9. *Magnetic Surveys of Volcano Asama.*

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1. Introduction.

With the object of ascertaining the relations between volcanic activities in Japan and variations in the terrestrial magnetism that accompany these activities, S. T. Nakamura and Y. Kato made a study of the changes in the magnetic dip at the time of the activity of Volcano Komagadake[1], in Hokkaido, in 1929, the Sanriku earthquake in March, 1933, the Sizuoka earthquake[3] in July, 1934, the Yamato-Kawati[4] earthquake in January, 1936, and other activities of volcanoes and seismic zones, they found that the variations in the magnetic elements usually accompanied both these activities, and came to the conclusion that these magnetic variations that appeared in the neighbourhood of epicentres of earthquakes and in the case of volcanic activities are due to the heat changes in the disturbed crust caused by these activities. Quite recently, H. Hatakeyama[5] found the time variations in the magnetic quantities by comparing two series of results of magnetic surveys in Formosa, the one carried out in 1914 and 1924, and the other soon after the great earthquake on April 21, 1935, at the same stations as previously. He reported that these variations in terrestrial magnetism are distinctly related to crustal movement caused by the earthquakes just mentioned and the situation of the epicentre.

On the other hand, soon after the earthquake on Dec. 27, 1936, the epicentre of which was determined by T. Hagiwara[6] to be near Nii-Sima, T. Nagata[7] made magnetic dip surveys in the shaken regions, namely, Nii-Sima and Oo-Sima. After studying the previous surveys

1) S. T. NAKAMURA and Y. KATO, *Jap. Journ. Astr. Geophys.*, 12 *etc.*

2) Y. KATO, *Disin*, (1935), 469, 529.

3) Y. KATO reported at the annual seance of Physico-Mathematical Society of Japan in 1935, 1936.

4) *loc. cit.*

5) H. HATAKEYAMA, *Bull. Cent. Meteor. Obs. Jap.*, **6** (1937), 467.

6) T. HAGIWARA, *Bull. Earthq. Res. Inst.*, 15 (1937), .

7) T. NAGATA, *Bull. Earthq. Res. Inst.*, **15** (1937), 498.

that had been made by S. Nakamura[8] in August, 1930, T. Nagata did not find any magnetic changes sufficiently marked to be put down as the result of the earthquake.

In summarizing the results of magnetic measurements that have been made in connection with volcanic and seismic activities, it is clear that some of these activities were followed by no changes in terrestrial magnetism according to their magnitude of activities.

Some years ago, S. Nakamura[9] made magnetic dip surveys of Volcano Mihara, Oo-Sima island, while recently R. Takahasi and T. Nagata[10] carried out absolute measurements of the three components of terrestrial magnetism, namely, the declination, horizontal and vertical intensities, at the crater margin and at the base of Mihara. It would no doubt be interesting to study the variations in these magnetic quantities in view of the expected forthcoming activity of Volcano Mihara.

Although it is not difficult to imagine the existence of marked local anomalies in magnetism near the crater of an active volcano, T. Nagata[11] found that the eastward and westward anomalies in the magnetic declination at the margin of the crater of Mihara, as observed in Aug., 1937, as well as similar anomalies near the crater of Asama, as measured by T. Fukutomi[12] in 1930, are both separated by the N–S and E–W lines that intersect perpendicularly at almost the centre of each crater.

H. Nagaoka[13], who suspected that the magnetic variations that appear at the time of an explosion are rapid in character, made observations of the differentiated quantities of the vertical intensity of the terrestrial magnetism at Volcano Asama. With the results of these observations as basis, he studied the mechanism of occurence of the explosion and the underground structure near Asama, and at the same time, reported the existence of rapid changes of magnetic intensity at the time of explosions.

2. Present Surveys.

The present surveys of the magnetic dip at Volcano Asama were made with the object of obtaining an outline of the terrestrial magne-

8) S. NAKAMURA, *Disin* **6** (1934), 637.
9) S. NAKAMURA, *loc. cit.*
10) R. TAKAHASI and T. NAGATA, *Bull. Earthq. Res. Inst.*, **15** (1937), 441.
11) T. NAGATA, *Disin* **9**, (1937).
12) T. FUKUTOMI, *Disin* **2**, (1932).
13) H. NAGAOKA and T. IKEBE, *Proc. Imp. Acad. Tokyo*, **13** (1937) 30, 34, 62.

tism of Asama as a whole to serve as the first step in the absolute measurements of the declination and the vertical and horizontal intensities to be shortly executed. Fortunately, we were able to use a dip circle, by courtesy of the Hydrographic Department, which had been tested in March, 1937, at the Magnetic Observatry, at Kakioka.

