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## REPORT ON ACTIVITY IN THE NORTHERN CRATER OF OL DOINYO LENGAI, JULY 1988 TO AUGUST 1989.

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### ABSTRACT

Ol Doinyo Lengai volcano, Tanzania, has shown almost continuous minor activity since early 1983. During July 1988 several small cones and lava flows formed, and further changes took place between the end of July and late October of the same year. The most striking change during that period was the flow of lava southwards from the floor of the active crater, across the 'saddle', a ridge that had been in existence since the end of the 1966-67 explosive eruption. During 4 days in late November 1988, several flows were observed to originate from a vent north of the saddle and flow across it to spread out over the previously inactive southern segment of the north crater. Eruptive activity between January and June 1989 appears to have been rather less than it was in the second half of 1988, though as of August 1989 it could not be said to have ceased entirely.

### INTRODUCTION

An earlier paper (Nyamweru 1989) provided an account of eruptive activity in the northern crater of Ol Doinyo Lengai volcano, Tanzania, between 24 June and 1 July 1988. Here I describe the evolution of the crater since then, using reports and photographs by people who have climbed the mountain or flown over it during the last months. Particular attention is given to events during the period 22-25 November 1988, when a group of geologists camped on the inner slopes of the north crater and a continuous record of eruptive activity was made.

### METHODS

The lettering and numbering system in the illustrations follows the scheme used in my earlier report on Ol Doinyo Lengai (Nyamweru 1989 Fig. 1 to 5); the major eruptive centres are designated T1, T2 etc., lava flows are F1, F2, etc., while hornitos are designated H1, H2, etc. Figure 5 of that report shows the state of the crater floor on the morning of 1 July 1988, with the two most recently formed features being the cone T8 and the lava flow F6.

### RESULTS

#### **Diary of Eruptive Activity**

##### *Changes between 1 and 26 July 1988*

Figure 1 is traced from a slide taken by Bert Grootenhuis on 26 July 1988 and shows changes since 1 July. The cone T8 had reached a height of between 6 to 8 m but was not active on 26 July; however about 5 narrow flows had recently spread in all directions from a point slightly to the west

of T8. A new cone (designated T9) had formed slightly to the north-east of T5. During a period of a few hours on 26 July, lava was observed bubbling near T9 and flowing from the vent to the west of T8. One of the flows had gone round T1 and had almost reached the saddle (M), but at this stage lava had not overflowed the saddle.

#### *Changes between 26 July and 20-22 October 1988*

Figures 2 and 3 were traced from slides taken by Martin Smith during a visit of a few hours sometime between 20 and 22 October 1988. No liquid lava was observed at the surface, although lava could be heard bubbling at depth. Significant changes in crater morphology had taken place since late July; most notable of these was the overflow of lava across the saddle, to cover the floor of the 'southern depression'. This area had been free of newly formed lava since it came into existence following the end of the 1966 eruption. The cone T1 visible just to the north of the saddle in Fig. 1 was completely buried by fresh lava between 26 July and 20-22 October 1988. Figure 2 gives an overall view of the crater from the south, showing the spillage of lava across the saddle between M1 and M2. On the original colour slide the formerly green vegetation on the saddle west (left) of M1 was brown, killed by sulphurous fumes. Figure 3 shows a cluster of cones (T9B, T10 and T10B) near the eastern wall of the crater, which formed after July 26.

#### *Changes between 20-22 October and 22 November 1988*

On arrival at the crater rim early on 22 November 1988 the following changes were observed since late October: (i) A new cone, T11, had formed slightly north of the former alignment of the saddle, and several new flows (e.g. F7 and F9) had spread from its base (ii) more lava had spilled across the saddle and the area of lava (F8) in the floor of the southern depression had increased. No major changes were observed in the areas of T4T7 and T5T9T10. The appearance of the crater on 23 November 1988 is shown in Fig. 4, based on a field sketch by the author. The direction of view is towards the east. Figure 5, also based on a field sketch by the author, provides a more detailed view of the area of T5T9T10, taken from the northwest.

#### **Diary of eruptive activity from 22 to 25 November 1988**

- 22 November 1988, 0800h: first sight of the crater floor from the eastern crater rim. Liquid lava was bubbling and splashing in the new vent (T11) from which very recent flows had spilled on to the north crater floor (Flows F7 and F9) and into the depression south of the saddle (F8). During the morning of 22 November, lava began to flow southwards into the southern depression, moving in a narrow (less than 1 m wide) channel that had vertical walls, sometimes undercut and up to 3 m deep. Below the saddle, sections of the channel were roofed over, forming a lava tunnel. The flow of lava continued virtually all day on 22 November 1988, with short pauses. Maximum effusion rate (by visual estimate based on the width, depth and speed of the flow) was about 30 cu-m per min with temperatures (measured with a thermocouple) from 568° to 579 °C (Pinkerton, personal communication). The lava frequently splashed down the channel as a 'waterfall' and spread out in various directions on the floor of the southern depression. No liquid lava was visible at other centres on 22 November 1988, although there was a shimmer of heat from one of the vents on the eastern side of T4T7 and irregular blasts of escaping gas from that centre.
- 22 November 1988, 1230h: small flows of very liquid lava escaped low down on the east side of T11, reaching the crater floor north of the saddle.
- 22 November 1988, 2000h: the flow from T11 continued after dark, when dull red incandescence could be seen at the eastern and southeastern slopes of the southern depression and which set fire to vegetation there.
- 23 November 1988, 0800h: more flows from T11 had formed during the night, covering a large area in the southern depression. By 0800h the southwards flow from T11 had ceased, and the overflow channel appeared blocked. Parts of the lower overhanging rim on both east and

west sides of vent T11 had collapsed so that it was possible to see a bubbling lake of black lava. A long flow (F10 in Fig. 4) had extruded from a hornito (H4) west of T5, and had reached the northwestern crater wall. Beginning at 0812h, and continuing during the morning, a series of thuds and bangs, followed by rapid bubbling noises, occurred near the western wall of the crater, towards the lower end of F10. These were caused by lava flowing over an uneven older lava surface, and trapping pockets of gas which then expanded explosively.

