An Investigation of the Earth-current on the Volcano Aso

Part V. Correlation of the Volcanic Activity of Mt. Aso with the Variation of the Vertical Earth-current

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Abstract

This is the summary report of a study on the variation of the vertical potential gradient of the earth-current of Aso, with special reference to its relation to the sequence of the volcanic activity. The relation revealed is interpreted with the experimentally proved fact that the positive local pressure constitutes a center of the negative electric potential. Also the problem of forecasting the volcanic activity is discussed.

I. Introductory

The occurrence of nearly constant upward earth-current in the surface layer of a slope is an established fact of early discovery. The writer made a survey on the distribution of the potential gradient of the upward earth-current at the flank of the cinder cone " Komé-tuka ", the top of which is 954 meters above the sea-level. For companison, he also performed an experiment with a soil column, following the method adopted by S. J. Mauchly. As the result of these studies, it has been clearly shown that the application of a positive pressure upon a part of homogeneous soil results in the fall of the electric potential in the electrode nearer to the pressure center and its rise in the remote electrode; that the magnitude of the potential difference thus produced is directly proportional to the intensity of the pressure applied, and that negative pressure produces the reverse effect. These statements can be simplified thus : A positive local pressure constitutes a center of negative electric potential.

If this is true, the high pressure produced far inside a crater by the accumulation of gas previous to an explosion must cause the change of the potential gradient of the earth-current. Though the horizontal gradient of the earth-current is affected to a great extent by the ionization conditions in the upper layer of the atmosphere and also by the so-called stray current in the surface of the ground, the vertical potential gradient is relatively unaffected by such external factors. The writer, therefore, tried to draw a parallel between the volcanic activity and the variation of the vertical potential gradient of the earth-current.

There are two methods of measuring the variation of the vertical potential gradient of earth-current, namely the dry-well method and valley-wall method. In the latter, any suitable natural valley with a perpendicular cliff is utilized and electrodes are buried in the cliff. In the former, a dry-well is dug as deep as possible into the earth's crust and two electrodes are inserted near the top and the bottom of it. The characteristics and relative advantages of these methods have already been discussed. The method adopted in this case was the valley-wall method, the western inner wall of the first crater of Mt. Nakadaké being utilized. A detailed description concerning the whole arrangement at Mt. Makadaké and special care about the measuring apparatus has beed given in the preceding paper.

From a close examination of the daily variation of the vertical gradient of the earth-current, it has been found that the rise of the earth-surface temperature causes the eqpansion of the earth-surface texture, which exerts various kinds of influences on the vertical component. Also it has been directly observed that rapid rise in earth-surface temperature exerts distinct downward pressure. And the effect of the atmospheric pressure on the vertical component was also pointed out. Thus we have arrived at the belief that the influence of the rapid change of the earth-surface temperature will play a more important part in the change of pressure within the earth crust than that of the variation of atmospheric pressure on the variation of the vertical potential gradient of the earth-current. Moreover, the existence of a satisfactory parallelism has been found between the daily variation of the earth-surface temperature and the amount of residuals, which signifies mainly the inherent or characteristic variation of the vertical potential gradient of the earth-current, obtained when the apparent daily variation of the vertical component is compared with that of the horizontal earth-current.

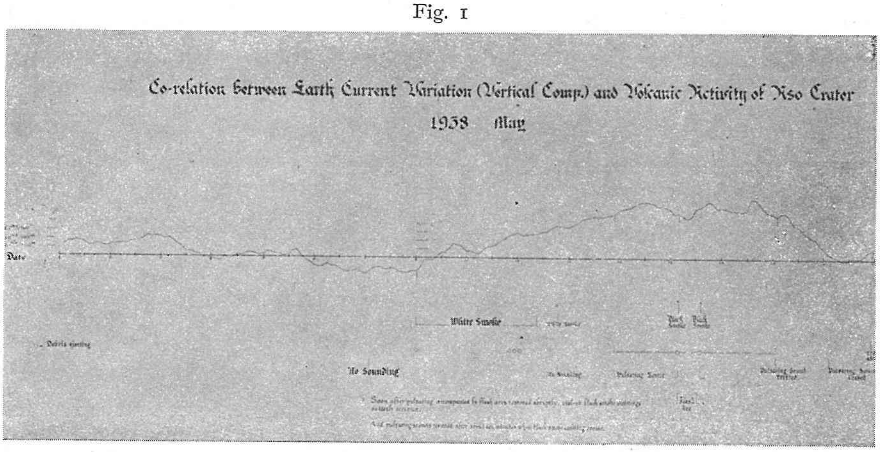
Under the guidance and encouragement of Prof. Nomitsu and by the support of the Japan Society for the Promotion of Scientific Research, the writer was able to carry out the observation on the variation of the vertical potential gradient of the earth-current at the first crater of Mt. Nakadaké of Aso in 1938–1939. This is the summary report of the results accumulated during these two years.

