

30. *Explosive Activities of Volcano Asama and Tiltings of the Earth's Surface.*

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1. Introduction.

It is well known that in some of the world's volcanoes, tiltings of the ground near them constitute one of the most general and remarkable of volcanic phenomena. In observatories on these volcanoes, changes in the inclination of the earth's surface are measured with numerous types of horizontal pendulums. The Hawaiian Volcano Observatory¹⁾ makes use of the two components of a Bosch-Omori seismograph for the purpose, while the Aso Volcano Observatory,²⁾ uses a horizontal pendulum apparatus of Rebeur's type. At our Asama Volcano Observatory,³⁾ tiltings of the ground are recorded optically by means of a pair of Ishimoto clinographs constructed of fused silica, which is scarcely affected by changes in air temperature.

This paper summarizes the remarkable changes in tilts observed during the period from January, 1934, to December, 1937.

2. Tiltings during Inactive and Active Periods of the Volcano.

It is reasonable to expect from the results of precise levellings that have been done in certain volcanic regions that tilts of the ground near an active volcano, such as Asama, even during the peaceful stage of the volcano, will amount as a rule to a much larger quantity compared with tilts in other regions, whence it follows that a comparison of the tilts of a volcano during its active and quiescent stages ought to be of help in elucidating certain volcanic phenomena and in understanding of the structure of the volcano. Although the year 1934 was a peaceful one for Asama, the year 1935, 1936, and 1937 were those of violent explosion.

1) T. A. JAGGAR and R. H. FINCH, *Bull. Seis. Soc. Amer.* **19** (1929), 38.

2) K. SASSA, *Mem. Coll. Sci. Kyoto Imp. Uni.*, **19** (1936), 11.

3) R. TAKAHASHI and T. MINAKAMI, *Bull. Earthq. Res. Inst.*, **15** (1937), 463.

Roughly speaking, the cycle of Asama's activities seems to be about five or six years.

The tilt curves in Fig. 1. of the two components, E-W and S-N, in 1934, the calm periods of the volcano, indicate that the seasonal changes in tilts during the winter season from October to April have a range of about four seconds of arc, their periods being less than seven days. The seasonal variations in the summer season the period from May to September are distinctly small compared with the former, namely, only one second in maximum amplitude and three or five days in their periods. The daily variation in the tilting moreover is less than one second throughout

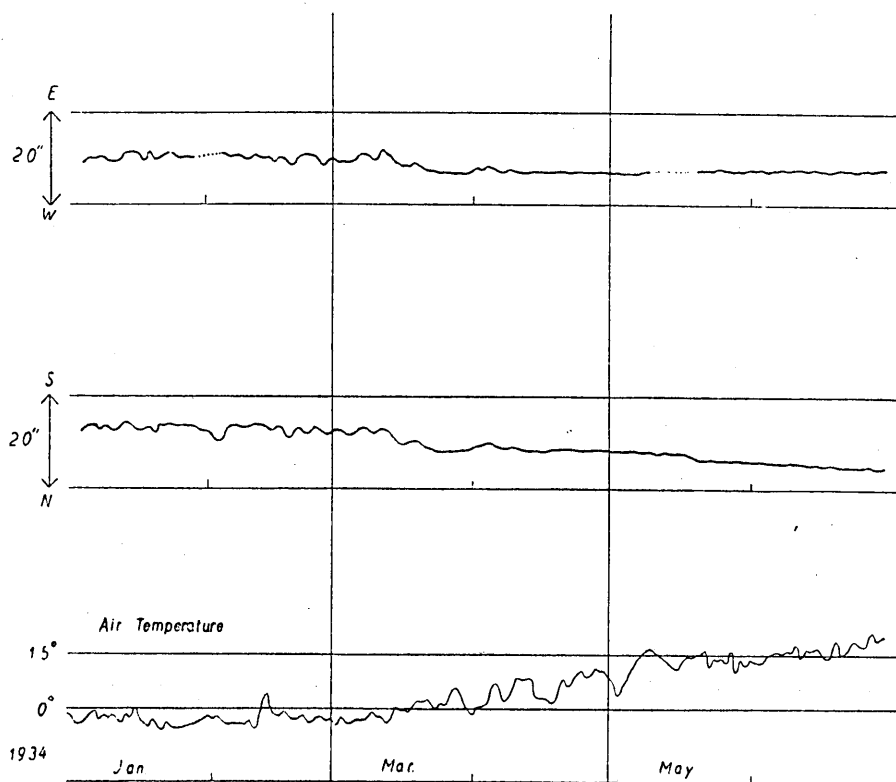


Fig. 1 a. Tilting of the ground observed at the Nakanosawa Station, in 1934.
(Inactive stage of the volcano.)

(The direction of tilt-curves is the one of depression of the ground.)

the year. Although there is practically no correlation between tilt and air temperature, either daily or seasonally, it is probable that the seasonal variations in the winter are due to the effects of the earth's surface being frozen.

The present activities, which began with the violent explosion on April 20, 1935, and ended with a still more violent one on April 16, 1937, which latter was the largest scale explosion since 1920, comprise about three hundred explosions of various degrees of intensity.

The ground tilts during these activities of the volcano in 1935, 1936, and 1937 are indicated by graphs in Fig. 2, 3, 4, with the air temper-

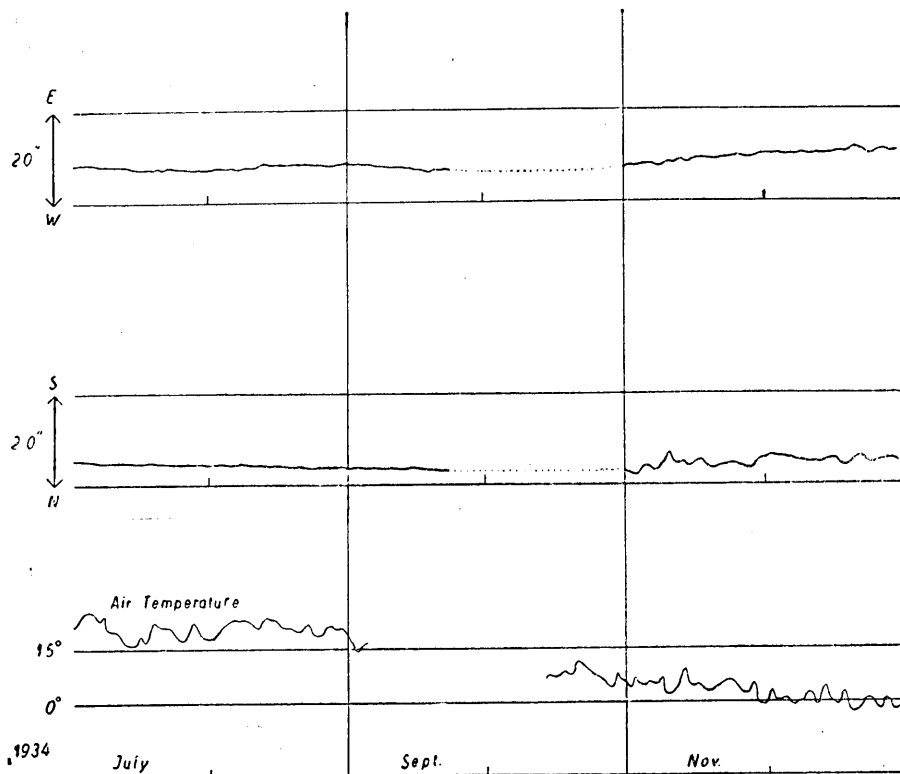


Fig. 1 b. Tilting of the ground observed at the Nakanosawa Station, in 1934.
(Inactive stage of the volcano.)

ature at noon each day, and the comparatively severe explosions that occurred in the intervals.

The marked tiltings that preceeded the present activities began on February, 15, 1935, and in the middle of April increased to 30 seconds of arc in a NE direction. Strictly speaking, this tilting which began with a SE direction on February 15, amounted to 24 seconds eastward and 23 seconds southward on March 31, after which the two components of tilts changed their directions, and continued to tilt. However, the

ground did not show any marked tilting after May. It returned to the original positions prior to occurrence of the conspicuous tilts.