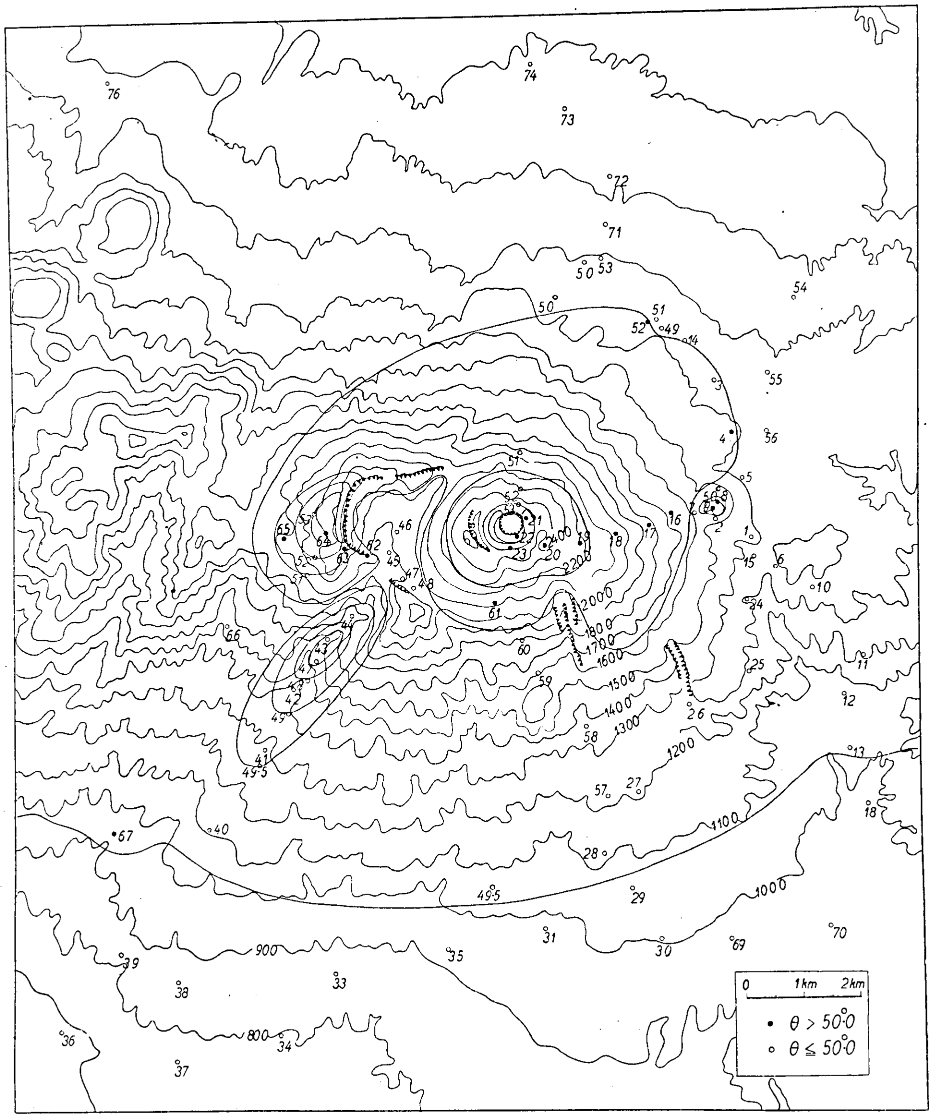

Fig. 1. Isoclinic lines.

The present surveys were begun in May, 1937, and conducted at 76 stations until November, the same year. The results of these surveys of the magnetic dip form the subject of this paper, although these surveys are still being continued.