II. Results of Observation on the Volcanic Activity and on the Variation of the Vertical Earth-current at Aso

The object of the present study was, as before stated, the first crater of Mt. Nakadaké, the most active crater of Aso. Observation began on the 25th of December, 1937, and closed at the end of September, 1939. As to the general view on its activity, though no large explosion occurred, a number of small activities took place continuously during this period. And as the arrangement for the measurement of the vertical potential gradient was set up within the crater, which is near the center of its activity, there was no hindrance to learning the general features of its behavior. Some representative cases will be presented here with the necessary explanation.

(1) The Activity about the Middle of May, 1938.

Fig. 1



This is the second activity of the first crater after the commencement of observation. As the writer was then staying at the cave-type observatory in the crater-wall to keep watch, a nearly complete record was obtained. Some of the results have already been reported at the General Meeting of the Japanese Association for the Advancement of Science held in October, 1938. Fig. 1 is a transcription of the record on the variation of the vertical potential gradient of the earth-current during the period from the 1st to the 18th of May. The ordinate indicates the variation of the vertical component per 100 meters in m. v. and the rise of the curve indicates the 'up' change, namely the increase of the potential gradient of the upward component. In the phrase we have adopted, the increase of the earth-current or the rise of the potential of the upper electrode is called a change toward ' up ' or an up change, and the reverse case a change toward ' down ' or a down change. The abscissa indicates the time, each record having heen made at noon of the date given. For the sake of comparison, a standard line is drawn in the figure based upon the value about the 9th of May.

General examination of the figure will reveal the following prominent facts: The vertical gradient, which continued almost constant during the early part of the month, turned toward ' up ' on the 9th of May. It rose impetuously afterwards to reach the maximum value noted from the 12th to the 15th, exceeding the standard line by some 100 m. v. And then it turned towards ' down ' and settled down to the neighborhood of the standard line.

As to the activity of the first crater, after remaining quiet during the early part of the month, the eruption of white smoke increased from about the 8th onward. Though the silent state prevailed, a momentary but violent eruption of white smoke was observed at intervals. On the 11th day the crater was in a quiet state. It became more active in the morning of the 12th, and pulsatory rumbles of explosive nature though on a small scale, continued from the 12th to the 15th. After that time, though a vomiting of some smoke with a vestige of eruption still lasted, the pulsatory rumbling faded away rapidly.

During the two days of the 13th and 14th, the pulsatory rumble reached a climax, and the well-known flashes observed at the time of the activity in February, 1933, were again distinctly observed. As many as 3 or 4 flash rings were counted. The view at night was splendid.

As a rule, when such a pulsatory rumble dominates, the ejection of ash or white smoke becomes very feeble and the detonation and ejection of red-hot lava fragments becomes the leading part of the volcanic activity. The pulsatory rumble is usually repeated almost rhythmically. Though its interval varies from several seconds to several minutes, it is generally short at the beginning of the activity, growing longer and longer till it lasts as much as 10 minutes or more. And finally it changes to a continuous roar of undertone. The rumble is accompanied by the dispersion of red-hot lava fragments. After the activity reaches the the stage where the two states, namely a pulsatory rumble accompanied by the eruption of lava fragments and roar of undertone accompanied by an ejection of a great amount of ash, alternate, the rumble fades away rapidly. In our present case, the rumble alternated at times with a roar of undertone and an ejection of a considerable amount of ash from the midnight of the 13th onwards. It ceased entirely on the 16th. The ejection of smoke lasted for some time longer, suggesting dying embers, until at last it also ceased altogether.

At the time of the pulsatory rumble, a number of volcanic thunders and volcanic showers were experienced. The volcanic thunders sounded only as unearthly snaps, as they were experienced near by. The showers burst violently and fell like a belt to the zone where the volcanic smoke hung. The lightning seemed as if emitted from the cluster of volcanic smoke. It is likely to appear when the atmosphere gives signs of a shower.

When the variation of the vertical gradient is compared with the sequence of the volcanic activity, the following facts will be found: The pulsatory rumble commenced when the curve of the vertical earth-current turned up and approached its shoulder; the eruption became violent when the curve about reached its maximum or had just passed the maximum; and when the curve turned down, the rumble began to fade away, only the ejection of smoke lasting longer. At last the volcanic activity ceased entirely as the curve settled down to the initial position. In the explanation of Fig. 1, the word 'fragments in white smoke mingled with lava fragments' means not the red-hot lava fragments but fragments that were lying about the mouth of the crater, lifted with the white smoke when it is ejected in great amount. Those which are actually ejected at the time of a pulsatory rumble consist mainly of red-hot lave fragments, or more correctly magma fragments, and they display a splendid sight of fireworks at night.