- 23 November 1988, 1200h: the lava lake in T11 continued bubbling, but there was no overflow. At infrequent intervals gas blasts continued from T4T7, but there was no other discernable activity in the crater.
- 23 November 1988, ca. 1700h: there was a short but heavy rainstorm, during which clouds of steam rose from the still warm lava surface south of the saddle (F8 in Fig. 4) and from F10. When the rain stopped and the steam cleared it could be seen that T11 and the flows around it (e.g. F9) which had been rather pale grey, had turned almost black, while F10, which had been dark brown, turned almost white.
- 23 November 1988, ca. 2000h: bubbling and splashing of lava continued in T11, with red incandescence and yellow flares of gas seen after dark, but there was no overflow. The 'snorts' of gas from T4T7 became more frequent in the evening than they had been earlier; one count gave 17 'snorts' over 30 s. These 'snorts' were being emitted from three different holes at the top of pinnacles around the northern and southern sides of T4T7; deep within one of these, a reddish glow could be seen, and much hot gas (maximum temperature 482°C) (Pinkerton, personal communication) was emitted. Some noise of liquid magma at depth could be heard below the eastern part of T4T7.
- 24 November 1988, 0510h: an eruption began to the west of T5, forming hornito H5. Gas emission from T4T7 was now continuous.
- 24 November 1988, 0540h: another vent opened on the southwestern slope of T5, with spattering and outflow of very fluid lava, extending a few tens of metres from the vent. This vent was named T5B, and the lava is F12 (Fig. 5).
- 24 November 1988, 0800h: activity at both H5 and T5B continued, with frothy lava bubbling within H5 and new streams of lava flowing from T5B. Other changes during the night included the spattering of fresh lava from one of the gas-emitting pinnacles on the north side of T4T7, and the building of a new little cone within T4T7. Bubbling of lava within T11 continued, but the eruption became restricted to the central part of the lava lake, resulting in the building up of a new, inner cone. By 0800h only the base of its slopes had been formed.
- 24 November 1988, throughout the day: lava levels fluctuated in H5, higher levels correlating positively with outflow from T5B. At T11 exploding bubbles in the centre of the lava lake continued to build up the lower slopes of an inner cone, and ejecta reached 10 m high. During the day emission rates from T5B averaged approximately 0.1 cu m per min and temperatures ranged from 565° to 579 ° C (Pinkerton, personal communication).
- 24 November 1988, 1700h: at T8 hot, shimmering gases were seen rising from a new opening on the lower west slope of the cone, with the sound of liquid magma moving about at depth.
- 24 November 1988, 1930 to 1950h: at T11 active bubbling and spattering built up the rim of the inner cone to about 1m above the general level of the lava lake. Glowing lava was still visible in H5. From the base of T5B small incandescent flows continued. The small vent on the western side of T8 showed a red glow at depth and some very localized fresh spatter had been ejected.
- 25 November 1988, 0700h: T11 had built up a wide inner cone reaching about 2 m high. At T8 liquid magma could be heard at depth, but there was no sign of any new spatter. The base of H5 had collapsed on its northeastern side, revealing liquid lava bubbling gently. H5 was a few cm higher, due to near-overflow of lava during the night before the collapse had occurred. Several new, small pahoehoe flows had formed below T5B during the night, and

flow in this area continued in the morning of 25 November 1988.

25 November 1988, ca. 1100h: flow from T5B continued, and had encircled a fumarole near the base of the east wall of the crater; loud bangs (like a firecracker) occurred when the liquid lava flowed into the fumarole. At T11 bubbling and spattering continued to build up the inner cone, and another part of the eastern outer wall had collapsed.

### Dimensions of crater in November 1988

The horizontal dimensions were obtained by rangefinder and the vertical dimensions by rangefinder and Abney Level; measurements were made by the author with J.B. Dawson and H. Pinkerton. Error factors estimated as of the order of 1 to 2 degrees for bearings, 4 to 4 m for lengths.

Diameter of main (northern) part of north crater across bearing 124°: 236 m

Diameter of main (northern) part of north crater across bearing 018°: 229 m

Diameter of southern part of north crater across the surface of the newly formed lava: 90, 101, 121 m. (different bearings).

Heights above central part of crater floor:

East rim of north crater (low point):	35 m
Top of rim cone C1 on north rim:	45 m
Southwest rim of north crater:	45 m
Top of cone A3 on northwest crater wall:	25 m
Summit of Ol Doinyo Lengai:	96.4 m
Top of cone T9B:	11 m
Top of cone T8:	20 m
Top of cone at west end of T4T7:	7.5 m
Top of cone T10:	13.2 m

Height of south slope of central part of saddle: 4.5 m

### List of features visible in the north crater in late November 1988

(See Fig. 4 and 5)

#### 1. Lava Flows

Flow 9: not observed forming; still relatively fresh during the period of observation but older than F7. Darker grey than F7, with a rough, 'blocky' surface; turned almost black in the rain on the afternoon of 23 November 1988.

Flow 7: this flow was relatively fresh during the period of observation but was not observed forming and did not have surface heat when we saw it. On the morning of 23 November 1988 it was pale grey, a clinkery surface with big lobes. It had spread to the west from the southern corner of T11, but was a relatively thick and not highly mobile flow. It was younger than F9.

Flow 8: this includes several different flows that originated from T11, flowed over the saddle and filled in the floor of the southern depression. During the period of observation several flows reached the base of the crater wall and pushed against the soft ash of the older slopes, setting fire to the surrounding vegetation and creating small 'push moraines' of the older ash. Most of the area south of the saddle was covered by fresh mainly 'clinkery' lava during the period from early 22 November 1988 to the following night.

**Flow 10:** This flow was brown when it formed during the night of 22 November 1988; minor movement at its western end was still continuing on the morning of 23 November 1988. It was largely composed of smooth pahoehoe. Its source was an inconspicuous vent close to hornito H4. The major part of F10 extended to the west wall of the crater but there was also an area of very similar smooth pahoehoe lava to the east of T11, close to the north side of the saddle. F10 turned almost white in the rainstorm on the afternoon of 23 November 1988, and most of it stayed very pale for the rest of the period of observation.

**Flow 11:** This small pahoehoe flow originated from the vent close to hornito H4 and flowed towards the northwest for a few tens of metres. It formed slightly earlier than Flow 10.

**Flow 12:** This refers to the thin pahoehoe flows that originated from T5B, starting at 0540h on 24 November 1988. Flow was continuing at 1100h on 25 November 1988.

## 2. Eruptive Centres

**D:** a deeply weathered lava flow on the west wall; not active during 1988 or 1989.

**A3:** four deeply weathered but well-defined cones on the north wall, of which the largest lies highest and furthest to the west. Not active (except for possible minor emission of steam) during 1988 or 1989.

**C1:** the 'rim-cone' not active during 1988 or 1989, except for fairly continuous gentle emission of steam. Possible collapse on west side has made the western edge (the highest part) particularly steep.