The unusual changes in the inclination of the ground which began to appear since the beginning of 1936, consisted of to and fro tilts within a range less than ten seconds of arc and with various periods not exceeding twenty days. These tilts have characteristics indicating that they differ distinctly from the previous conspicuous tilts of March and April,

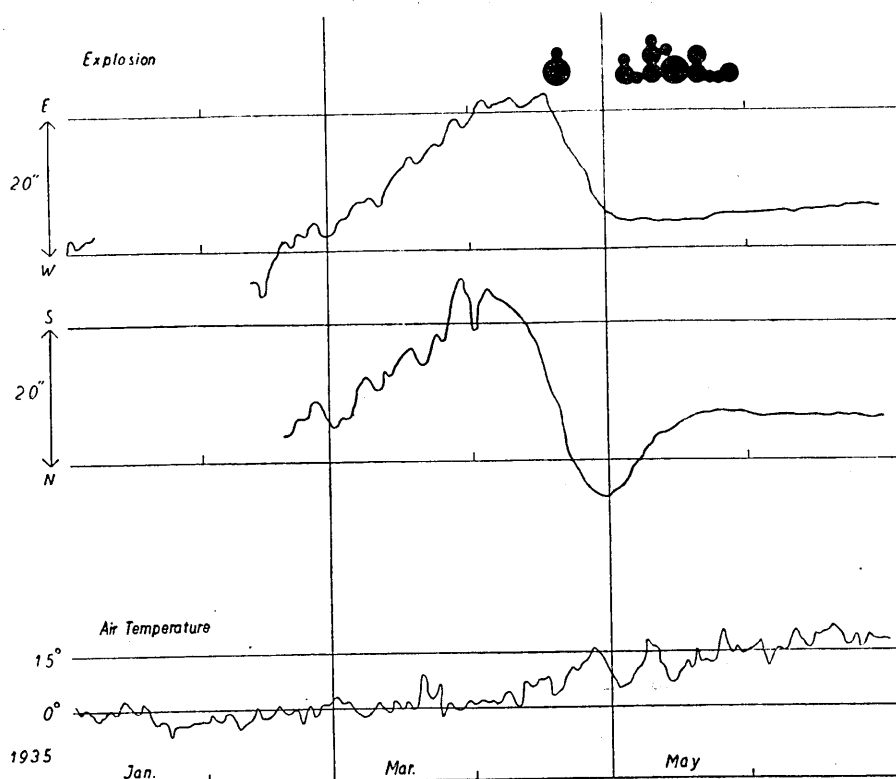


Fig. 2 a. Tilting of the ground observed at the Nakanosawa Station, in 1935.
(Active stage of the volcano.)

- Explosion of Class A
- " " B (Defined in the previous paper.*)
- " " C

1935; they also differ from the seasonal change during the calm period of 1934. No doubt, they are volcanic origin. From the later part of March to the end of June, 1936, the ground continued gradually to incline with long periods. During August and September of the same year, as

* T. MINAKAMI, *Bull. Earthq. Res. Inst.*, 13 (1935), 629.

in the interval between June and December, 1935, notwithstanding the active stage, changes in inclination did not appear. Toward late October 1936, and after, the clinographs recorded tiltings that might have been related more or less to the volcano. Since the beginning of 1937, the earth's surface began to incline in a northerly direction until March 26, when it amounted to 23 seconds of arc. Although on that day, the ground changed its direction of tilt, to E-S, it changed again on April 12 to W-N. On April 16, four days after the change in direction of the tilting of

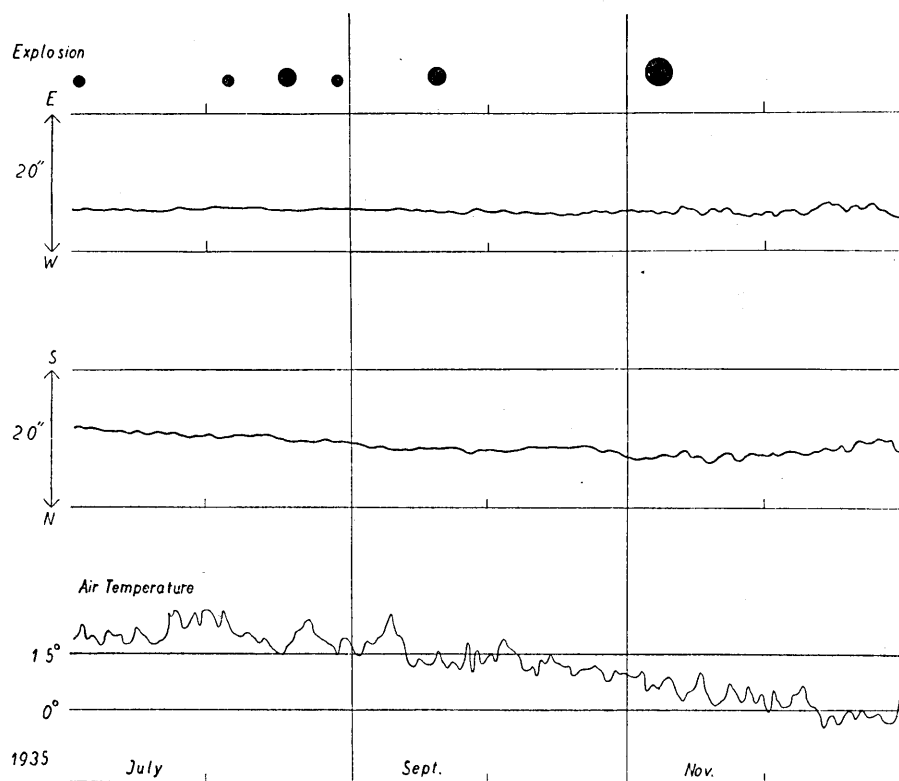


Fig. 2b. Tilting of the ground observed at the Nakanosawa Station, 1935.
(Active stage of the volcano.)

the ground, there was a severe explosion of the volcano. At the time of this severe explosion on April, 1937, about 10^6 tons of young lava were ejected from the crater in the form of volcanic bombs and ash. The clinographs both before and after this explosion recorded very striking tilts of the ground with the great speed of a daily rate of 5 seconds, which finally on May, amounted to as much as 42 seconds in the E-W component and 40 seconds in the other component all in the course of

three months. It would seem resonable to expect that displacement of lava on such a large scale with consequent marked change in loading might cause serious changes in the inclination of the ground. These remarkable tilts and this severe explosion formed the climax in the present cycle of activities.

In the beginning of 1936, another station of Asama was erected on the great lava flow, of the Tenmei era, the Oni-Osi-Dasi, on the northern slope of the volcano, in which a pair of the same type of clinographs

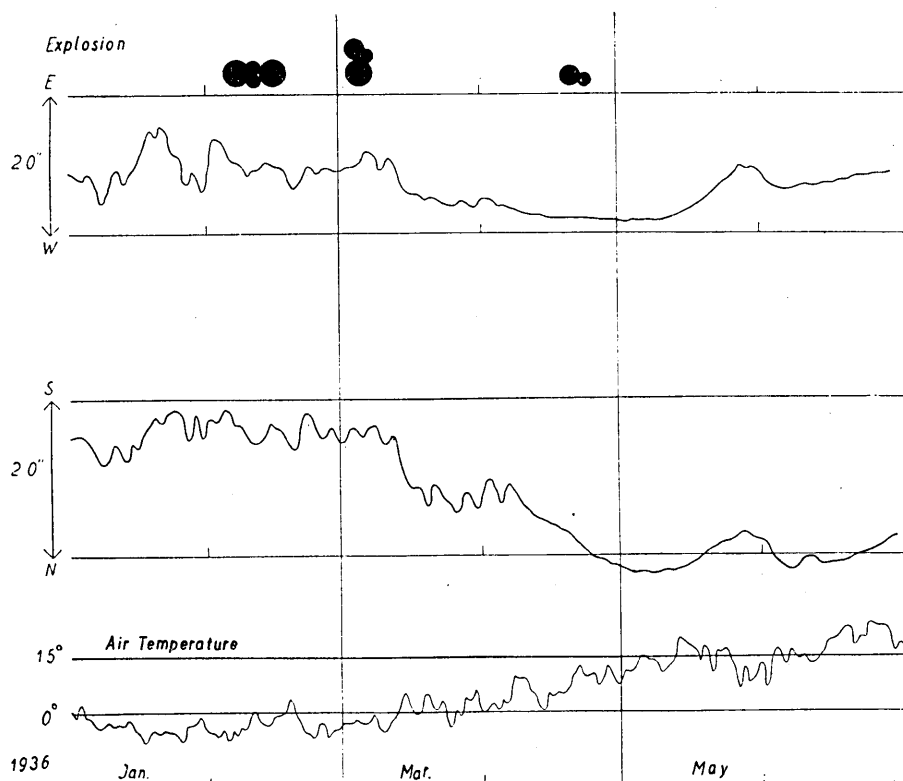


Fig. 3 a. Tilting of the ground observed at the Nakanosawa Station, 1936.
(Active stage of the volcano.)

as used in the other station was set up, and measurments of changes in the inclination begun. The tilt curves in 1937 at the new station are shown in Fig. 5. these curves, show tilts in a S-N direction from the beginning of 1937. On February 6, the tilt changed its direction to south, and on March 3, it returned to its former direction. Although on March 18, the accumulation of tilt amounted to 40 seconds, it continued in the same direction without stopping, but inclined at a less rapid rate. On

the other hand, the clinograph of the other component recorded during that time only small changes in tilt. After May, 1937, tilting of the ground ceased at both the Nakanosawa station and the Oni-Osi-Dasi station.