A close examination of Fig. 1 reveals that the vertical potential gradient at the begining of the month was higher than the standard line and its minimum value (that is the maximum change toward down) appeared about the 7–8th of May. This can be explained as the after effect of the up change at the end of April, its gradual fall tailing over the early part of May. Again, it is noticed that the curve of the vertical potential gradient turned toward up at the end of May to reach its maximum at the beginning of June.

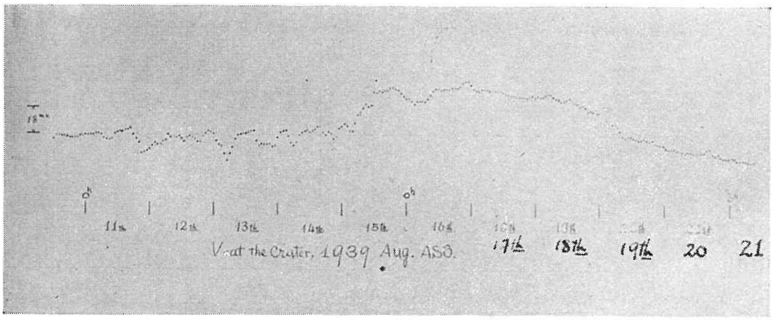
Here let us study an interesting question: The phenomenon of violent explosion attracts general notice, but does this phenomenon occur quite suddenly? Let us re-examine the activity of May. As the activity of Volcano Aso is usually gentle, the commencement of the pulsatory rumble and the ejection of the red-hot lava fragments passes in most cases without public notice, and the activity becomes noticeable from a distance only after it has grown to the stage of violent eruption of smoke such as was observed at 2 a. m. of the 13th. But as this happened in the middle of the night, it was not until the next morning that the activity was fist noticed by distant observers. The usual photograph referred to as the sight of the explosion of Volcano Aso is one taken after its activity had reached this stage. Especially the photographs of eruptions of Mt. Aso in early times when communication was difficult and the reports of distant observers, must be regarded as referring almost entirely to this stage. In our case, though the surface activity could be distinctly observed at the scene, on the 12th, a distant observer must have noticed it for the first time on the 13th, a day after its actual commencement. The violent activity of 1933 is generally reported to have begun on the 24th of February, but it is significant that the observer, unable to stay any longer at the brink of the crater, descended at midnight of the 23rd.

Thus, if the time of commencement of the surface eruption is defined as that of a pulsatory rumbling, it coincides with the time when the curve of the vertical potential gradient reaches its shoulder and the eruption becomes violent when or just after the curve reaches its maximum. Alternatively, if it is defined as the time of the commencement of violent eruption, then it coincides with the time when the curve reaches its maximum or just after it. If we remember that in our case the outward destructive action did not become so violent as to be noticeable to everyone till the 13th of May, we may adopt the latter definition. At any rate, it must be noticeable that the eruption of Volcano Aso does not happen without warning, but proceeds by stages, and that the record of its eruption must be different according to the site of observation. The writer believes that any previous statement about Aso that the eruption broke out "suddenly with a terrific rumbling" does not describe the real precess of its activity. In other words, we may reasonably assume that in previous eruptions of Aso the surface eruption had already commenced about one day before the time reported.

Activity similar in duration to the one described in May, 1938, was also experienced in April, 1938; in April, 1939; and in the period covering the end of September and the beginning of October, 1939. All of them lasted for several days. It is a hard and laborious task to take complete records in such cases.

(2) The Activity about the Middle of August, 1939.

Fig. 2



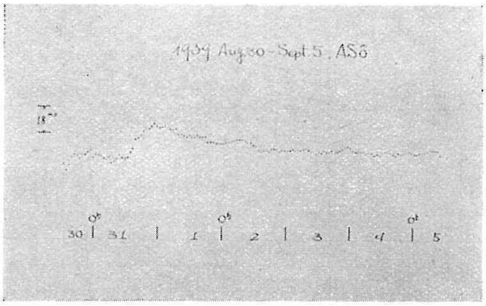
In August, 1939, the ash-fall continued almost every day from the beginning of the month. It was rather severe, and as the east wind prevailed the pasturage in the western half of the old atrio of Aso was almost destroyed. But during those days, the outward appearance of the crater seemed quite quiet and a silent state lasted. Then the pulsatory rumble, though on a small scale, commenced on the 15th and continued till the 18th. The ejection of ash decreased as usual and that of red-hot lava fragments took its place. But the distribution of the latter was limited to the area of the crater itself. At last, the last traces of ash-fall like burned-out embers ceased entirely on the 24th, and a silent state without smoke was restored again.

