An Investigation of the Earth-current on the Volcano Aso

Part IV. On the so-called Residuals in the Daily Variation of the Vertical Earth-current at Aso, and the Details of the Observation Arrangements

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Abstract

In the preceding paper, it has been pointed out that the daily variation of the vertical component of the potential gradient of the earth current observed by a dry-well method, contained a remarkable amount of residuals independent of the daily variation of its horizontal components. The present paper deals with the comparison of these residuals with the daily variation of the vertical earth-current observed by a valley-wall method. In addition to the above, the writer will describe the details of the obervation apparatus.

I. Introductory

In the preceding paper, it has been clearly shown that the daily variation of the vertical component of the earth-current observed by an ordinary drywell method in the ground of the Volcanic Laboratory of Aso contained socalled residuals of considerable magnitude independent of the daily variation of its horizontal components.

The possible role of the influence of the variation of the earth-surface temperature as one of the causes of such residuals has also been discussed, and the effect of the atmospheric pressure on it is also pointed out.

The dry-well at the laboratory mentioned in the preceding paper had a depth of 20 meters and a diameter of 2 meters, and two electrodes had been buried 2 meters deep : one at its bottom and the other near the earth surface. Unfortunately, the results obtained with such an arrangement must have been influenced by the difference in temperture between the two electrodes themselves. Again the influence of the local earth-current needed to be taken into account. The writer therefore made further observations by alternative methods. The valley formed by a group of the crater of Mt. Nakadaké and the Totinoki Valley offered a very suitable place for the purpose. Arrangements were made at these places to take the records of the vertical earth-current. The comparison of these records with those obtained at the dry-well of the Laboratory revealed very interesting facts which will be presented here.

II. Arrangement at the Crater of Mt. Nakadaké

The deep volcanic canal of Mt. Nakadaké of Aso measures about 1000 meters by 350 meters, with its longitudinal axis north and south. The 1st. 2nd, 3rd, 4th and 5th craters numbered from north to south lie in a row at its bottom. The whole neighbouring region is sandy land, barren because of the volcanic activity. The western side of the inner wall of the first crater forms a precipice about 70 meters in height. On this precipice, two places were selected 50 meters apart in vertical distance, and an electrode was settled in the earth 2 meters or more deep at each place. From each electrode an aerial cable was led to the inner room of a cave-type observatory of concrete str-

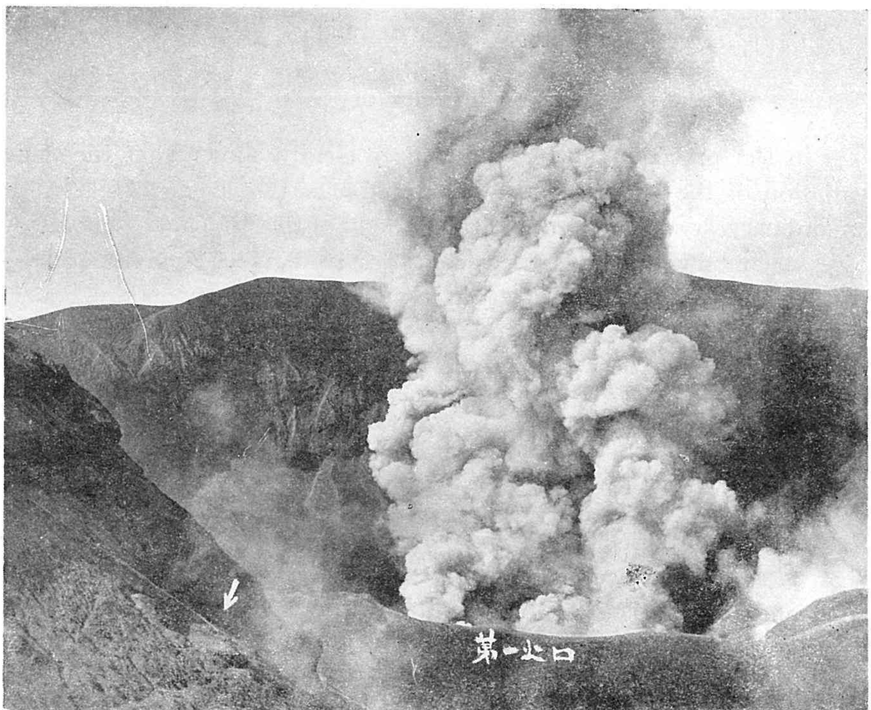


Fig. 1. The 1st-Crater of Aso and the Cave-type observation room (Photo on Sept 5 th, 1939)