As will be seen from these tilt curves, the remarkable variations during the active stage of the volcano differ entirely from the seasonal and daily changes, and the other changes that occur when the volcano is quiet.

The two tilt curves recorded by the N-S and E-W components at the

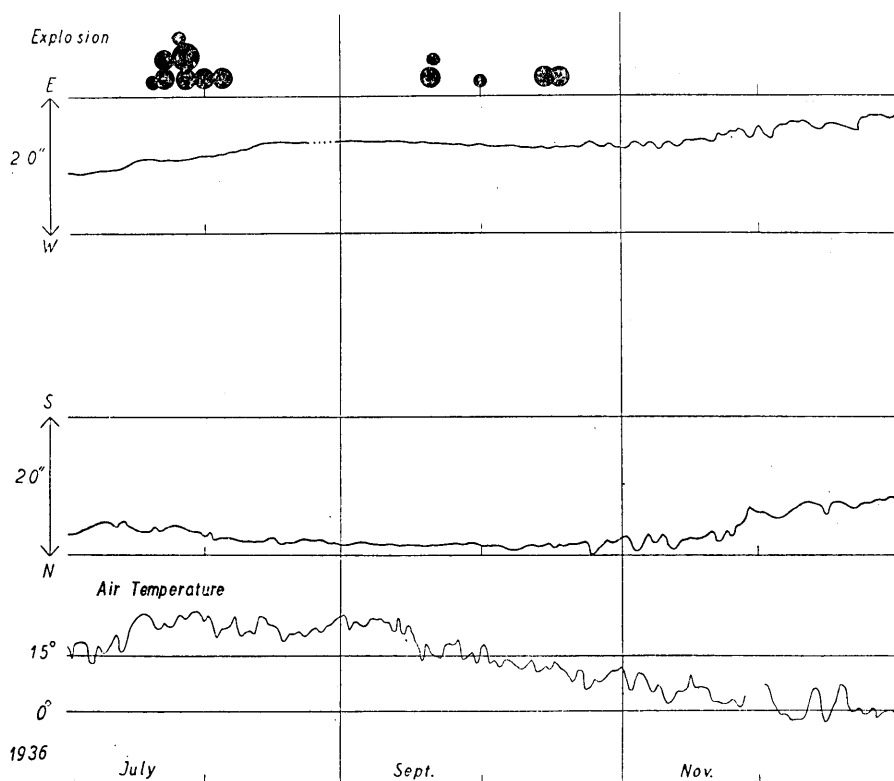


Fig. 3b. Tilting of the ground observed at the Nakanosawa Station, 1936.
(Active stage of the volcano.)

Nakanosawa station correspond each other not only in the large variations caused by volcanic activity, but also in the small fluctuations of tilt due to seasonal and the other causes.

Comparing the tilt curves of March, April, and May, 1937, at the above two stations, it is clear that, although these changes in inclination at the two stations do not agree, not only in the amounts, but also in the direction of tilt, these remarkable tilts at the time of the severe

explosion on April 16 were recorded at the two stations at almost the same time, whence it may be reasonable to suspect that such volcanic phenomena as the remarkable ground tilts of 1935 and 1937, and the swarms of explosion are geophysically connected and have the same origin. Moreover, the time relation between the occurrences of explosions and the remarkable tilts show that the latter are more clearly related to the occurrence of explosion swarms, that is, to the beginning of the cycle of activities, than to the occurrence of the individual explosion.

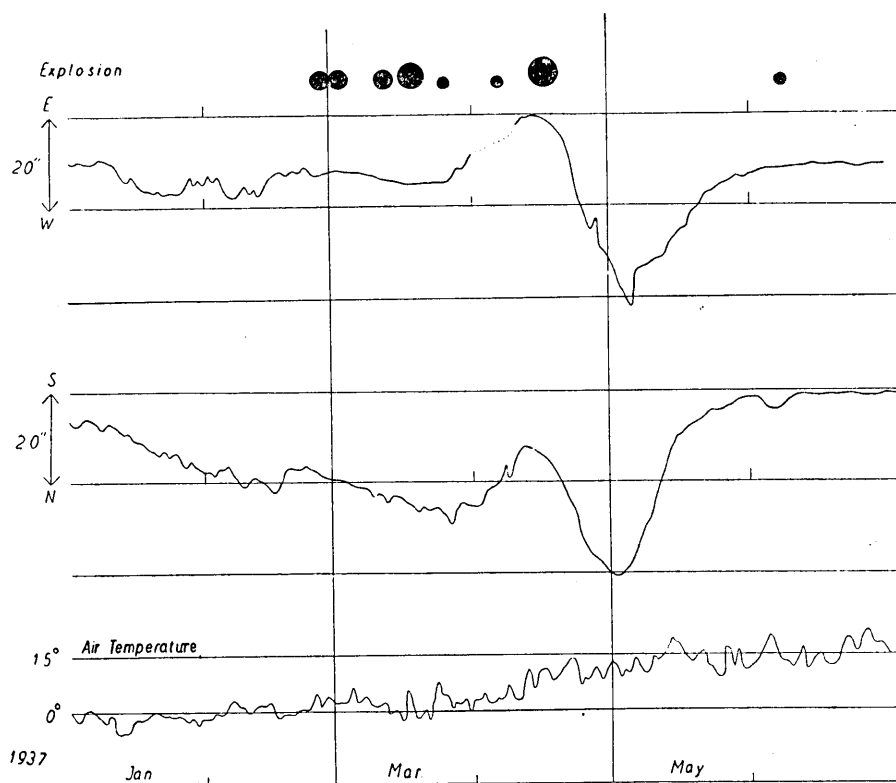


Fig. 4a. Tilting of the ground observed at the Nakanosawa Station, 1937.
(Active stage of the volcano.)

3. Vector Diagram of Tilts.

In Fig. 6, 7, 8, 9 and 10, vector diagrams of the tilts for each year are shown together with those for the violent explosions, in which the directions of the vector coincide with those for the depression of the ground.