**H5:** a hornito that began to form at 0510h on 24 November 1988, to the west of T5, close to and slightly above H4. It reached a maximum height of about 1.5 m and had a flat top (diameter of open vent about 1.1 m).

**T2:** this cone may have come into existence as early as October 1984; by late 1988 it was virtually buried by younger lava flows from the east; only the upper parts of the northern and southern slopes and the central mound were visible. There was active emission of steam and sulphur fumes and considerable deposition of sulphur crystals around the remaining visible sections of T2. Estimated thickness of lava cover between June and November 1988: at least 1.5 m.

**T4T7:** the overall appearance of this centre did not change between June and November 1988, but some local changes occurred, most noticeably the building of a rather large, rounded cone on its south side. Collapse occurred within the centre of T4T7, though at least two central pinnacles remained and there was some overhang on its east side. Some centres emitted blasts of gas at varying intervals throughout the period of observation. Occasionally, liquid magma was heard moving around at depth below the eastern side of T4T7. The only signs of fresh lava were some spatters on one of the pinnacles on the north side, formed during the night of 23 November 1988. A large (over 1.5 m high) open but inactive hornito (H3) stood between the east end of T4T7 and T8.

**T5:** this centre became more complex between June and November 1988; the cone T9 continued to grow and largely merged with the north side of the original T5. A new cone (T9B; see Fig. 5) formed on the east side of T5 and a separate cone (T10) formed close to the east crater wall, with a smaller mound (T10B) to the north of it. West of T5 a number of hornitos were still very fresh on 22 November 1988, including a spectacular vertical hornito about 1.5 m high (H4). At 0540h on 24 November 1988, a small vent (T5B) opened low on the southwest slope of T5, and over the next 24h several small hornitos were built up below it, while small flows of highly liquid pahoehoe lava (F12) were extruded throughout the remaining period of observation.

- T9: this steep, flat topped cone with an open crater at the top, joined by a high level saddle to T5 formed between 1 and 26 July 1988; in the same vicinity, T9B came into existence by 20-22 October. There was no sign of activity from the top of T9 or T9B in late November 1988.
- T10: a steep, sharp pointed pinnacle, with an asymmetrical opening at its top and an inner ('nested') cone within the outer crater. Joined to the east crater wall by a high saddle. A smaller cone (T10B) with a collapsed top lies south of T10, also close to the crater wall. Both these features formed between 26 July and 20-22 October 1988 and were not active in late November 1988.
- T8: the lower slopes of this cone were formed between 1 and 26 July 1988 and the steep pinnacle approximately 20 m high formed between 26 July and 20-22 October 1988. By late November this cone showed some signs of slight collapse at its top and near its base. The lower (gentler) slopes were blackened; the upper (steeper) slopes were pale grey and cream with white patches.
- T11: this came into existence after 20-22 October 1988; a large asymmetrical cone, with long axis approximately NNE-SSW and its highest point (overhanging in late November) to the NNE, rising about 13 m above the surrounding crater floor. Lava from the south side of this cone flowed across the lowest point of the saddle and filled in the floor of the southern, formerly inactive segment of the north crater. Activity continued within or from this centre throughout the period of 22-25 November 1988. The overhanging slopes of the outer cone began to develop cracks and collapse occurred several times.

### 3. Fumaroles

East rim: deep cracks, steam, sulphur fumes and sulphur crystals; similar to or slightly increased since late June 1988.

East wall: much fumarolic activity on lower slopes between T10B and the saddle.

Southern slope of T4T7: a wide (ca. 5 to 10 cm) crack approximately parallel to the south slope, emitting steam virtually throughout the period of observation. Blackening of lava surface around the lower slopes of T4T7.

Saddle: vegetation on its western slopes and to the southwest had been killed, presumably by sulphur fumes. The original large crack on the west side of the saddle, observed in June 1988, had widened to over 10 cm in parts and showed yellow (sulphur), black and white staining, with constant emission of sulphurous fumes. Above (west of) it ran several transverse (almost SE-NW) cracks of white staining which also emitted steam and crossed the saddle from its lower southern slope to its lower northern slope. The eastern side of the saddle showed much staining by sulphur and emission of sulphurous fumes.

West wall: steam emitted from at least 3 vertical cracks running almost the whole height of the wall, to the south of D.

North wall: steam emitted to the west of A3 and also near the top of the wall above A3 and towards C1.

West rim: still active emission of steam from the cracks observed in June 1988, killing some of the vegetation around these cracks.

#### *Changes during December 1988 and January 1989*

Figure 6 is traced from a slide taken from the air on 14 December 1988; the view southwards shows the major features as in late November, with some small recent lava flows from the western slopes of the T5T9 cluster. Figure 7 is traced from a panorama provided by Peggy Forrest and

taken on 12 January 1989. Little change seems to have occurred in cones T10, T11, T8 and T4T7, and no fresh lava is visible on the sections of the crater floor included in the panorama. During that visit there was no liquid lava at the surface but it could be heard bubbling at depth. It would seem that conditions in December 1988 and January 1989 were considerably less active than they had been in October and November 1988.

#### *Changes between January and June 1989*

In late May 1989 a pilot (Steve Cunningham) reported bubbling lava in the vicinity of T10, that is at the south-eastern side of the crater. A video film of the crater on 28 June 1989, taken by Alex van Leerdam, gave a clear aerial view of the crater from the north. The overall colour of the crater floor was very pale grey, with a large patch of slightly darker grey lava on the west side of the floor. The general pale colour of the crater floor implies that no fresh lava had flowed out during the two to three weeks before the date of observation. The main cones (i.e. T4T7, T5T9, T8 and T11) were all visible and essentially unchanged since November-December 1988.

#### *Changes between June and July 1989*

Figures 8 and 9 were traced from slides taken by Alan Fowler, who climbed the volcano on 26 July 1989 (exactly a year after the Grootenhuis' ascent!) No lava was observed at the surface, although it could be heard bubbling in several vents. Figure 8, taken from a similar viewpoint on the west rim to figure 4, shows T11 now inactive; the inner cone which was observed forming on 25 November 1988 did not develop to any size and was now not visible. The extent of lava overflow across the saddle has not increased significantly; the large boulder (B1) visible on the edge of the lava in Fig. 4 is still visible in Fig. 8. The general appearance of the crater floor (both north and south of the saddle) is very pale, indicating no fresh lava flows for several weeks previous to 26 July 1989. The most recent flow may have been in existence on 28 June 1989. It is identified as F13 in Fig. 8 and 9 and is mid-grey in colour, rather 'blocky' in surface texture, and covers the south-western quadrant of the north crater floor. Dark staining to the north-west of T11 (x in Fig. 8) may indicate a very persistent line of fumaroles that was clearly visible in June 1988 but had been covered up by young lava in late November 1988. Figure 9 is taken from the east rim, looking broadly southwards and shows T8, T10 and T11 all basically unchanged since November 1988. However a rather indeterminate feature (T12) can be observed close to the east wall north of T10 and this may be the vent at which lava was observed bubbling in late May 1989. A higher pinnacle seems to have developed on the west side of the T5T9 cluster and is labelled T13 in Fig. 9. Another medium grey flow at the base of the southeast wall is labelled F14.