ucture lying half-way up the crater wall (Fig. 1). This observatory measures 2 meters by 6 meters in dimension and consists of two rooms. The inner dark room above mentioned was equipped with the requisite recording apparatus. The front room served for preparatory work and also for refuge in time of eruption. Fortunately the hummidity in the inner room was so low that there was no anxiety about electric leakage from any part of the apparatus. But unexpected high temperatures, 62°–63°C., during the observation periods and the invasion of volcanic smoke necessitated some special precautions.

(1) To get rid of the troubles caused by the volcanic smoke that might creep in through the doorway, the following precautions were taken.

a. An all-sealed type galvanometer has been newly designed.
   Critical resistances.........1740 Ohms
   Sensibility ....1.8×10^{-6} volts
   Period ....5.5 sec.

b. Also an all-sealed type resistance box made of hard porcelain was used with every metallic part of its terminals sealed in.

c. Every piece of apparatus including the galvanometer, the resistance coil and a watch was concealed in a double wooden box and all the crevices packed with water-proof material.

(2) The wall of the inner dark room was painted elaborately with waterproof cement to prevent moisture and gases from leaking in.

(3) Room temperature was considerably higher than expected before the construction of the room, but financial conditions prevented its reconstruction. The main troubles caused by high temperatures were occasional damage to lamp sockets or of leads, but these were later obviated. In winter, though the outdoor temperature sometimes measured as low as −23°C. at the brink of the crater, the high temperature in the observatory made the work there rather comfortable.

(4) Concerning the potentiometer, except the care about the contact with leads, there was no trouble.

(5) The record of the earth temperature at a depth of 2 meters has been taken with a distant thermograph. It was found to be entirely constant throughout the observation periods. Now the temperature at a depth of 20 centimeters is on record on the advice of Prof. T. Nomitsu.

(6) In this cave observatory, there has been no fear of danger from the volcanic ejecta, and only once, was there so severe an eruption of dense volcanic smoke mingled with yona that breathing was difficult and the observation work became hard to continue.

(7) The most frequent trouble with the observation arrangements was concerned with the cables between the electrodes. At first an underground type was adopted, but was found to be damaged by every landslip caused by heavy rain fall, frost throw or snow throw. To avoid the difficulties of finding the damaged place and repairing it, it was afterwards changed to an aerial type. This cable was also cut several times by suicides as the precipice has been a favorite place for the purpose. It was all painted with pitch and kept in a bamboo tube to protect it from the volcanic gas and mechanical injuries.

In short, the main accidents in the measurement at the active crater were (a) those due to the volcanic bombs and gasses at the time of eruption and (b) those due to the severe cold in winter. The high temperature in the observatory was rather an advantage in winter. Happier still was freedom from worry about leakage that is commonly associated with electric current of low intensity.

III. Arrangement at the Totinoki Valley.

The water gathering from the area of the Valley of Nangô, the southern half of the old atrio of Aso, forms a baranco, the River Sirakawa. Immediately on leaving a water-fall, the Ayugaeri-no-taki, it passes through a deep gorge produced by erosion, called the Valley of Totinoki-Tosita. This valley extends 10 kilometers till the river joins the River Kurokawa which comes from the northern half of the atrio. The floor mersures some 150 meters in width. The right side (the eastern side) is surrounded by a perpendicular wall some 100 meters in height and the left side (the western side) by a screen of the somma some 900 meters above the sea-level). The whole valley is densely covered with old trees and bushes, said to be the only primeval forest on Aso. Under these conditions, the sun rises late in the morning and sets early and the earth-surface temperature fluctuates only narrowly. In the perpendicular wall which stands on the erstern side of the valley, two electrodes have been buried 2 meters deep each and 50 meters apart in vertical distance. The cable from them is led to an observatory of concrete construction half-way underground at Totinoki Onsen, where the records of the variation of the vertical earth-current have been taken automatically.

