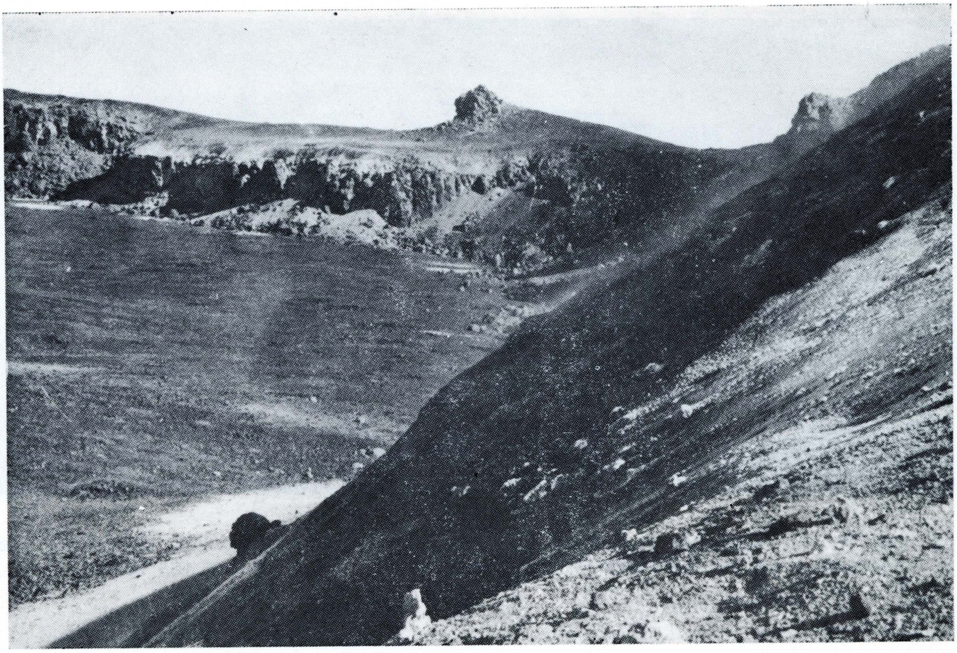
1. A general view of the Saddle between Mawenzi (right) and Kibo (left).
2. Several houses in the area of Rombo and Old Moshi have cracked walls as a result of a recent rise in the seismic activity.

3. The members of the expedition on the rim of Inner Crater.
4. The Southern Part of the Inner (Reusch) Crater. The whitish patches are fumaroles deposits which have slipped down the slope. The rim of the Kibo Crater, containig Uhuru Peak, in the background.

5. The N. W. quadrant of the Inner Crater with sulphur deposits shown on the northern scarp of the Terrace. The middle left shows a part of the Cone.

6. The S. W. quadrant of the Inner Crater, showing extensive sulphur deposits and fumaroles on the crater scarp and the southern end of the Terrace. Small patches of snow are also shown.





7. The S. E. quadrant. Rock Pinnacle in the background, the area of active fumaroles on the Crater scarp. Steam and gases as well as chemical deposits are clearly visible. More fumaroles are on the floor along the base of the scarp.
8. A detailed view of an area above active fumaroles and of chemical deposits in the S. E. quadrant.

9. The Northern Glacier as seen from Gillman's Point. The foreground shows the top of the „Cathedral". Note the barren slope of the Inner Cone.
10. Relics of the western part of Cathedral glacier. The middle shows all that remains of the Ice Dome. Uhuru Peak is shown in the background.

11. The „Battleship“ glacier as seen from Leopard's Point. Note the extensive gap in the Northern Notch and the barren rocks on the outer rim of the caldera.
12. The south-eastern slope of the Inner Cone with few remnants of once-complete ice cover. (Photos 1—12 by *V. Cílek*).