#### *Changes between July and August 1989*

Figure 10 was traced from a slide taken by Dr. Lester Eshelman on 23 August 1989 and shows an aerial view of the crater from the northeast. All the cones and flows visible in Fig. 9 are clearly recognizable. The darkest feature is the pinnacle of T13, although this may be due to shadow rather than fresh lava. No new flows are visible, but both F13 and F14 show a clear contrast of colour, darker than the rest of the crater floor. The overflow across the saddle between M1 and M2 has not increased since June - July 1989.

### GENERAL OBSERVATIONS AND CONCLUSIONS

Liquid lava has continued to be present at or near the surface of the crater throughout the period July 1988 to August 1989. Lava was flowing out on the surface on 26 July 1988, between 22-25 November 1988 and in late May 1989. Significant changes in crater morphology occurred between 26 July and 20-22 October 1988, and between 20-22 October and 22 November 1988. Most important of these was the overflow of lava across the saddle and the beginning of infilling of the southern depression. Apart from this (associated with the formation of the cone T11), activity

has generally been concentrated towards the north-eastern and eastern sides of the north crater floor. Changes between July and December 1988 were more striking than those between January and August 1989, but activity has not ceased yet.

### ACKNOWLEDGEMENTS

I am extremely grateful to Professor J.B. Dawson, Department of Geology, University of Sheffield, U.K., for making it possible for me to join his expedition to Ol Doinyo Lengai, and to David, Thad and Michael Peterson of Arusha, Tanzania, who handled all the arrangements for our visit. The account of the activity between 22 and 25 November 1988 owes much to the contributions of Professor Dawson, H. Pinkerton, D. Pyle and G. Norton. I also acknowledge those who have made their slides and information on their climbs of Ol Doinyo Lengai available to me, namely Bert Grootenhuis, Martin Smith, Alex van Leerdam, Alan Fowler and Lester Eshelman. Dr. Eshelman's photographs would not have been available to me without the help of Joe Moran (Chief Pilot of AMREF), to whom I am also very grateful. My thanks are also due to the Vice-Chancellor, Kenyatta University, for permission to be away from the university during our expedition.

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NYAMWERU, C.K. 1989. Report on activity in the northern crater of Ol Doinyo Lengai, 24th June to 1st July 1988. *J. E.A.N.H.S. & Nat. Mus.* 79, (186): 1 - 15.

### GLOSSARY OF TERMS

**CLINKERY:** describes a lava surface that is rough, jagged and very porous, resembling the clinker or slag of a furnace.

**FUMAROLE:** a vent, usually volcanic, from which gases and vapours are emitted.

**HORNITO:** a small mound built up on top of a lava flow by clots of very fluid rock escaping from openings in the roof of an underlying lava tube.

**PAHOEHOE:** a lava flow with a smooth, 'billowy' or 'ropy' surface.

**PUSH MORaine:** this term is properly applied to an arc-shaped ridge consisting of unconsolidated sediments mechanically pushed or shoved along by an advancing glacier. Applied in this case to small ridges of debris pushed along by the advancing lava on the margins of the 'southern depression'.

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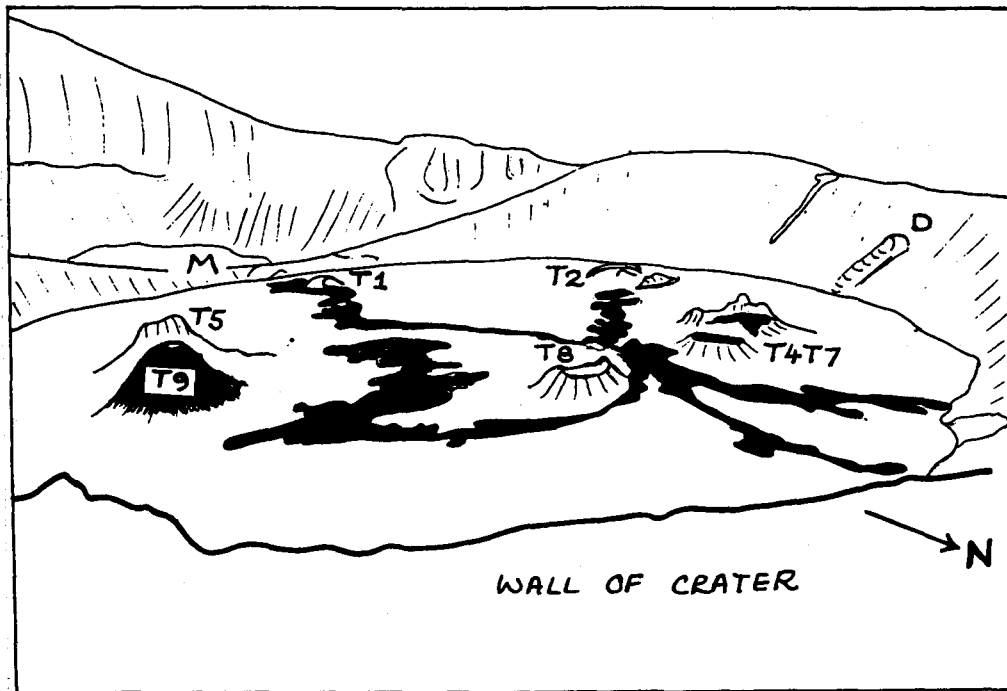


Figure 1: view towards the south across the crater from the north-east rim, traced from a slide taken by Bert Grootenhuis on 26 July 1988. Cone T9 is the most recently formed cone. Diameter of crater floor is ca. 230 m; crater rim at T2 is ca. 45 m above crater floor.