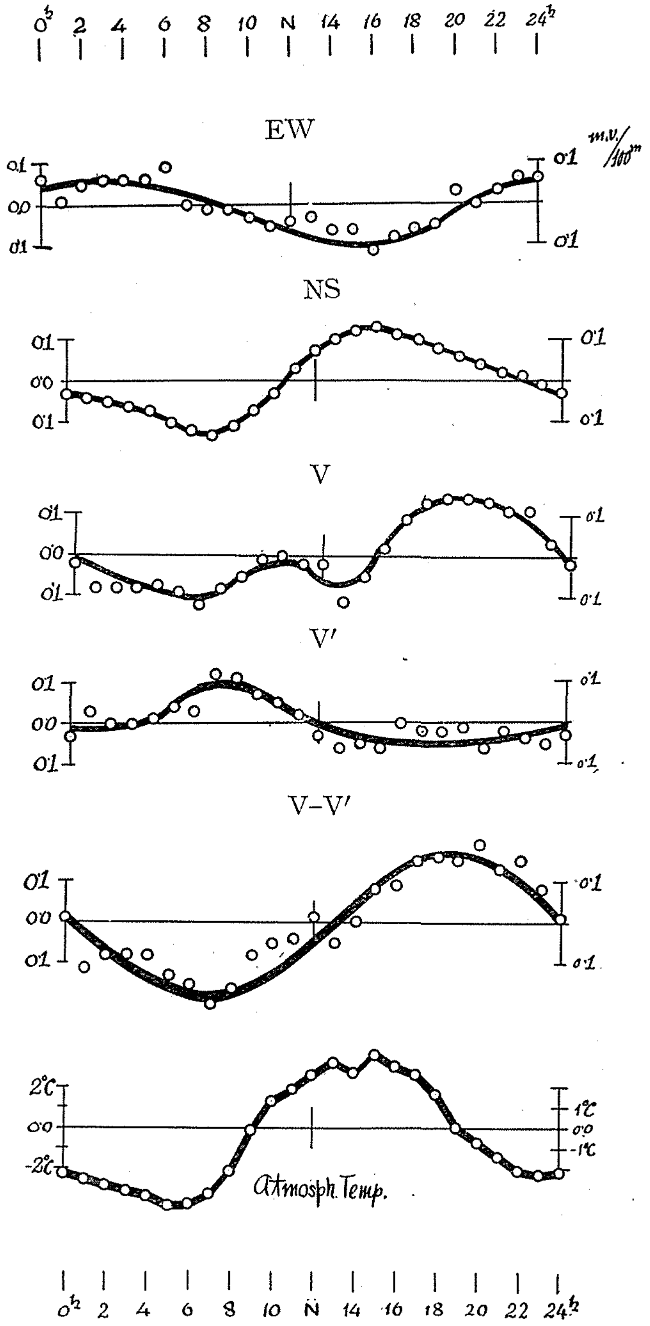
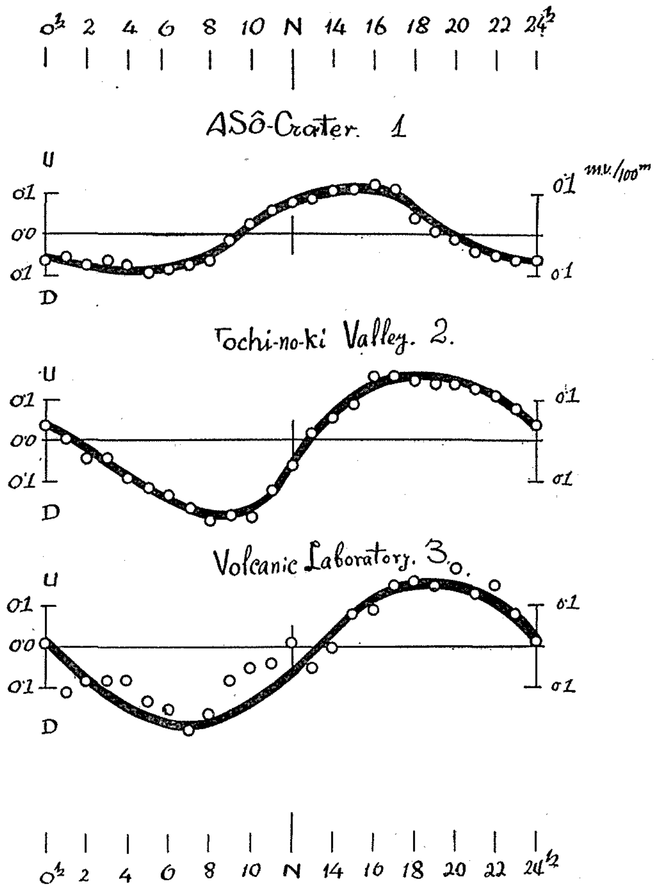


Fig. 2. Daily Variation of the Earthcurrent in the yard of the Laboratory.