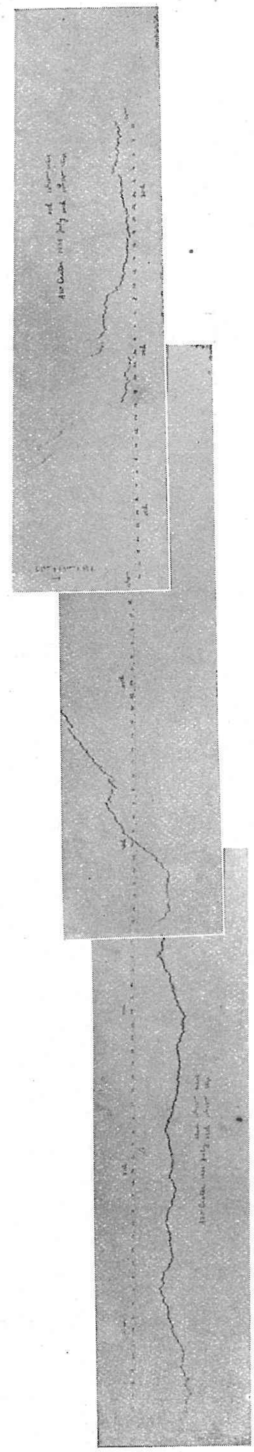
The record of the variation of the vertical potential gradient shown in Fig. 2, shows that it changed conspicuously toward 'up' on the 15th, and then turned toward 'down' on the 18th, and fell contintously to the mimimum value on the 24th. After that, it changed again towards up to form the next rise, at the end of August and the beginning of September.

(3) The Activity during the Period from the End of August to the Beginning of September, 1939.

After remaining in a silent state with some ash ejection, the first crater became somewhat active on the 31st of August and a gentle pulsatory rumble continued from the 31st of August to the 1st of

Fig. 3





September. The distribution of lava fragments did not extend beyond the crater brink or rim. Meanwhile the ash ejection diminished as usual. While the curve of the variation of the vertical potential gradient turned towards up from the minimum value of the 24th of August onward, as is shown in Fig. 3, and the rate of rise became graduably more rapid. It tended to rise after the beginning of September and exhibited a variation coincident with the variation of the crater activity at the end of September and the beginnig of October.

(4) The Activity during July 23–30, 1938.

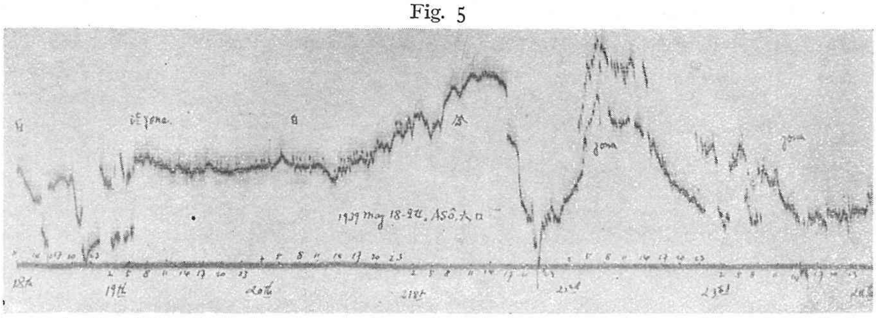
The crater, after remaining in a silent state with some ash ejection, raised on the 27th of July a pulsatory rumble that lasted during the next day, while the ash ejection diminished. The lava ejection was but small in amount. On the 29th, the rumble ceased and it returned to the state of continuous ash ejection. The curve of the vertical potential gradient after remaining in a quiet state, as is shown in Fig. 4, turned, rapidly towards up from the 26th onwards, and was restored to the initial state by the 29th.

(5) The Activity during May 18–24, 1939.

As is shown in Fig. 5, the record on the variation of the earth-current runs as follows: After remaining continuously almost in a tranquil state, it changed rapidly towards up about the 21st; after a temporary steep change towards down at the midnight of the same day, it turned again towards up; then it was restored to the initial value from the 23rd onwards.

The sequence of the activity of the first crater was as follows: On the 18th, white smoke; on the 19th and 20th, white smoke mingled with some ash; on the 21st, the violent pulsatory rumble noticeable at the Laboratory 7 kilometers west of the crater. This condition continued also in the morning of the 22nd. On the 23rd, the activity degenerated and became silent, though the ejection of ash hung about, trailing towards the north. On the 24th, the ejection of ash mingled with lapilli continued without rumble. On the 25th, it came to the stage of white smoke without rumble, The ejection of lapilli fell off decidedly.