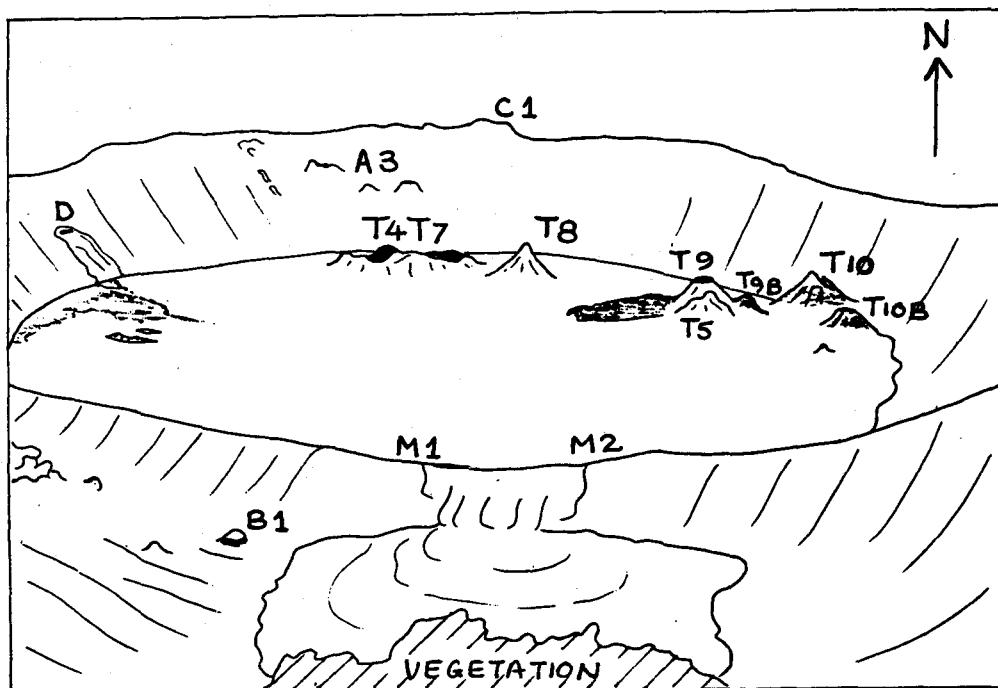


Figure 2: view northwards from the summit, traced from a slide taken by Martin Smith between 20-22 October 1988. Lava has overflowed the saddle between M1 and M2 but has not reached the boulder B1 on the floor of the southern depression. Diameter of crater floor is ca. 230 m; crater rim at C1 is ca. 45 m above crater floor. Diameter of lava patch in front of M1M2 is ca. 90 m.

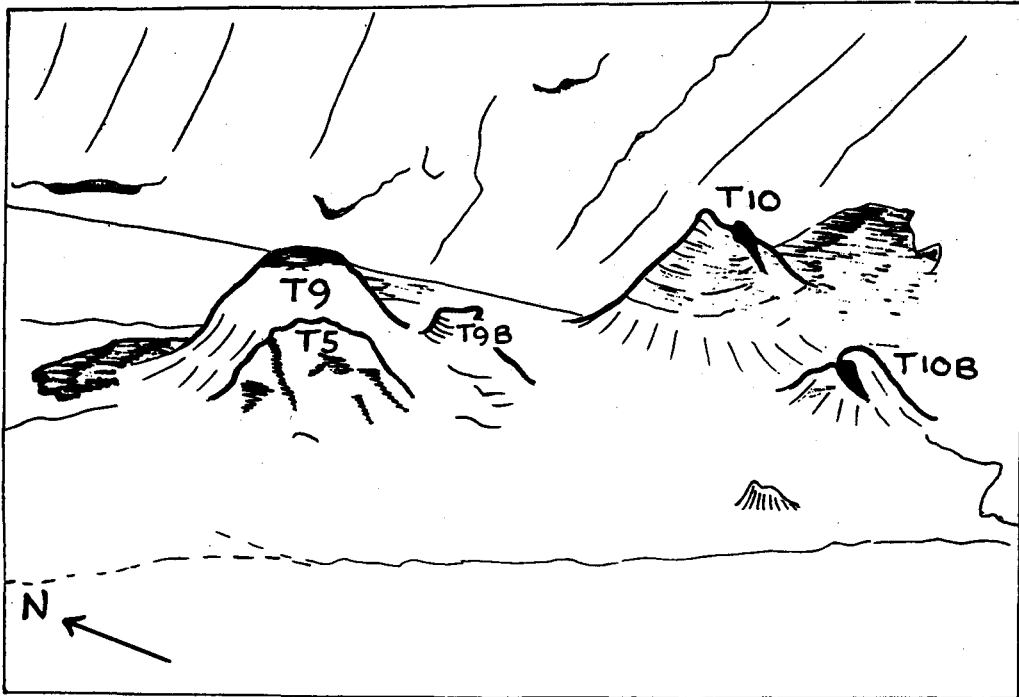


Figure 3: cluster of cones at the base of the east wall (looking approximately north-eastwards); traced from a slide taken by Martin Smith between 20-22 October 1988. T10 and T10B at base of the east wall are rather dark grey and (together with T9B) formed since 26 July 1988. Top of T9 is ca. 12 m above crater floor, top of T10 is ca. 13 m above crater floor. Distance between T9 and T10 is ca. 42 m.