The vector diagram for 1934, gives the annual variation in the tilts during the calm stage of the volcano, in which the locus of the tilts is almost an ellipse. On the other hand, the vector diagrams at the Nakanosawa station for 1935, 1936, and 1937, show also an approximate ellipse, of which the longer radius points NW. Although these vector diagrams of tilts include the annual variation, etc., their principal parts are the tilts due to volcanic causes. It may be pointed out that the

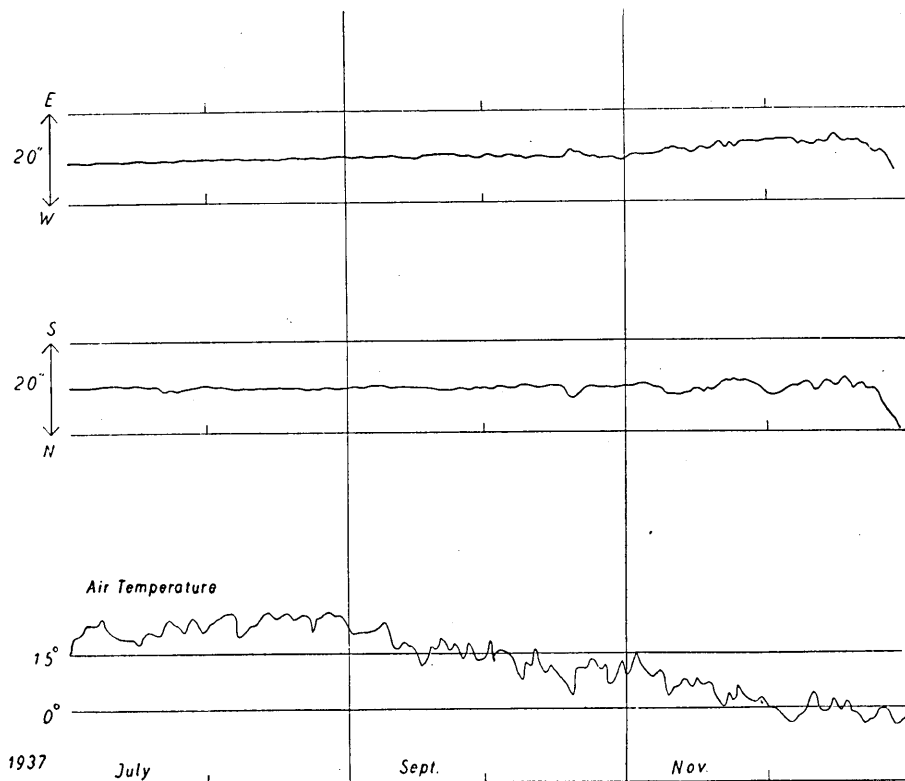


Fig. 4b. Tilting of the ground observed at the Nakanosawa Station, 1937.
(Active stage of the volcano.)

shapes of these vectors of the annual variation in the calm stage and the remarkable tilts of volcanic origin resemble each other, from which it may be suspected that the two kinds of tilt are affected, primarily, by some force having the property of moving in certain restricted directions more readily than in others. Recently, A. E. Jones⁴⁾ reported that the results of tilt-observations and topographical surveys made near the crater

4) A. E. JONES, *Bull. Seis. Soc. Amer.*, 27 (1937), 113.

of Volcano Kilauea, are satisfactorily explained by assuming the formation of blocks.

As already mentioned, if we pay attention only to the large changes in the inclinations in the vector diagrams, ignoring the small fluctuations

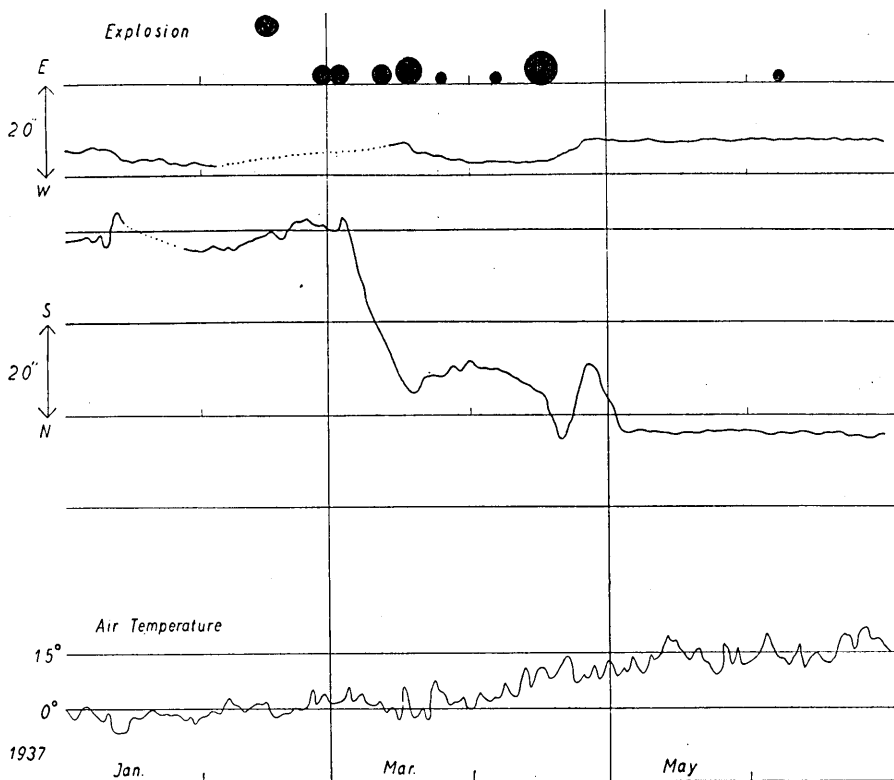


Fig. 5a. Tilting of the ground observed at the Oni-osi-dasi Station, 1937.
(Active stage of the volcano.)

in tilts, the annual change and the tilts of volcanic origin are represented by an ellipse, of which the length of the longer radius is nearly twice that of the shorter. Moreover, the longer radii of these ellipses point in a direction almost N 30° W.

	Longer diameter	Shorter diameter	Direction of the longer radius
1934	11".5	5".7	31°
1935	32".0	14".0	27°
1936	25".5	13".0	31°
1937	46".0	22".0	37°

4. Secular Variations in Tilt.

In addition to changes in inclination due to the various origins above mentioned, there is the secular variation, as shown in Fig. 11. The secular variation as observed at the Nakanosawa station for the past four years were

1934	8".7 N	1".5 E
1935	5".3 N	2".3 E
1936	7".2 N	7".2 E
1937	3".5 N	4".1 W
Total	24".7 N	6".9 E

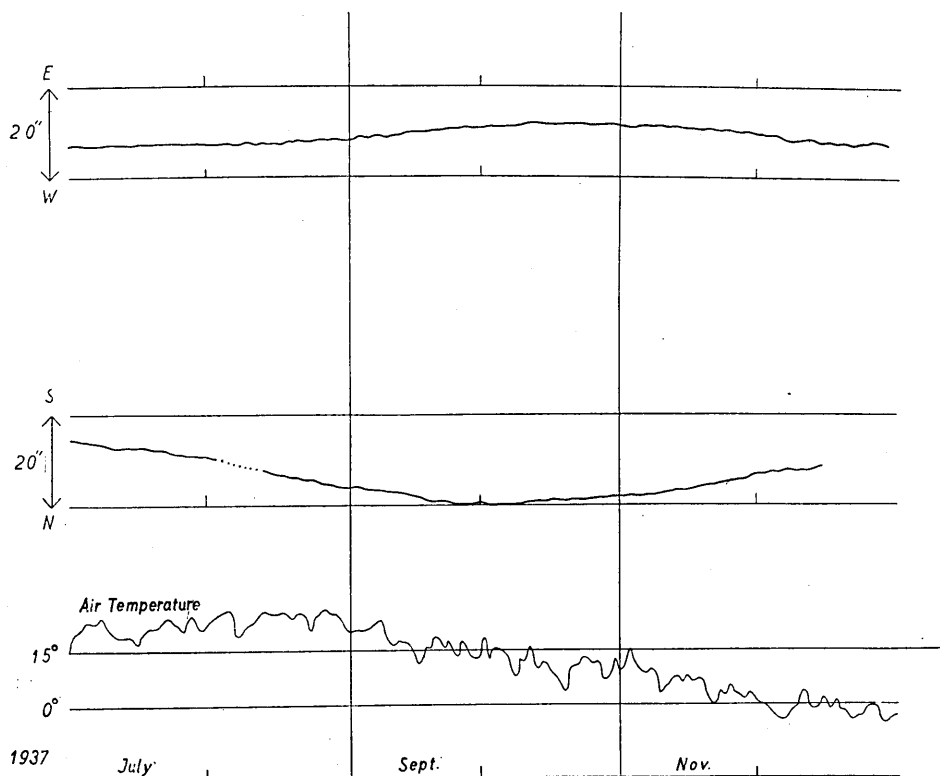


Fig. 5b. Tilting of the ground observed at the Oni-osi-dasi Station, in 1937.
(Active stage of the volcano.)

These secular variation have been continuing to incline to the north with a mean annual rate of about 6 seconds and to the east with a rate of about 1.5 seconds, although these annual rates are small compared with the accumulations of tilts during the active stages.