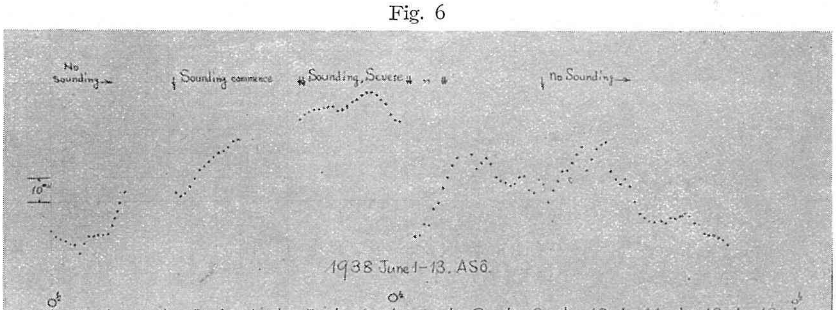
Fig. 5



(6) The Activity from June 1 to 13, 1938.

The variation of the vertical potentiai gradient of the earth-current, which is shown in Fig. 6, behaved much the same as in the previous case, As to the activity of the first crater, after remaining silent with white smoke the pulsatory rumble commenced on the 3rd of June. The violent pulsatory rumble lasted during a period of five days, from the 5th to 9th; then it faded and reverted to the initial quiet state again. Though the rumble was very violent, the ejection of lapilli and ash was rather moderate in amount.

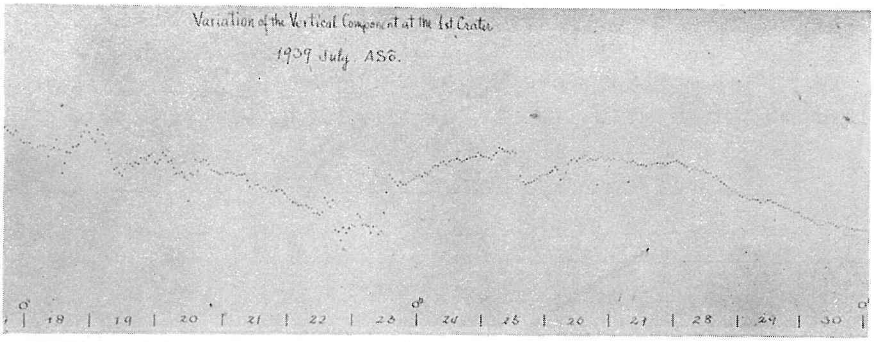
Fig. 6



(7) The Activity in July, 1939.

In this case, the variation of the vertical potential gradient was somewhat complicated as is shown in Fig. 7, and exhibited a composite type as if formed from the first type intertwined with those noticed in the preceding two sections, (5) and (6). As a whole, however, it is a continuous down change mixed with a sharp up change, though on a small scale.

Fig. 7



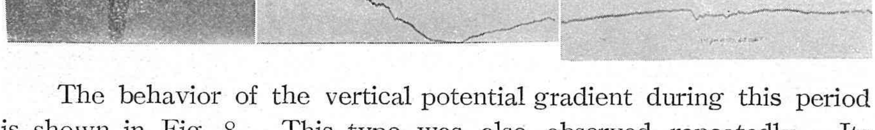
About the crater activity, the long-continued ejection of smoke was suspended for a while from the 23rd of July onwards and a pulsatory rumble commenced on the 25th and lasted till about the midnight of the 25th or the morning of the 26th. Then the silent state accompanied by the ejection of ash was restored.

Such small scale activity was observed so many times during the term of the present study that no record was made of them all.

(8) The Activity during January 15–21, 1939.

At the first crater, the ejection of ash continued every day from the opening of the year, but on the 18th of January, the eruption changed to mist-like white smoke. During the 19th and 20th, a silent and smokeless state lasted, A rumble accompanied by the ejection of lava fragments commenced on the 21st. The continuous ejection of ash began again next day and continued afterwards.

Fig. 8



The behavior of the vertical potential gradient during this period is shown in Fig. 8. This type was also observed repeatedly. Its characteristic feature is the acute down change with the period of quiet before and after it. But when it is examined more closely, two adjacent active periods will be found: One at the end of December and the beginning of January and the other at the end of January and the beginning of February. In these periods, the roars were so violent as to be heard at the Laboratory. The middle of January corresponds exactly with the transition between these two active periods. So the down change of the vertical potential gradient may be considered as the indication of a cessation of the volcanic activity. When thus viewed, this type is not at variance with other cases.