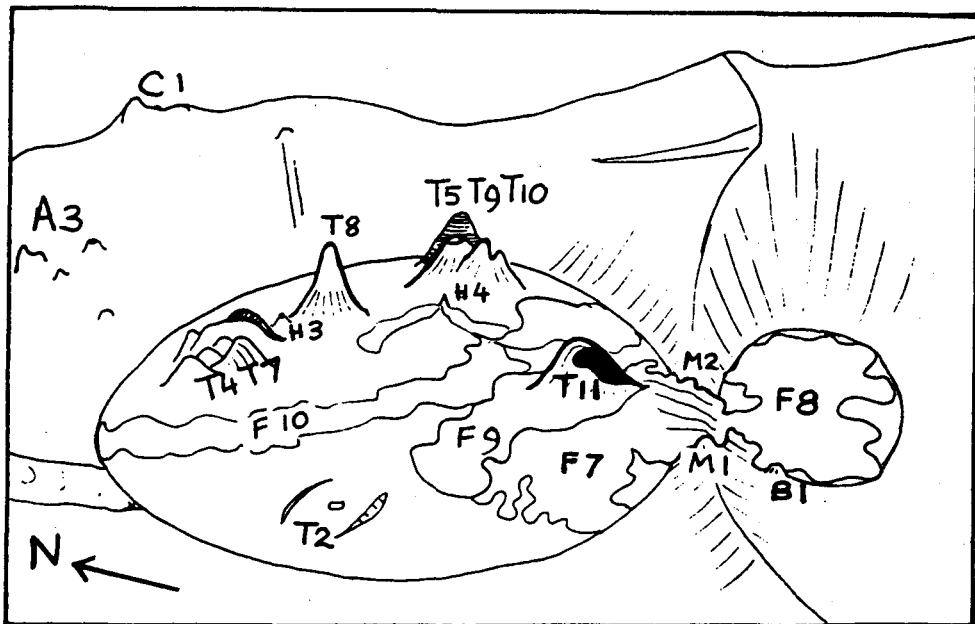


Figure 4: the crater from the west, sketched by C. Nyamweru on 23 November 1988. The cone T11 is new and several new lava flows cover the crater floor both north and south of the saddle. The lava south of the saddle (F8) has just reached the large boulder B1. Diameter of crater floor is ca. 230 m; C1 is about 45 m above the crater floor.

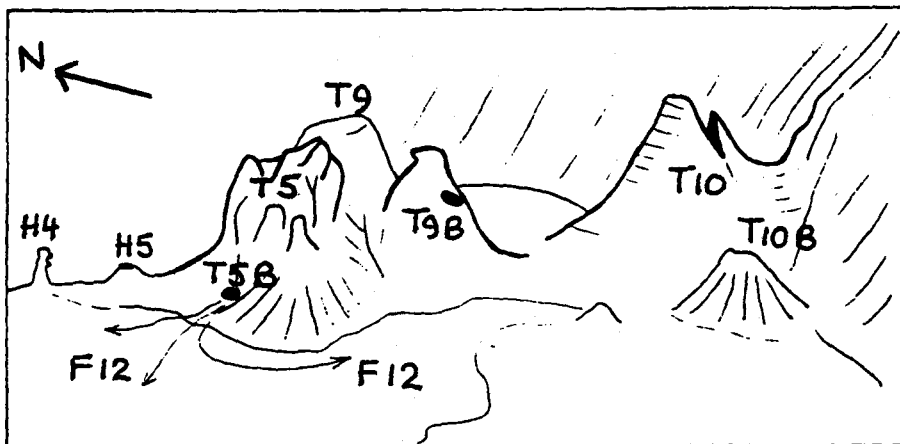


Figure 5: cluster of cones at the base of the east wall; direction of view very similar to that of Fig. 3. Sketched by C. Nyamweru on 23 November 1988. No change in cones T9, T9B, T10 or T10B; formation of homitos to the west of T5 and effusion of small lava flows (F12). Dimensions as for Fig. 3.

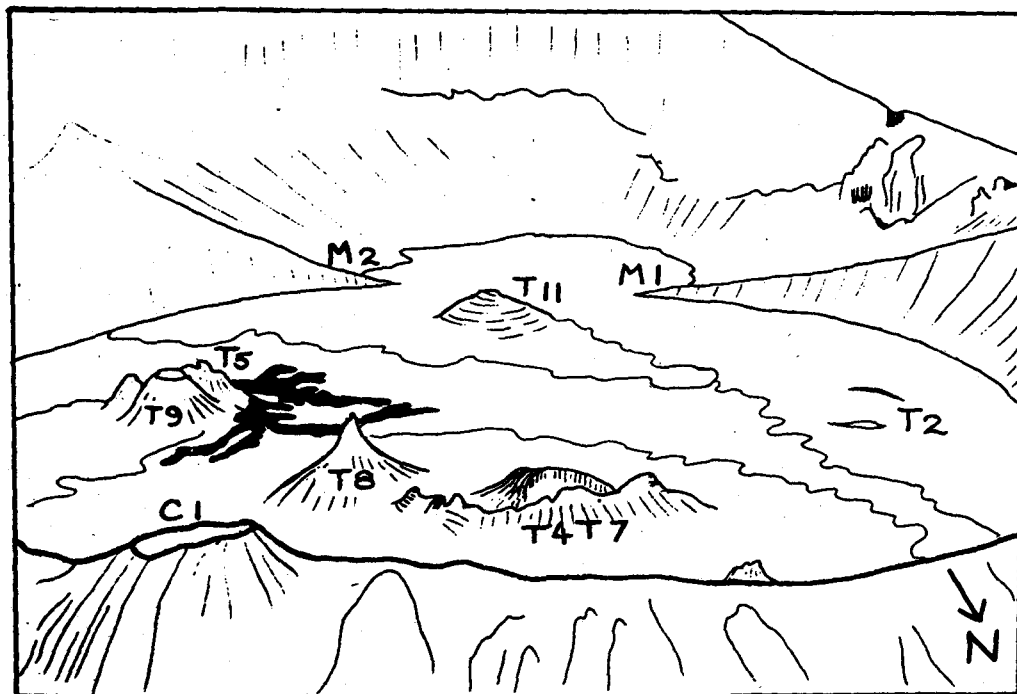


Figure 6: aerial view of the crater from the north, traced from a slide taken by C. Nyamweru on 14 December 1989. Small recent flows from the western side of the T5T9 cluster. Diameter of crater floor is ca. 230 m.