In Table I are given the latitudes and longitudes of the 76 stations, with their heights above sea level, and in Table II the dips and the dip anomalies (defined in following pages) and the dates and the times when the observations were made. The topography around the stations and the isoclinic lines are shown in Fig. 1. We find, first of all, that dip is intimately related to the topography. It will be seen from Fig. 1 that the dip generally increases with increase in the heights of the stations, although remarkably small dips are found for stations in the bottom of the ravine, notwithstanding the high altitudes of these stations above sea level. That is to say, the magnetic dip is affected distinctly by the gradient and the uneveness of the topography near the station. The contour lines at the principal mass of Volcano Asama are as a whole represented by closed curves—almost concentric circles with the crater as the center. Here the isoclinic lines also form closed curves approximately parallel to the contour lines. In order to show more clearly the corelation between dip and topography, the dips along

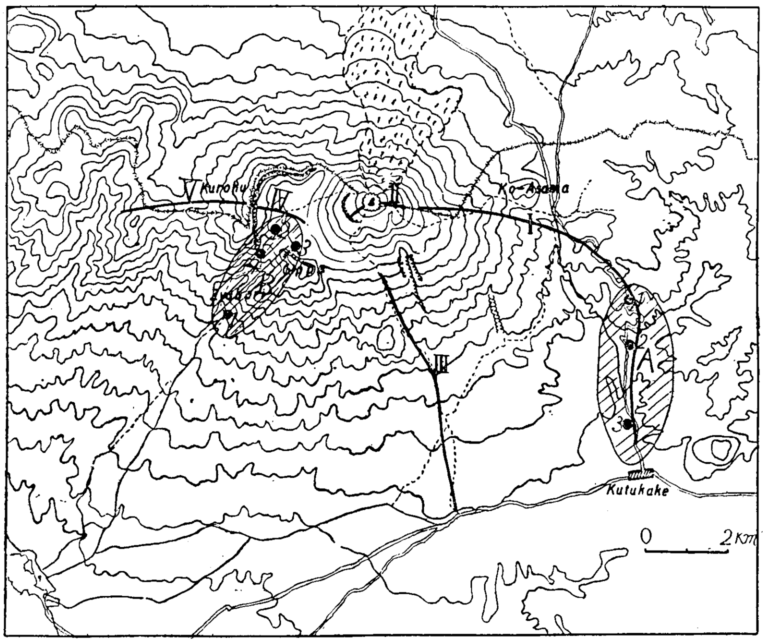

Fig. 2. Observation routes and regions A, B.

the lines of observation in radial directions from the summit to the foot of the volcano, and the heights of the stations above sea level are shown

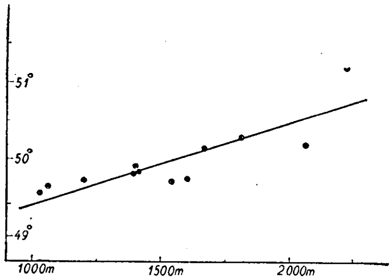

Fig. 3 a. Dips along observation route I.

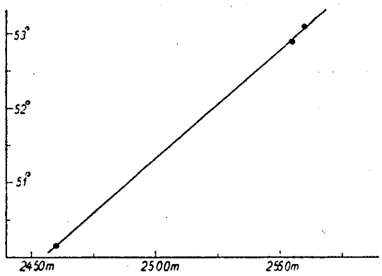

Fig. 3 b. Dips along observation route II.

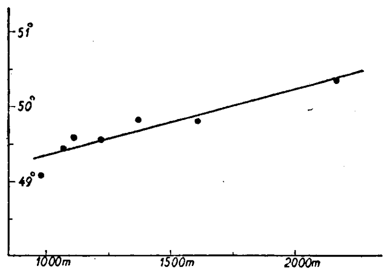

Fig. 3 c. Dips along observation route III.

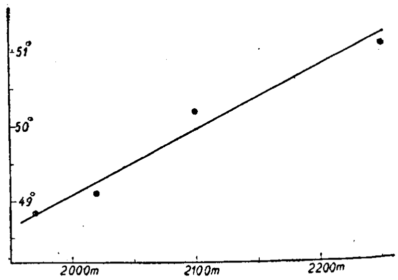

Fig. 3 d. Dips along observation route IV.