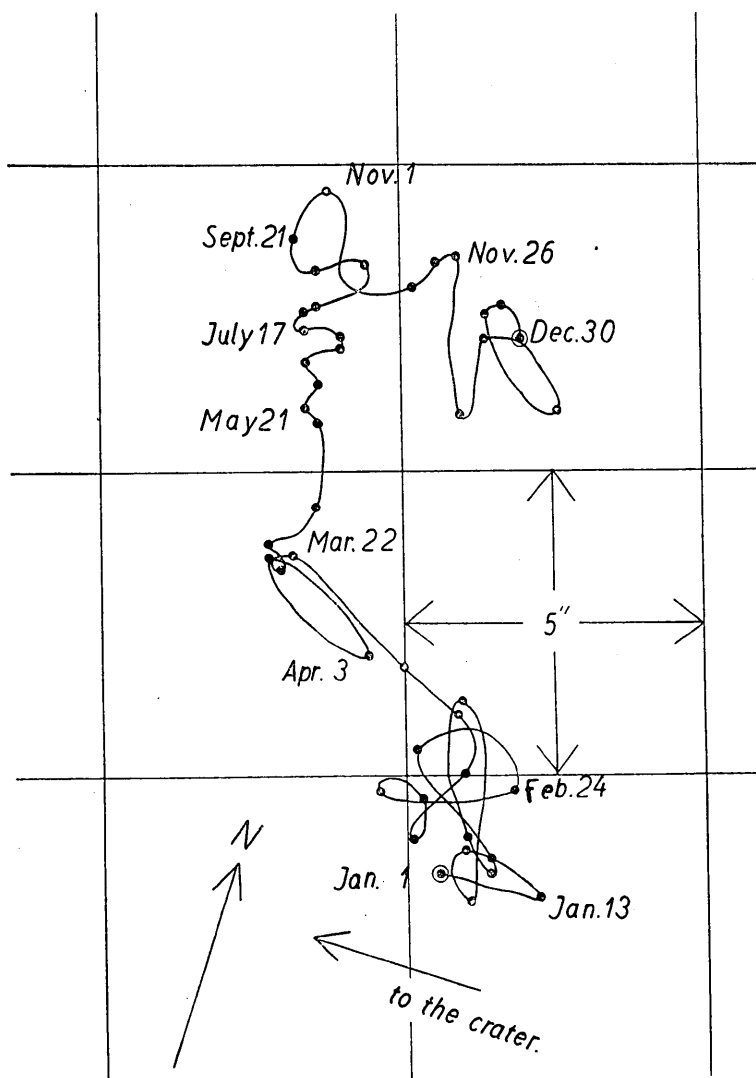


Fig. 6. Vector Diagram of Tilt during 1931. (at Nakanosawa.)
(The direction of vector is the one of depression of the ground.)

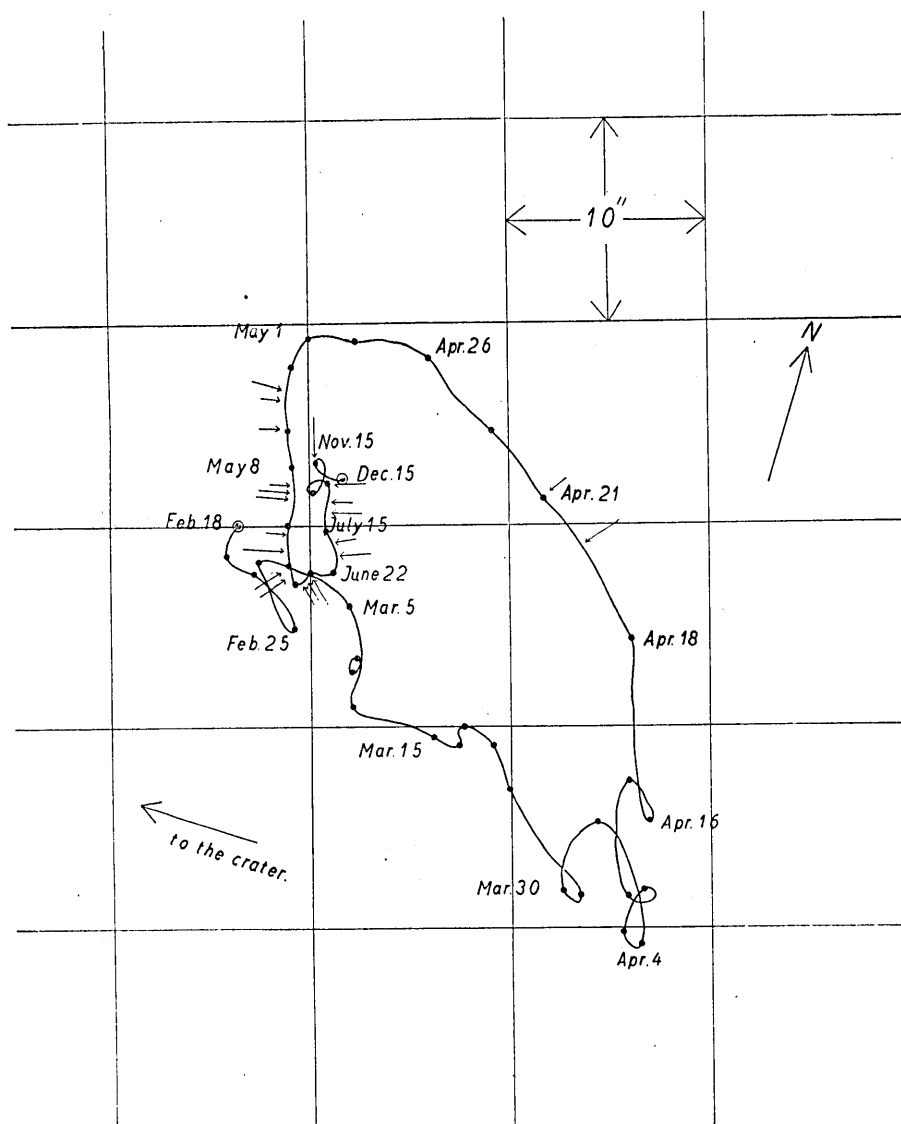


Fig. 7. Vector diagram during 1935. (at Nakanosawa.)

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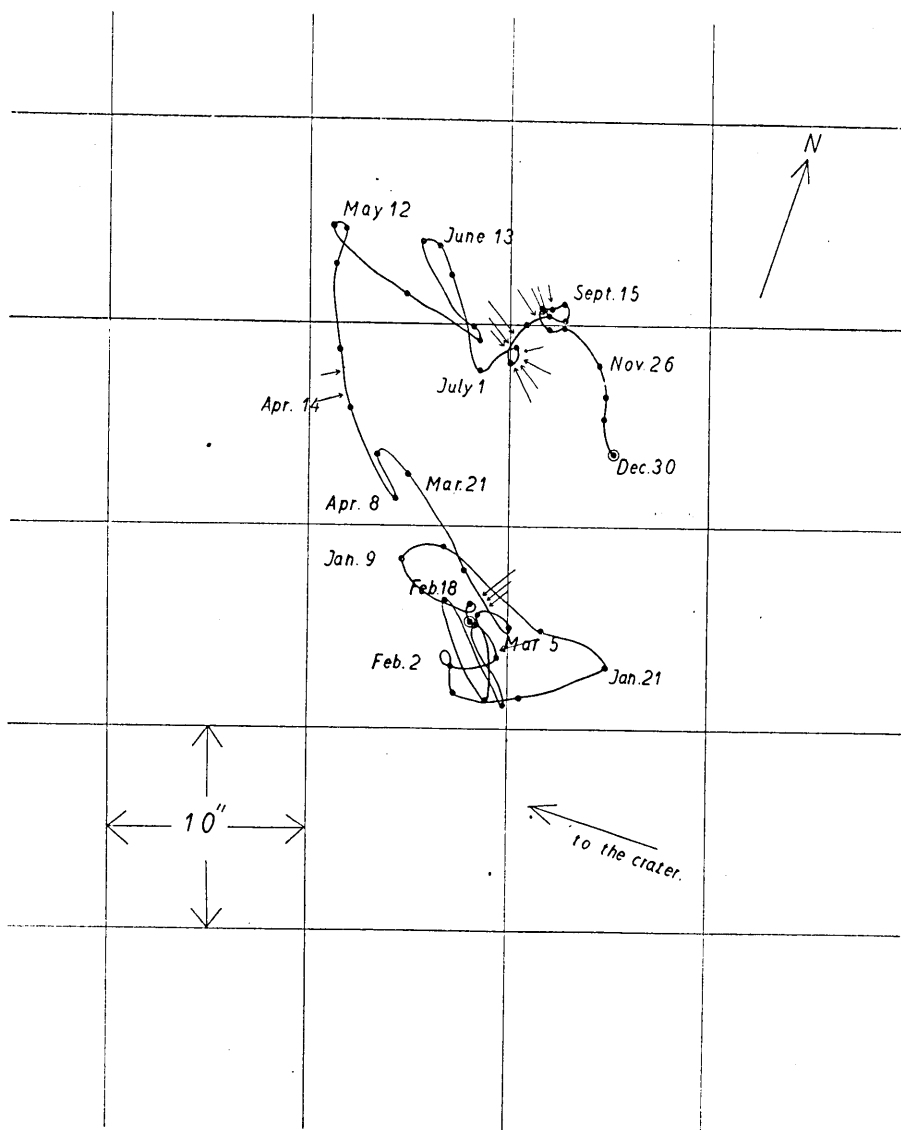


Fig. 8. Vector diagram during 1936. (at Nakanosawa.)