Above is a brief list of apparently different types in the behavior of the vertical potential gradient with reference to the crater activity. On the examination of these data, some general conclusions may be drawn :

(i) The typical sequence may be represented by the following scheme: The rapid change of the vertical potential gradient of the earth-current towards ' up ' is followed directly by the break of a quiet state and the commencement of a pulsatory rumble. And just when or immediately after the former reaches its maximum, the rumble begins to fade and the ejection of ash increases in amount. And finally the initial quiet state is restored.

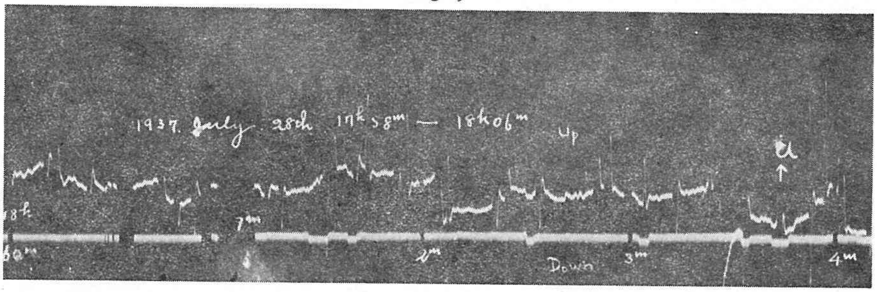
Closer examination will also reveal the following facts :

(ii) As to the behavior of the vertical potential gradient before its rapid rise, there are two cases: One with a frequent fluctuation and the other with a rather smooth course.

(iii) As to its behavior after the volcanic activity, there are also two corresponding cases, namely the descent of the vertical potential gradient with frequent fluctuation and that with smooth process.

(iv) Generally. in the vicinity of the maximum value, the vertical potential gradient varies conspicuously without refereuce to the amplitude.

Fig. 9

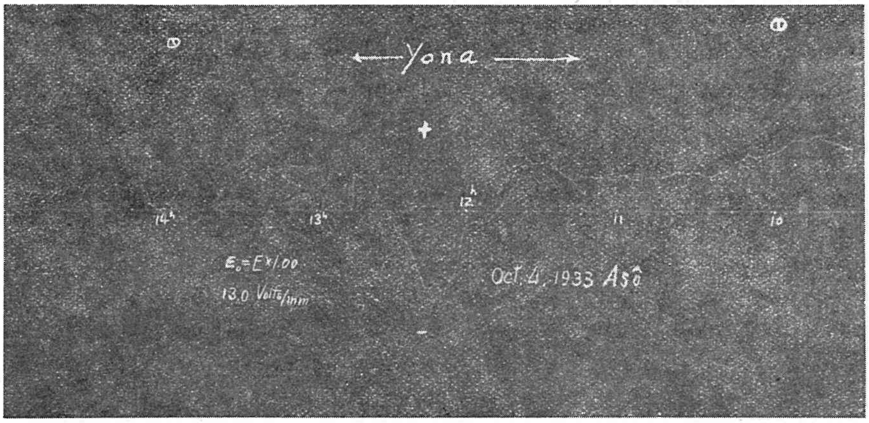


(v) The value of the vertical potential gradient of the earth-current after the activity does not necessarily coincide with its initial value; it may be sometimes higher and sometimes lower than the latter.

Nevertheless, the rapid change of the vertical potential gradient toward 'up' is always accompanied by the commencement of the pulsatory rumble. Moreover, this phemomenon seems to be universal irrespective of the violence of the volcanic activity. In the beginning of the descending stage of the vertical potential gradient the volcanic activity is usually already in process.

L. Palmieri has found that the earth-current between the summit and the foot of Mt. Vesuvius turns towards 'up,' (to use the writer's expression), and finally returns to the initial state as the activity decays and that the daily variation is obscured by this variation. These observed facts agree with the present results on the variation of the vertical potential gradient obtained by the valley-wall method at the first crater of Aso.