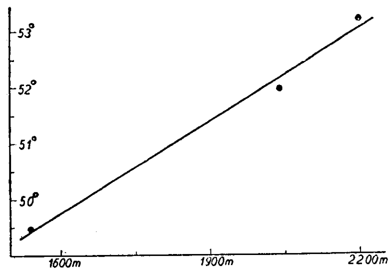

Fig. 3 e. Dips along observation route V.

by graphs in Figs. 3, (a), (b), (c), (d), (e). The positions of the lines of observation are indicated in Fig. 2. The values of the dip with change in height along every five lines of observation are represented by the following equations.

$$\theta_1 = 49°24'\cdot5 + 0'\cdot0631h \qquad \text{along line I.}$$
$$\theta_2 = 51°21'\cdot1 + 1'\cdot787h \qquad \text{along line II.}$$
$$\theta_3 = 49°30'\cdot9 + 0'\cdot053h \qquad \text{along line III.}$$
$$\theta_4 = 48°59'\cdot3 + 0'\cdot605h \qquad \text{along line IV.}$$
$$\theta_5 = 49°45'\cdot0 + 0'\cdot333h \qquad \text{along line V.}$$

Along the line I and its extension which extends on over a simple topography from the S–E foot of the volcano, Kutukake, to the crater, the dips are better expressed by the quadratic equation

$$\theta = 49°19'\cdot7 + 0\cdot0464h + 0\cdot000049h^2,$$

where as the origin of h the lowest position of the lines of observation is taken, with the meter as unit. The increasing rates of dip along the various lines of observation markedly differ from one another, that is, the dip increases 6′·3, 178′·7, 5′·3, 60′·5, and 33′·3 with every 100 m increase in height.

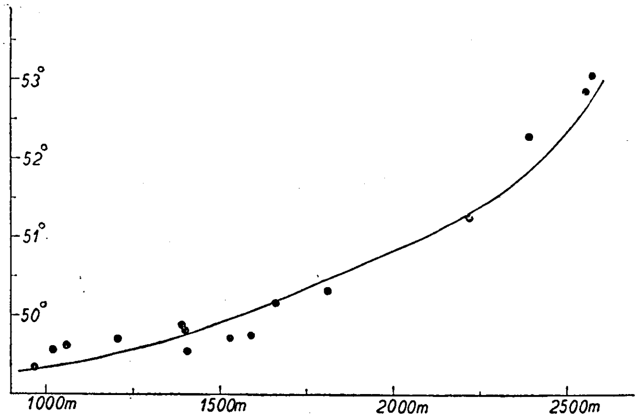

Fig. 4. Dips and heights above sea level along east route, from the foot of volcano to the summit.

There are many alternative explanations of these remarkable differences in the increasing rates of dip. Of these, the relative position between the direction of inclination of the mountain body, which is a huge magnetic mass, and the direction of the magnetic meridian, the steep and gentle inclinations according to the particular line of observation, and the concave or convex topography as a whole, all these differences in the conditions according to the lines passing through them, caused the various increasing rates. Moreover, line II is on the present central cone, lines I and III pass the slopes in an E–S directions from the crater in the second somma, and lines IV and V are on Kurohu-Yama, the first somma, in an east and west direction, respectively, from the summit of Kurohu-Yama. Owing to diversities in the magnetic permeability of the various lavas that compose the mountain, these local anomalies in the terrestrial magnetism are inevitable. The lava ejected does not always flow along the slope uniformly in all directions from the crater, but rather in a narrow belt as one usually sees on volcanoes; for example, the Temmei lava ran down the northern slope of Asama. Consequently, although the lines of observation are on the same mountain, owing to the varieties of lava ejected and to differences in the time they were ejected, the permeabilities of these lavas are not alike.

During the period from July 19 to July 27, 1937, the writer carried out similar surveys at Volcano Kusatu-Sirane, situated 25 km at Volcano

Asama. The result at the 8 stations on the margin of the crater of Kusatsu-Sirane show that the maximum, minimum, and mean values of dip were respectively 51°4′·3, 49°40′·7 and 50°19′·6, while at the 3 stations on the bottom of the crater the values of the dip were 49°17′·4, 49°7′·2, and 48°53′·5, the mean value being 49°6′·0. It was thus found that the former mean value exceeds the latter by 1°13′·6.

Moreover, the results of magnetic surveys at Volcano Mihara, Oosima island, made by R. Takahasi and T Nagata[14] also showed that the distribution of terrestrial magnetism is affected by the topography, which cannot be neglected.