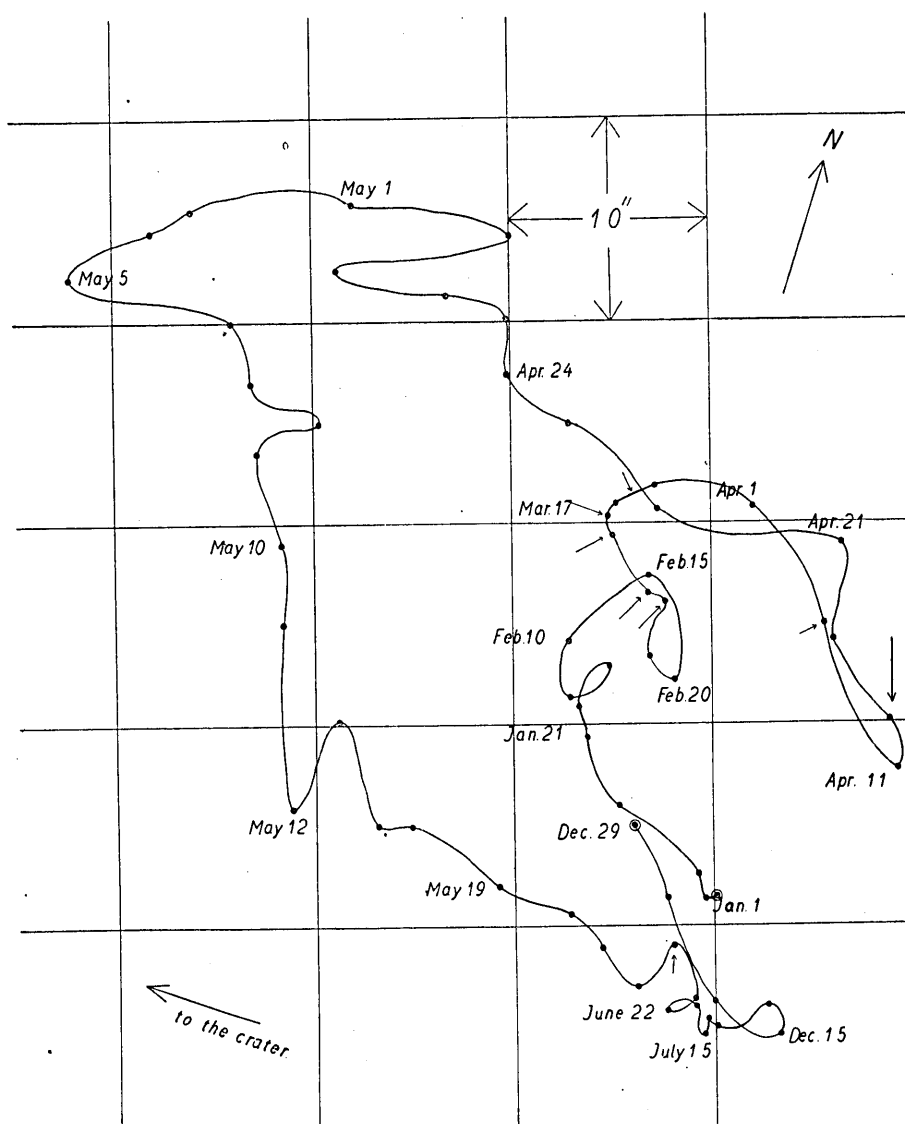


Fig. 9. Vector diagram during 1937. (at Nakanosawa.)

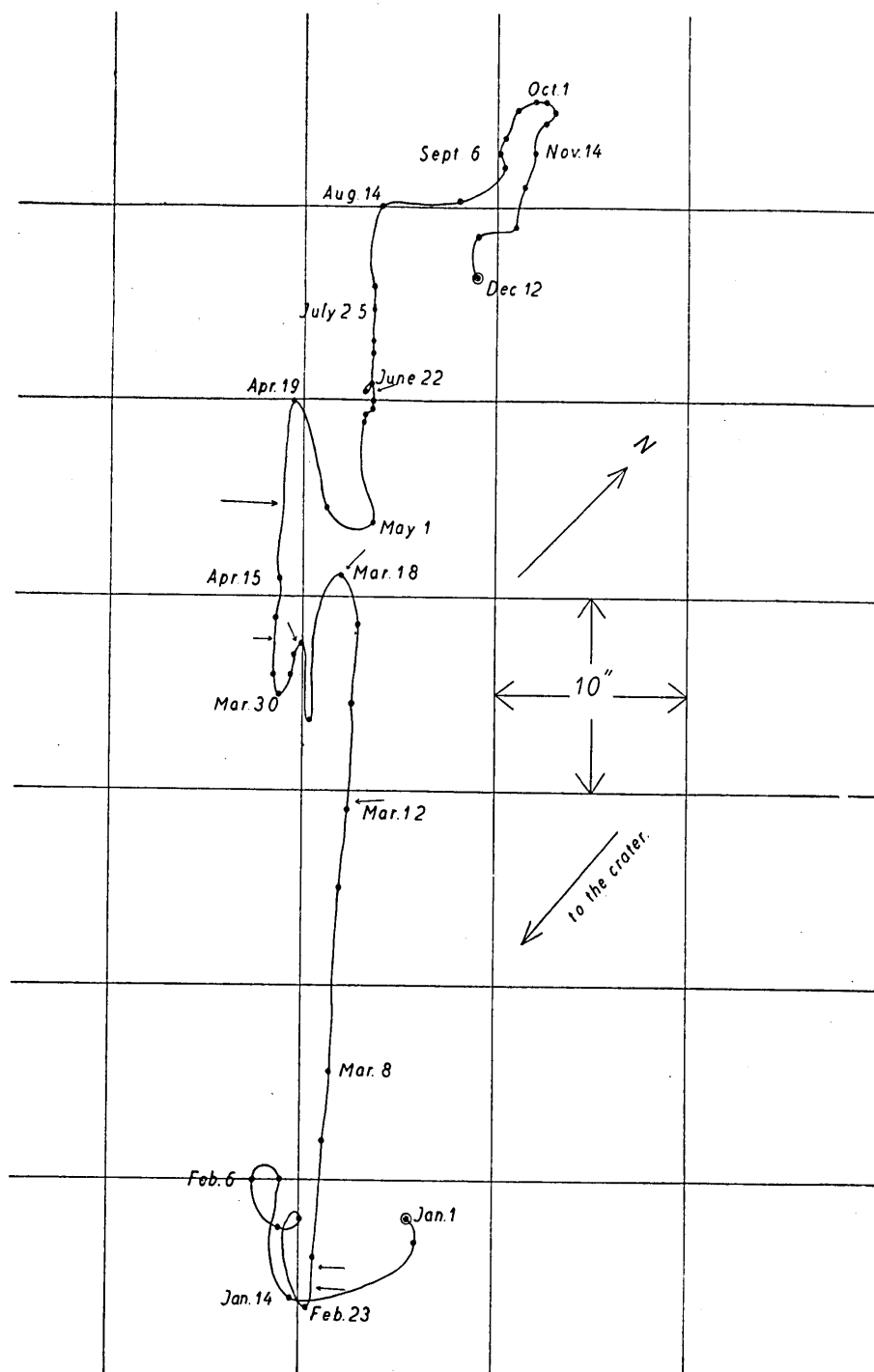


Fig. 10. Vector diagram during 1937. (at Oni-Osi-Dasi.)