Fig. 10



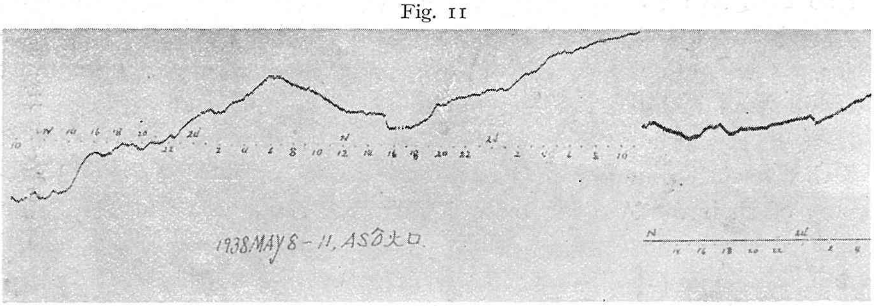
According to E. O. Walker, the earth-current is influenced by atmospheric electricity at Kandy. With the present arrangement, the vertical potential gradient of the earth-cerrent was affected to a considerable degree by the electric discharge of thunder, as seen in Fig. 9, and as is usual also in the record of the horizontal potential gradients of the earth-current. This fact must be remembered in interpreting the data. Also the volcanic smoke of Aso was found to make the atmospheric charge negative, as seen from Fig. 10, a record taken at the Laboratory. But this influence was unnoticeabl in the record of the crater-wall earth-current of Aso. This may, however, be ascribed to the sensibility of the instrument, and further study is required to check this point. Nevertheless, if we recognize that it has an influence, it would exert a down change, and the above interpretation will cover it.

III. The Problem of Forecasting the Volcanic Activity of Aso

From what has been stated in the preceding chapter, the fact of correlation between the variation of the vertical potential gradient of the earth-current and the activity of the first crater of Aso seems more than probable. Then comes a question: Is it possible to forecast tne volbanic activity from the behavior of the vertical potential gradient of the earth-current? The writer's view deduced from his own experience during this term runs as follows:

(i) As was experienced at the time of activity in May, 1938, if watched with apparatus of high sensibility, the vertical potential gradient will rise so conspicuously that the recording paper must be shifted upwards, indicating the approach of the active period; and the rapidity of rise tells us that the violent activity is within one or two days. Again the down change necessitates changing the recording paper and while the volcanic activity is still in process, appries us of its decay. (Fig. 11).

Fig. 11



(ii) As for the violence of activity, all the volcanic activities experienced during this term were rather moderate and every one of them allowed its complete record to be taken in a single recording paper. Therefore, no remarkable record was obtained. For this purpose, it is desirable to have several sets of apparatus differing in sensibility and to take a set of complete records for every activity.

(iii) Judging from the sequence of the volcanic activity experienced durieg this term, the smaller the rate of the up-change of the vertical potential gradient i. e. the longer it takes to complete the up-change, the greater the volcanic activity will be, and vice versa. So if we judge correctly the composite type, the general features of the coming volcanic activity can be forecast.

(iv) Lastly, the most difficult question of all must be considered whether the above stated behavior of the vertical potential gradient is necessarily followed by a surface volcanic eruption or not. The behavior of the vertical potential gradient and the volcanic surface activity coincided in all cases experienced during this term, and there was no doubtful case. But volcanic activity comprises also phenomena other than the surface activity. There must presumably be a case where, though the vertical earth-current may behave typically, the volcanic activity decays after some underground activity without any surface activity. This important point has not been solved during this brief experiment, but some pertinent facts are found in our records. In one type of variation of the vertical potential gradient of the earth-current, see Fig. 4, 5 and 6, the variation behaved almost normally before the volcanic activity. But after that, it exhibited immoderate fluctuations. In this case, though the rumble was rather violent, the crater activity ceased without any severe ejection. May this procedure not be taken as a phenomenon of decay of the volcanic activity without a corresponding surface activity (i. e. with underground activity)? If so then as an extreme case, we may expect a special variation type of the vertical potential gradient accompanied by no surface activity. Owing to the dearth of knowledge about this point, we must refrain from making any assertion.

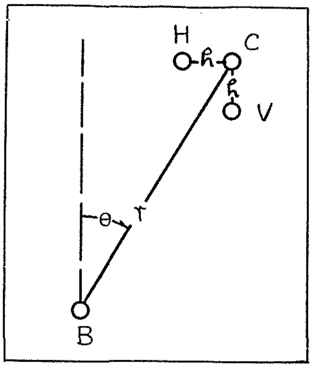
(v) Regarding the influence of climatic factors upon the variation of the vertical potential gradient of the earth-current, the general features of their mode of action and their magnitude have already been clarified in previous reports. Since this influence can be distinguished from the inherent or characteristic variation of the vertical potential gradient of the earth-current, an experienced observer, will not be misted by it.

IV. Discussion and Conclusion

It has been proved that a close correlation holds between the variation of the vertical potential gradient and the volcanic activity of Aso,-that the volcanic activity commences and the pulsatory rumble takes place when the vertical potential gradient of the earth-current rises and the variation curve reaches its shoulder, and that the activity decays after the variation curve begins to decline. How can this procedure be interpeted?

In this connection, the relation of pressure to the variation of the potential gradient of the earth-current, that " a positive local pressure constitutes a center of negative electric potential," already reported must be remembered. We will apply the fact of this relation to homogeneous earth.