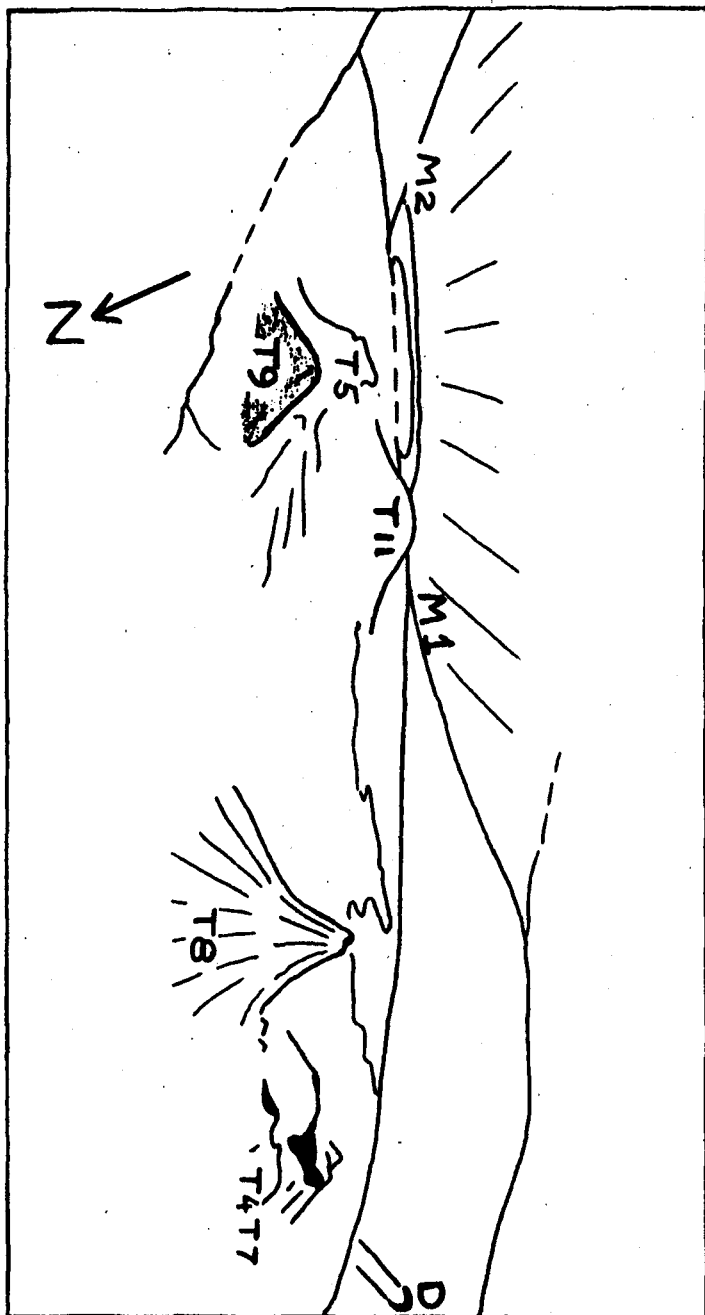


Figure 7: view across the crater to the south-west, traced from a panorama supplied by Peggy Forrest and taken on 12 January 1989. Little change in the overall appearance of the crater though T9 is rather dark in colour and may have had recent spatter of fresh material on its outer slopes. Diameter of crater floor is ca. 230 m.

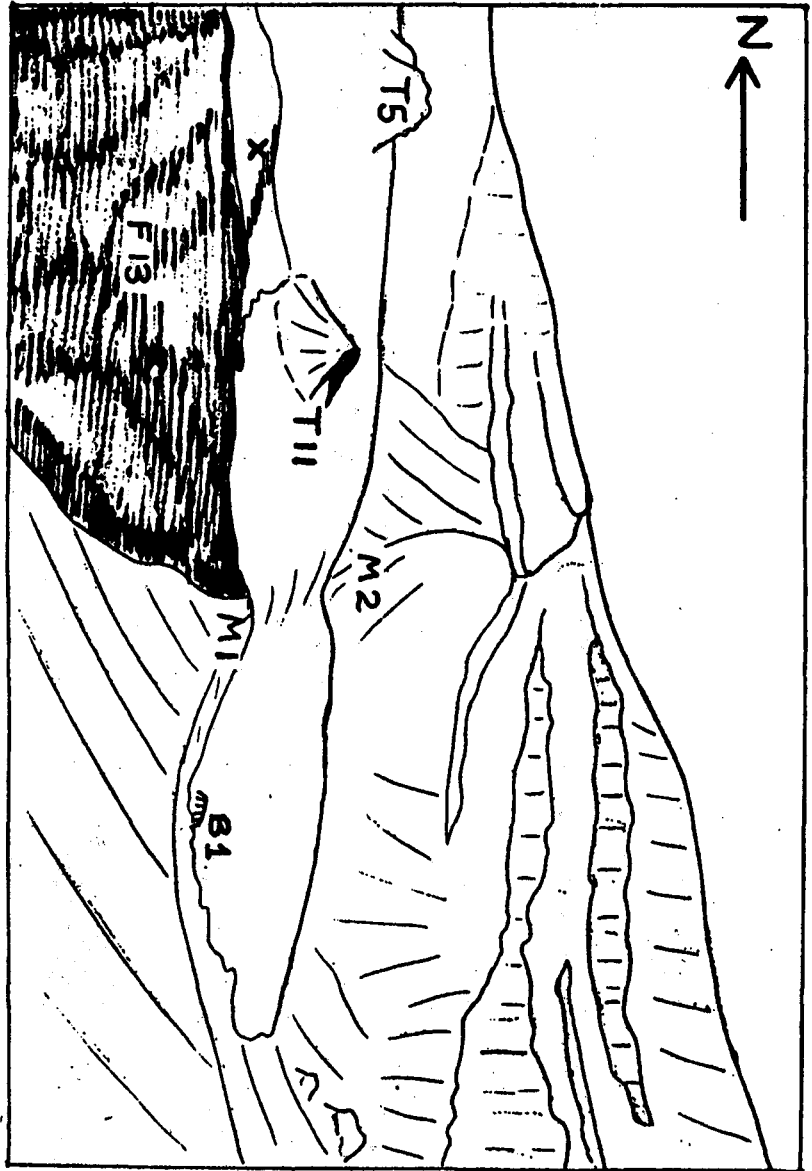
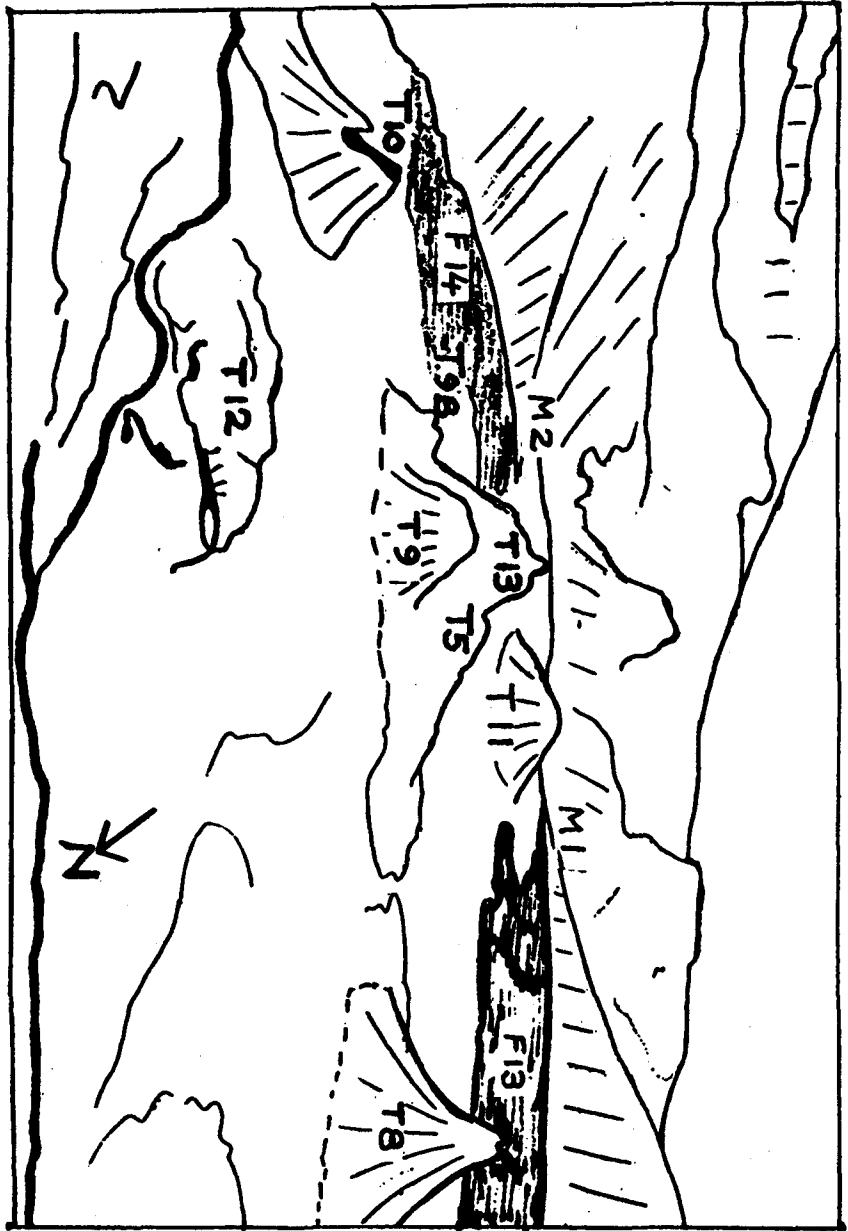