On the other hand, T. Hagiwara⁵⁾ concludes from observations of tilts on the earth's surface and in a cave about 20 m under the surface, at Mt. Tukuba, that the secular variation is affected so much by the local structure of the ground as to have no particular geophysical meaning, in view of which we shall refrain from discussing these secular changes observed at Asama, but merely remark that the fact that these secular changes continued in the same direction and the almost same rate during 1934 and 1937 is worth noting.

It was in the summer of 1935 that the precise levelling of Asama, the lines of levels running through its southern foot, the eastern and southwestern slopes, and the central cone, were executed for the first time. At the same time, the writer⁶⁾ made observations of the zenith distance between the bench mark in the grounds of our observatory and the one imbedded in the central cone, the object being to ascertain the relative height changes in the two positions. From these observations, it was made clear that the angle of elevation between the two bench marks diminished $23''.4 \pm 3''.5$ during the interval between October, 1934, and April 26, 1935. These values however do not agree with the results of tilt-observations made during the same interval. This negative result suggests that the central cone may deform independently of the movements of the block, on which the bench mark at our observatory and the Nakanosawa station are situated. On the other hand, according to the geological survey of Asama by H. Tsuya,⁷⁾ the lava flow on which the clinographs are set, does not extend to the central cone, which geological fact supports the view that the deformations of the ground in the two

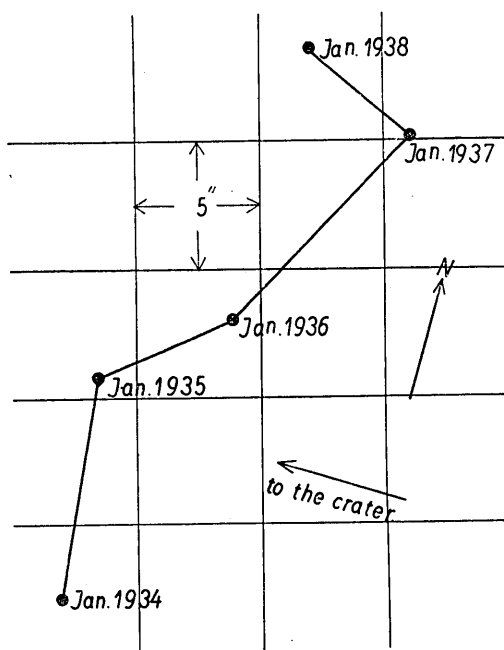
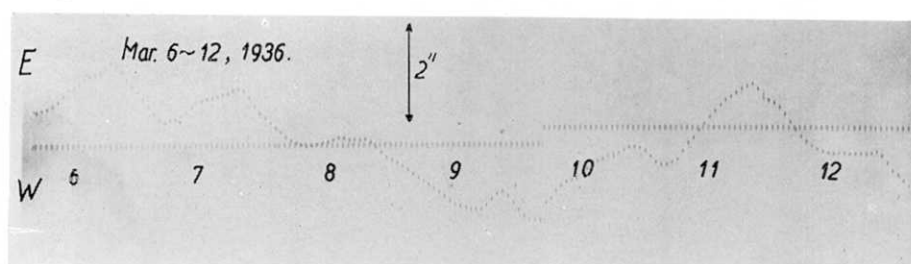
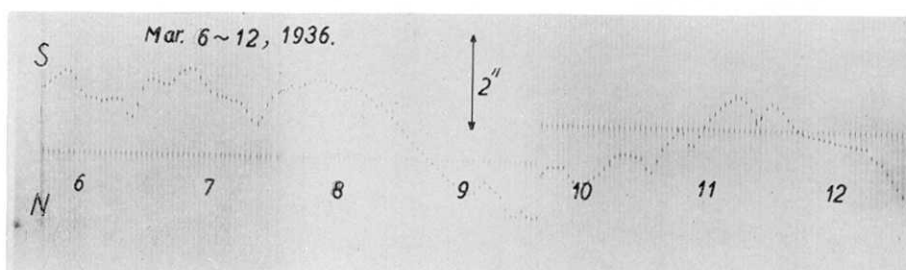


Fig. 11. Secular variation of tilt during 1934 and 1937. (at Nakanosawa.)

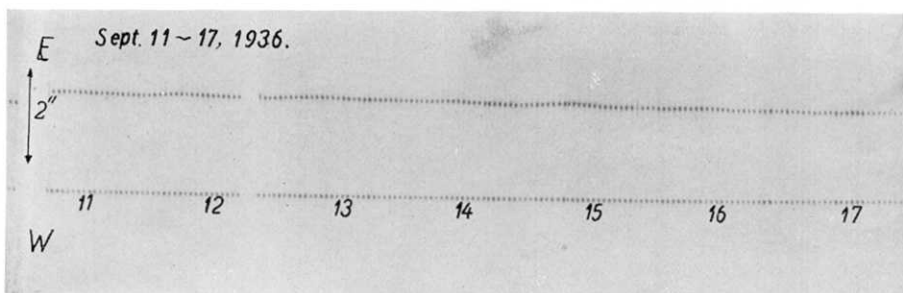
- 5) T. HAGIWARA, *Bull. Earthq. Res. Inst.*, **16** (1938), .
- 6) T. MINAKAMI, *Bull. Earthq. Res. Inst.*, **14** (1936), 222.
- 7) H. TSUYA, *Bull. Earthq. Res. Inst.*, **11** (1933), 575.



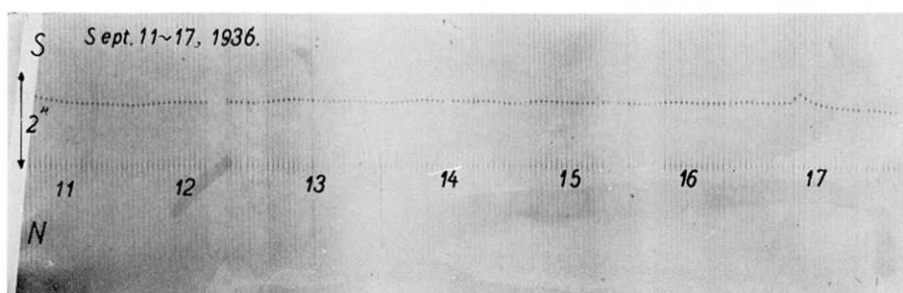
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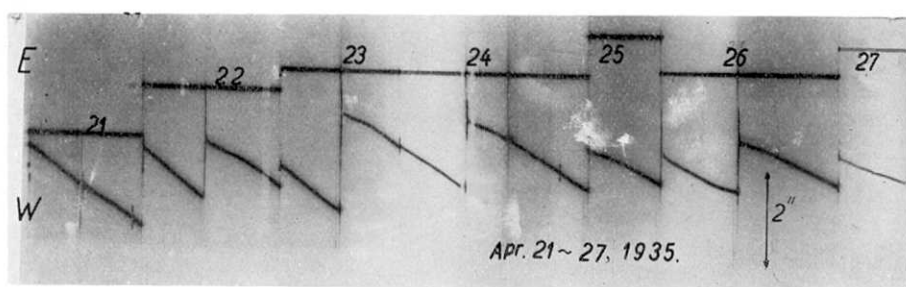


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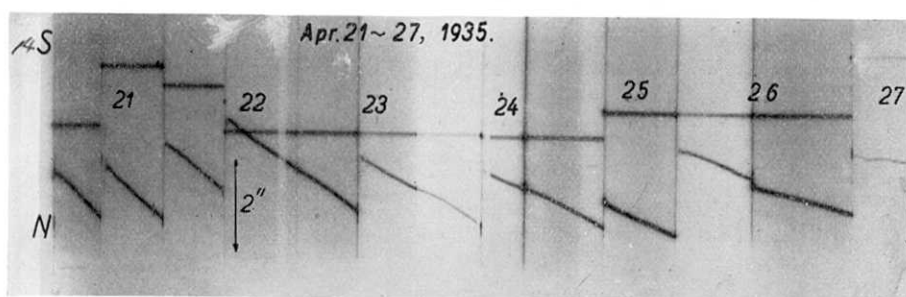


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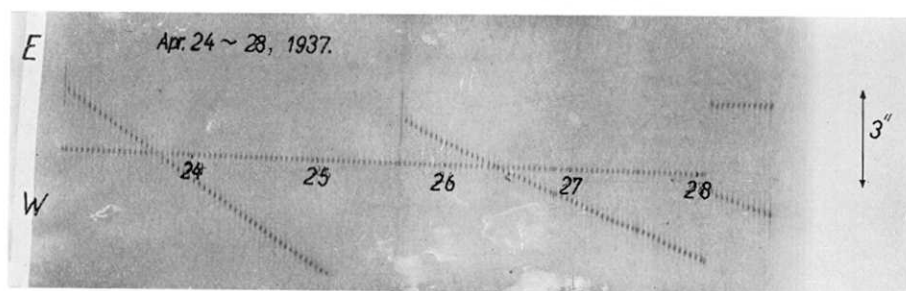
Fig. 12, 13, 14, 15. Records of Clinographs at the Nakanosawa Station.