IV. Arrangement in the Grounds of the Laboratory.

The Volcanic Laboratory of Aso is located on a hill situated west of Mt. Ebosi, and its main ferro-concrete structure 40 meters square stands on the summit, All the hill is covered with low grasses and consists of deep layer of loam without pebbles. Its altitude is 567,7 meters above the sea level. Three dry wells were dug in the yard. Each well was equipped with two electrodes: one 2 meters below its bottom and the other 2 meters below the earth surface and also 2 meters in from its wall. The cable from each of the electrodes was led to an observatory near by. What concerns to the present paper is the record obtained from one of these wells, which is named V_3.

Fig. 3.



V. Results.

(1) The daily variation of the vertical earth-current at the crater-wall of Aso. The resistance between the upper and lower electrodes meaured 250 ohms at the end of July 1939. A resistance was inserted between them and from the resultant series resistances of 70,000 ohms, 160 ohms have been taken for the purpose of recording. The mean daily variation of the vertical earth-current during 14 days in August 1939, is shown in Fig. 3 (1).

(2) The daily variation of the vertical earth-current at the Totinoki Valley.

The risistance between the electrodes measured 300 ohms. From 30,000 ohms of series resistance, 100 ohms have been taken for measurement. The mean daily variation during 11 days covering the end of August and the beginning of September is shown in Fig, 3 (2).

(3) The daily variation of the vertical component of the earth-current in the yard of the Laboratory.

The resistance between the electrodes measured 200 ohms. resistance was inserted between them and from the resultant series resistance of 9,000 ohms, 600 ohms have been taken for measurement. The mean daily variation of of the vertical and horizontal componets of the earth-current during 11 days in August 1939, is shown in Fig, 2. And the residual is shown in Fig. 3 (3). In this season, the upward change of the vertical component was accompanied by the W-S fluctuation of the horizontal component, and the downward change of the former by the E-N fluctuation of the latter. The results have been treated in the same way as is shown in the preceding paper. The residuals thus obtained are tabulated in the table.

By comparing these residuals with the results obtained at the Crater-wall and at the Totinoki Valley, Fig. 3 was obtained. Close examination of this figure reveals the following facts:

(a) There is a noticeable parallelism among the records of the three localities.

(b) The variation curve in the yard of the Laboratory coincides, though with slight irregularities at 5 and 10 o'clock, almost entirely with that of the Totinoki Valley.

(c) The variation at the crater-wall is about half of the others in magnitude.

(d) The minima (the extremes of the downward change) occur earlrest at the crater-wall, next in the yard of the Laboratory, and latest at the Totinoki Valley.

(e) The maxima (the extremes of the upward changes) occur earliest at the crater-wall, next at the Totinoki Valley, and latest in the yard of the Laboratory.

How can these facts be interpreted? The writer's view will be presented in the next section.