Figure 8: view from the west rim of the crater looking eastwards across the saddle; traced from a slide taken by Alan Fowler on 26 July 1989. The width of overflow (M1 to M2) has not increased significantly and the boulder B1 is still visible. Youngest flow would seem to be F13. Dark line at x may mark persistent fumaroles. Diameter of lava patch to south (right) of saddle M1M2 is ca. 120 m.



*Figure 9: view from the east rim of the crater looking approximately southwards; traced from a slide taken by Alan Fowler on 26 July 1989. There is a possible new vent (T12) at the base of the east wall north of T10. Diameter of visible part of crater floor is ca. 180 m. Top of cone T8 stands ca. 20 m above crater floor.*

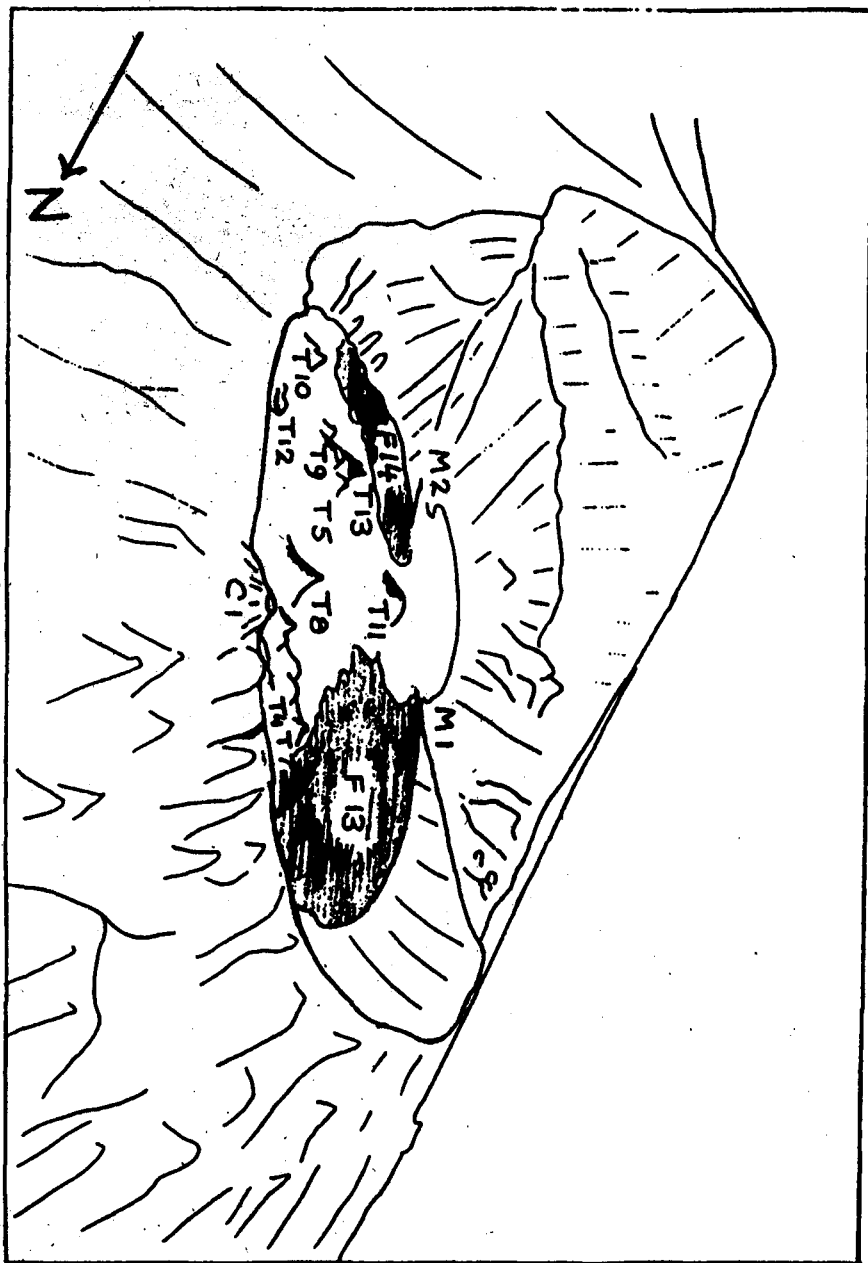


Figure 10: aerial view from the northeast, taken by Lester Eshelman on 23 August 1989. The features visible in Fig. 9 can all be seen with little or no change. The darkest feature is the pinnacle of T13; this may be partly due to shadow as well as to fresh spatter of lava. Diameter of crater floor is ca. 230 m. Summit rises ca. 96 m above level of crater floor.