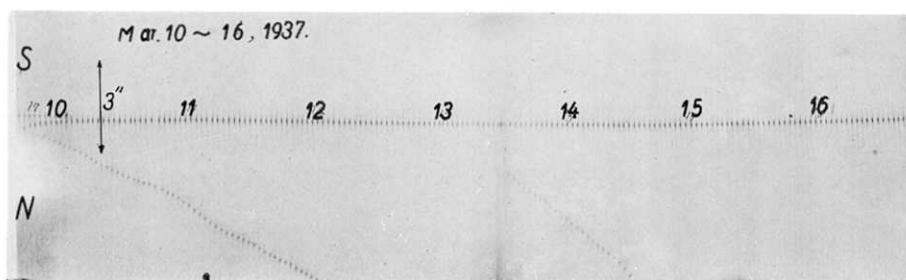
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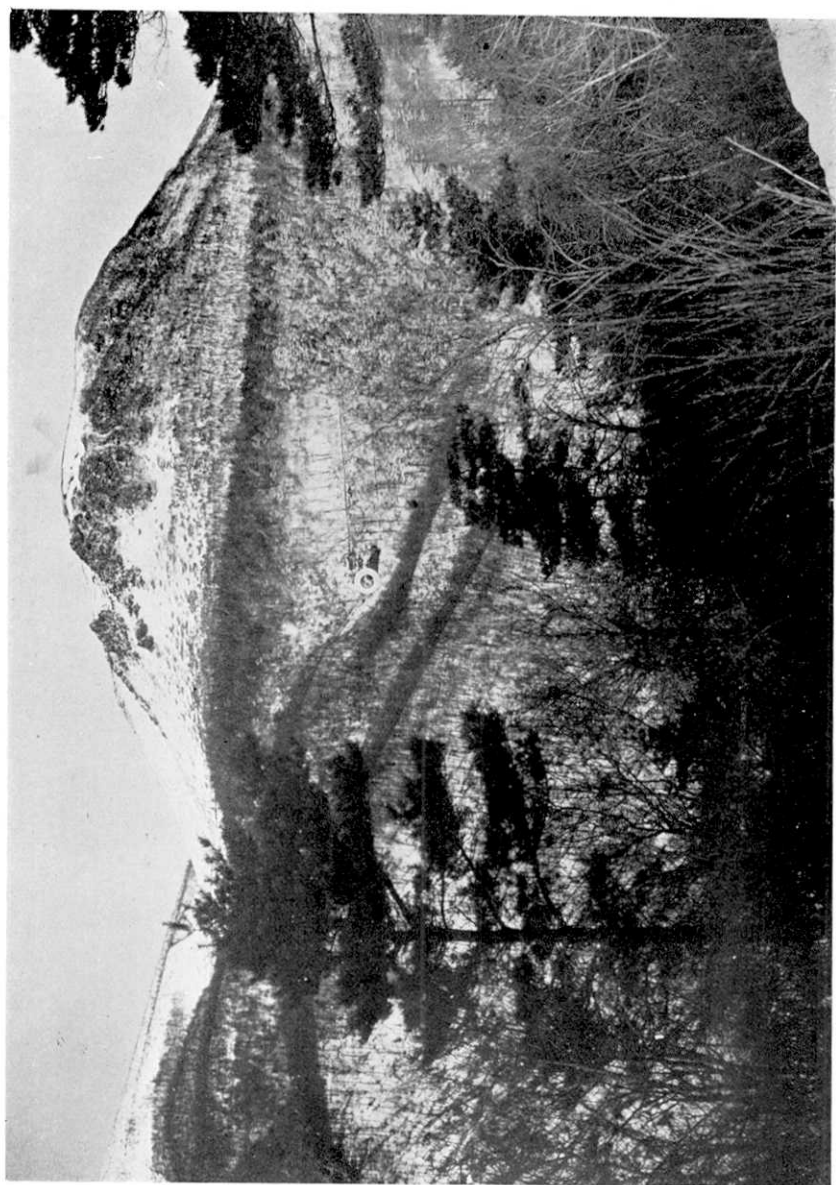


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(19)

Fig. 16, 17, 18. Records of Clinographs at the Nakanosawa Station.
Fig. 19. Records of Clinographs at the Oni-osi-dasi Station.



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Fig. 20. The Nakanosawa Station and Parasitic Volcano Ko-Aioma, (4 km east from the Crater.) O clinographs setting.



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Fig. 21. The Oni-osi-dasi Station and the Lava Flow of the Tenmei era (4 km north from the Crater.) ○ clinographs setting.

positions of the volcano just mentioned are independent of each other.

5. Conclusion.

The results of tilt-observations made during the period from 1934 to 1937, that is, during the active and inactive stages of Volcano Asama are reported in this paper. The marked changes in the inclination of the ground during the active stage of the volcano clearly differ from the seasonal and other variations that occur during the calm stages. Tilting on a large scale began about two months preceding the explosive activity which began on April 20, 1935, suggesting the possibility of forecasting coming activities.

In conclusion, the writer wishes to express his cordial thanks to Professor M. Ishimoto for his encouragement in the course of this study. He also acknowledges his great indebtedness to the Foundation for the Promotion of Scientific and Industrial Research of Japan, with whose grant this study was made possible.

30. 浅間火山の活動と地表傾斜變化

地震研究所 水上 武

昭和9年1月より昭和12年12月に至る4ヶ年の浅間火山に於ける傾斜観測の結果を綜合して報告せるものである。

昭和9年の火山の平穩期と10, 11, 12年に亘る活動期との傾斜變化を比較し、著しい相異の存在する事を示し、特に昭和10年2月より4月に亘つて現はれた傾斜及び昭和12年3月から5月に現はれたものは夫々30"及び40"に達し、何れも火山活動に關係して現はれた山體の傾斜變化である。此等の異常傾斜は北西方向が沈降し、略橢圓を畫いて再び元の位置に復する方向に起つてゐるが、その傾斜運動の形狀は平穩期に於ける年變化のそれと甚だ類似して居る。

又鬼押出に於ける昭和12年2月より5月に亘る傾斜變化は約60"に達して居る。この傾斜と中の澤に於ける観測を比較するに、量に於いてのみならず、その方向が必ずしも一致して居ないが、出現の時期は略一致して居る。

一方、昭和9年7月より10月に亘る三角術的水準測量と昭和10年5月に於けるものと比較から得た相對的水準變化と傾斜観測結果とは一致して居ない。是等の事實からも傾斜變化及び地形變動を獨立に行ひ得る幾つかの小地塊より火山が構成されて居る事を示すものと考へられる。

永年變化は過去4ケ年間年平均約6"の割で北西へ向ふ傾斜を示して居る。この變化は火山活動に際して現れた異常傾斜に比して小さいものであり、且萩原理學士が指摘せる如き局部的のものを含むと考へられる。然し是等の永年變化がどの程度の地域が共通の傾斜を示して居るかは、精密水準測量の再測により明かなる可能性がある。

最後に、淺間火山に於ける傾斜變化の研究は、日本學術振興會の補助に資ふ所多く、こゝに厚く感謝の意を表す。又冬期間の困難な觀測を繼續するに當り助力された、内堀、河合、及び内嶋の三氏に感謝の意を表し度い。