	$Ew\frac{m.v.}{100^m}$	$NS\frac{m.v.}{100^m}$	EW+NS	V	$\left\lvert\frac{Ew+Ns}{V}\right\rvert$	$\frac{Ew+Ns}{1,1}\equiv V'$	V−V'	V in the Crater	V in the Totinoki-Valley	Atmospherci Temperaturo
0h	0.06	−0.03	−0.03	−0.02	1.5	−0.03	0.01	−0.06	0.04	−2.2
1h	0.01	−0.04	0.03	−0.08	0.4	0.03	−0.11	−0.05	0.01	−2.5
2h	0.05	−0.05	0.0	−0.08	0	0.0	−0.08	−0.07	−0.04	−2.8
3h	0.06	−0.06	0.0	−0.08	0	0.0	−0.08	−0.06	−0.04	−3.1
4h	0.06	−0.07	0.01	−0.07	0.1	0.01	−0.08	−0.07	−0.09	−3.3
5h	0.06	−0.10	0.04	−0.09	0.4	0.04	−0.13	−0.09	−0.11	−3.8
6h	0.09	−0.12	0.03	−0.12	0.3	0.03	−0.15	−0.08	−0.13	−3.7
7h	0.0	−0.13	0.13	−0.08	1.6	0.12	−0.20	−0.07	−0.16	−3.2
8h	−0.01	−0.11	0.12	−0.05	2.4	0.11	−0.16	−0.06	−0.19	−2.1
9h	−0.01	−0.07	0.08	−0.01	8.0	0.07	−0.08	−0.01	−0.18	−0.1
10h	−0.03	−0.03	0.06	0.0	—	0.05	−0.08	0.03	−0.18	1.3
11h	−0.05	0.03	0.02	−0.02	1.0	0.02	−0.04	0.06	−0.12	1.6
12h	−0.04	0.07	−0.03	−0.02	1.5	−0.03	0.01	0.08	−0.06	2.6
13h	−0.03	0.10	−0.07	−0.11	0.6	−0.06	−0.05	0.09	0.02	3.2
14h	−0.06	0.12	−0.06	−0.05	1.2	−0.05	0.0	0.11	0.06	2.7
15h	−0.06	0.13	−0.07	0.02	3.5	−0.06	0.08	0.11	0.09	3.6
16h	−0.11	0.11	0.0	0.09	0	0.0	0.09	0.12	0.16	3.0
17h	−0.08	0.10	−0.02	0.13	0.2	−0.02	0.15	0.11	0.16	2.6
18h	−0.06	0.08	−0.02	0.14	0.1	−0.02	0.16	0.04	0.15	1.7
19h	−0.05	0.06	−0.01	0.14	0.1	−0.01	0.15	0.01	0.14	0.0
20h	0.03	0.04	−0.07	0.13	0.5	−0.06	0.19	−0.01	0.14	−0.7
21h	0.0	0.02	−0.02	0.11	0.2	−0.02	0.13	−0.04	0.13	−1.4
22h	0.03	0.01	−0.04	0.11	0.4	−0.04	0.15	−0.05	0.11	−2.1
23h	0.06	−0.01	−0.05	0.03	1.7	−0.05	0.08	−0.06	0.08	−2.3
24h	0.06	−0.03	−0.03	−0.02	1.5	−0.03	0.01	−0.06	0.04	−2.2
	Mean of 11 days in Aug. 1939				Mean 1.1			Mean of 14 days in Aug. 1939	Mean of 11 days in Aug.-Sept.	Mean 23.°5C Mean of 11 days in Aug.-Sept.

VI. Discussion

As has been stated, the residuals obtained from the daily variation of the vertical component of the earth-current observed by the dry-well method in the yard of the Laboratory resemble closely the daily variation of the vertical earth-current obtained by the valley-wall method at the Totinoki Valley. What may be the meaning of such resemblance?

The writer's view runs thus: The apparent variation of the vertical earthcurrent observed at any locality is composed of the inherent variation proper to or characteristic of that locality at the time of observation and the secondary variations conditioned by the variations of its horizontal components or by any other factor correlated with it. Such secondary variation may be called for the present. an accessory variation. The same reasoning may apply to the daily variation. In the case of the dry-well method, the apparent daily variation should be to a considerable degree a subject of this accessory variation since the dry-well method is itself subject to criticism as has been noted in the introduction of this paper. The so-called residuals obtained with consideration for the daily variation of its horizontal components may be recoguised as manifesting mainly the inherent variation. On the other hand, in the valley method, with the greater distance between two electrodes, the influence of the accessory variation must be smaller. Therefore, in this case the daily variation of the vertical earth-current may be assumed to have been governed mainly by its inherent variation. This is why the residuals obtained by the first method coincide with the daily variation itself observed by the second method. The writer is sorry to have on arrangement at present at Totinoki Valley to ascertain the magnitude of the accessory daily variation, to correct the daily variation of the vertical earth-current and thus to measure the real inherent daily variation of the earth-current at that locality. But the following facts may complement the deficiency to some extent:

(1) As is shown in Fig. 4, the record of the variation of the vertical component in the Totinoki Valley shows also the irregularities at 5 and 10 o'clock corresponding to those in the residuals of the daily variation in the dry-well method.