Fig. 12



Let us suppose that a positive local pressure has been produced at the center (B) of a sphere of homogeneous earth at constant temperature. B will become the center of a negative electric potential. We will assume that the electric current flows into B at the rate of qp er second to reach a state of equillibrium. The conductivity of the earth is regarded as remaining constant. C and H indicate a pair of horizontal electrodes, and C and V a pair of vertical electrodes. The distance between each pair (h) is taken to be very small as compared with the distance (r) between B and C. If we represent the intensity of the current flowing towards B by i, the total quantity of electricity q will be given by $4\pi r^2 i = q$ (constant)

$$i = \frac{q}{4\pi r^2} = K.\frac{d\varphi}{dr}$$

$$\therefore \quad \varphi = \frac{q}{4\pi k} \cdot \frac{1}{r} + \text{Constant.}$$

Then, the potential difference between C and H and that between C and V will be given by the following equations:

Horizontal Component

$$\varphi_{C-H} = \frac{g}{4\pi k}\left(\frac{1}{r-h.\sin\theta} - \frac{1}{r}\right).$$

$$= \frac{q}{4\pi k} \cdot \frac{h}{r} \cdot \frac{\sin\theta}{r-h.\sin\theta} \quad \cdots\cdots\cdots\cdots(1)$$

Vertical Component

$$\varphi_{C-V} = \frac{q}{4\pi k}\left(\frac{1}{r-h.\cos\theta} - \frac{1}{r}\right)$$

$$= \frac{g}{4\pi k} \cdot \frac{h}{r} \cdot \frac{\cos\theta}{r-h.\cos\theta} \quad \cdots\cdots\cdots\cdots(2)$$

Fig. 13

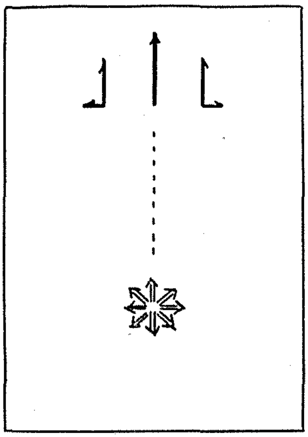
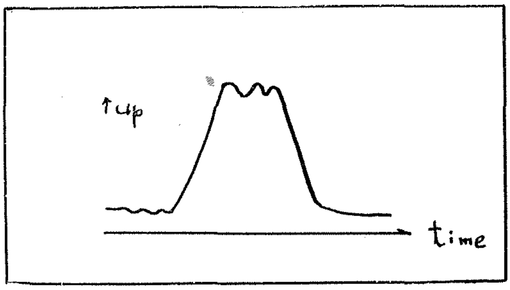


Fig. 13 is a diagram showing a vertical section near the epicenter. The arrows indicate the direction of the rising potential gradient. According to this, in the case of the vertical component, the upper electrode will be higher than the other in potential gradient, and in the case of the horizontal component, the electrode farther from the epicenter will show a higher potential gradient than the nearer one. When translated to our common usage, this means that the vertical component reaches a maximum and the horizontal component a minium at the epicenter.

If so then at the time of an eruption, the storage of explosive substances (mainly gas) should cause high pressure, which occasions the 'up' change of the vertical potential gradient of the earth-current. As their accumulation in the deep underground requires a long lapse of time, their absolute amount cannot be found from a mere record of the variation of the potential gradient of the earth-current. But when the accumulation reaches a definite amount and the accumulated gas rises and seeks its way out, then the vertical potential gradient will be disturbed and it will fluctuate up and down repeatedly. And when a large amount of gas almost reaches the earth-surface, the distance from the pressure center (r) becomes very small, causing the rapid rise of the vertical potential gradient till it reaches a maximum. After the first eruption, the temporary reduction in pressure brings about the down change of the potential gradient. The supply of gas again makes the electrical potential rise, but once more it will fall after the second eruption. By repeating such processes, a series of explosions will result. But after that, when the supply of gas is exhausted, the vertical potential gradient will keep on falling till it returns to the ininial state and remains there, or for some reason changes to some their point. These procedures are illustrated in Fig. 14.

Fig. 14



A variety of mechanisms concerning the underground activity or an intrusion might be postulated, but it is beyond the scheme of the present paper.

With this reasoning it seems that the data obtained during this term may be interpreted with fair satisfaction. Of course there remain many problems which await closer examination, and the writer hopes for opportunity to go on with the study. The removal of the obsevatory in the crater-wall to a safer place is one of the points to be modified.

In conclusion the writer wishes to express his sincere thanks for the continuous guidance of Prof. T. Nomitu and also for the financial support granted by the Japan Society for the Promotion of Scientific Research. And Mr. M. Hotta, the assistant must be remembered for his enormous efforts in watching the instruments during the study.