(2) If we compare the record of the daily variation of the verti-

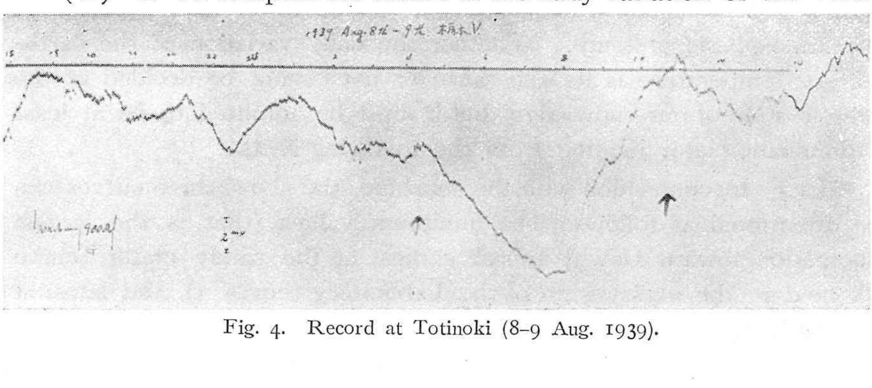
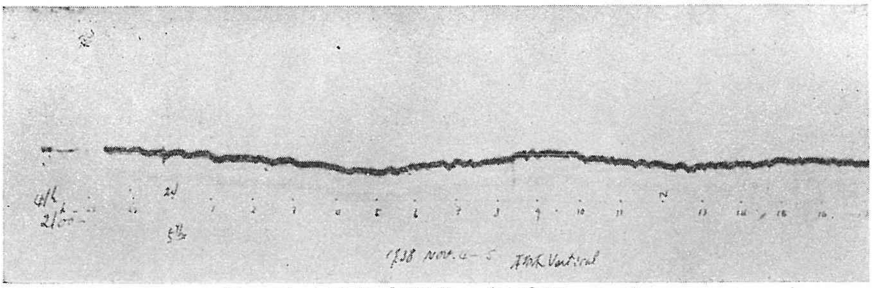


Fig. 4. Record at Totinoki (8–9 Aug. 1939).

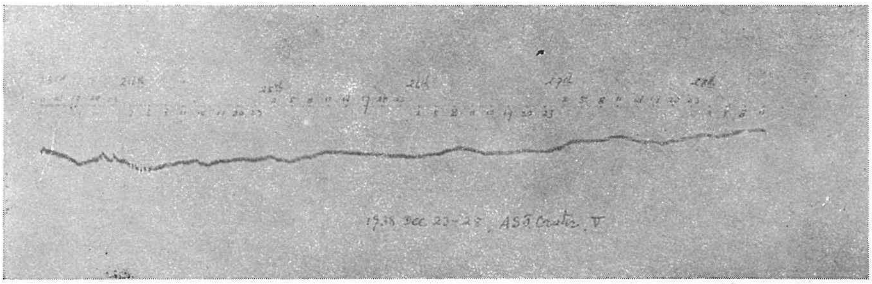
cal component at the Totinoki Valley taken in November 1938. Fig. 5, with the accessory variation in the yard of the Laboratory, V', Fig. 2, they coincide very closely.

(3) Similarly, the record at the crater taken in December 1938, Fig. 5, also resembles the latter (V'). Fig. 6 represents a record of the valley-method.

Fig. 5.



Record at Totinoki-Valley. (1938 Nov. 4–5).



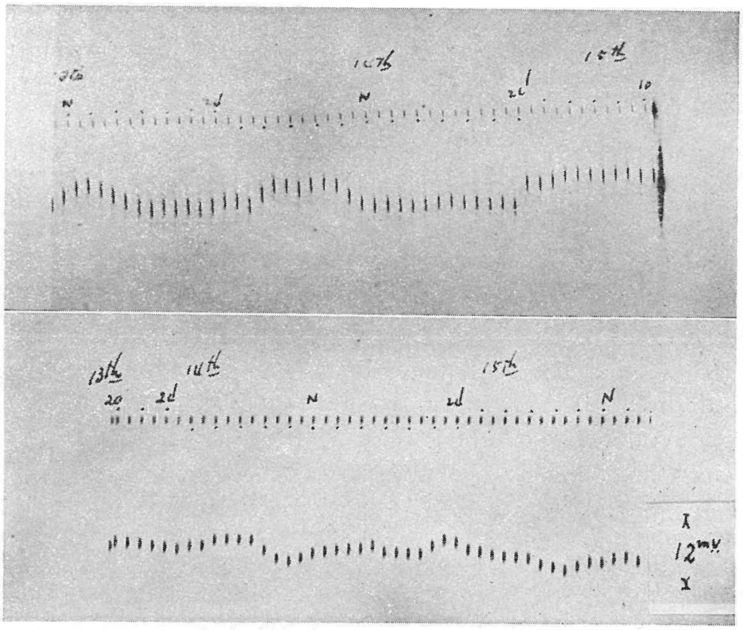
Record at the Crater. (1938 Dec. 23–28).

Then comes the question what is the cause or causes of the inherent or characteristic daily variation of the vertical component. The writer has discussed in the previous paper, the possible role of the daily variation of the earth-surface temperature as at least one of its causes and has made a suggestion of the effect of the variation of the atmospheric pressure. Whether the daily variation of the earth-surface temperature is its sole cause or not cannot be decided at the present state of our knowledge, but it must be admitted to be at least a dominant factor judging from the following facts:

(1) In connection with the sunshine, the above three curves can be interpreted as follows: The minimum values (that is the largest fluctuation toward Down) appear earliest at the sandy crater (curve 1), next in the grassy yard of the Laboratory (curve 3), and latest at the Totinoki Valley with its dense plantation (curve 2).

(2) The maximum values (that is the largest fluctuation toward Up) appear in the order of Curve 1, Curve 2, and Curve 3. As previously stated, the west side of the Totinoki Valley is bounded by a somma wall measuring 900 meters above the sea level and there the sun sets earlier than at the yard of the Laboratory.

Fig. 6.



Totinoki-Valley (1939 Sept 13-15).
Crater (1939 Sept 13-15).
Records of the Valley method

(3) The yard of the Laboratory and the Totinoki Valley are situated on the so-called primary lava plateau formed by Mt. Ebosi-daké and the homogeneous loamy land at these places belongs to the most ancient in the atrio of Aso. But the crater is very porous ashy land newly formed. Accordingly there is very distinct difference between them in the moisture content and we may expect to find considerable difference in the amplitude between daily variations of the earth-current at these localities.

(4) The amplitude of the daily variation is not unreasonably large, judging from the results reported in the previous paper.

From these points of view, it seems to be permissible to assert that the characteristic daily variation of the vertical component of the earth-current is caused by the daily variation of the earth-surface temperature and other factors connected with it. The result reported by Walker on the variation of the earth-current between the foot and the summit of a mountain can be regarded as the characteristic daily variation of the vertical component, though the considerably great horizontal distance between two electrodes is a matter for criticism.

Lastly, there remains a question about the most suitable of method for observing the variation of the vertical component of the earth-current. Consideration of the following points may furnish useful ground for its decision:

(1) The Dry-well Method.

(a) Generally, it is difficult to make a deep dry-well and obtain a long distance between two electrodes. Accordingly results obtained by this method are apt to be influenced considerably by the accessory variation.

(b) The great difference between the variations in temperature of two electrodes themselves is a source of apprehension.

(c) But it has the advantage that it can be placed at any place desired.

(2) The Valley-wall Method.

It has the following characteristics.

(a) In general, as the long distance between two electrodes can be obtained whenever a suitable valley-wall is available, the influence of the accessory variation of the vertical component can be minimized. Moreover, the influence of the stray current due to the leakage from an electric track can be avoided.

(b) It is an advantage of this method that the temperature of the two electrodes can be maintained almost alike.

(c) But unfortunately, it is impossible to obtain at any desired locality a valley suitable to set up the measuring equipment.

Though each method has its merits and its weak points, the valley-wall method is desirable for the study of the characteristic variation of the vertical component whenever it is practicable. The writer adopted this method for the study of the relationship between the volcanic activity of Aso and the vertical earth-current. The study of Palmieri at Mt. Vesuvius on the variation of the earth-current can be classed as a study of the variation of the vertical earth-current by the valley-wall method though not in a strict sense.

This study has been accomplished under the continued guidance of Prof. T. Nomitu and under the financial support of the Japanese Society for the Promotion of Scientific Research. The writer wishes to take this opportunity to express his thanks.