Of the values of the dip at the 76 stations in the present survey, the maximum is 53°15′·5 on the summit of Kurohu-Yama, the first somma, and the minimum 46°29′·1 in the bottom of a ravine, the difference in the two values amounting to 6°46′·4. However, the present measurements do not cover Kengamine, Gippa-Yama, the first somma, and Amidagazyo, an explosion crater. When the survey of Volcano Asama is completed, it may be possibly to find a difference of 10° in the dip notwithstanding that the region is circumscribed to within a radius of 10 km only from the crater.

For convenience, the dip anomaly is expressed by

$$\theta_0 = \frac{\Sigma\theta_i}{n} = 49°40'\cdot 8$$

$$\Delta\theta_i = \theta_i - \theta_0$$

$$n = 76, \qquad i = 1, 2, \ldots\ldots\ldots 76.$$

where,

θ_0 = mean value of dips at 76 stations,

θ_i = dip at each of the 76 stations,

n = total number of stations,

$\Delta\theta_i$ = dip anomaly.

It need hardly be said that the distributions of the dip anomaly as shown by means of iso-anomaly lines in Fig. 5, indicate the same tendency as those of the isoclinic lines. Generally speaking, however, the regions of positive and negative anomalies have been separeted by contour lines of 1400 metres, although there are regions of very large negative anomalies, notwithstanding that the regions are more than 1400 metres high, namely, the interiors of the first and the second sommas and the valley of the Zyabori river.

14) R. TAKAHASI and T. NAGATA, *loc. cit.*

From the following quadratic equation which was obtained as the result of magnetic surveys of Japan made by the Hydrographic Depart-

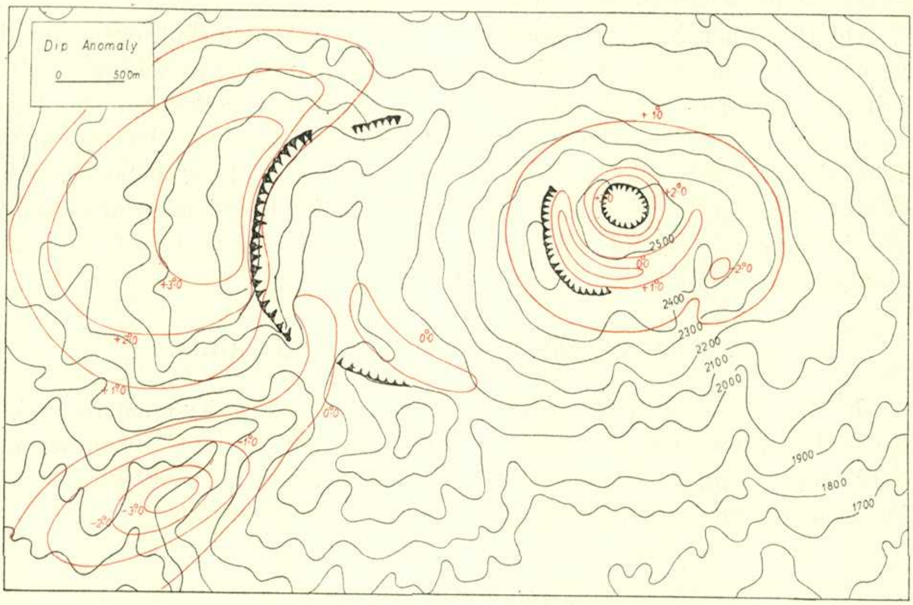

Fig. 5. Dip anomalies near the crater.

ment[15] in 1927, the value of the dip corresponding to the mean latitude and longitude of the 76 stations of Asama is given by

$$\theta_c = 34°4'\cdot 9 + 88'\cdot 61\Delta\varphi - 3'\cdot 08\Delta\lambda - 0'\cdot 768\Delta\varphi^2 - 0'\cdot 2356\Delta\varphi\Delta\lambda + 0'\cdot 1330\Delta\lambda^2$$

$$\varphi_0 = \frac{\Sigma\varphi_i}{n}, \qquad \lambda_0 = \frac{\Sigma\varphi_i}{n}$$

$$\Delta\varphi = \varphi_0 - 25° \qquad \Delta\lambda = \lambda_0 - 145° \qquad \theta_0 - \theta_c = -16'\cdot 5$$

As the result of this, the calculated values of Volcanoes Asama and Sirane are 16′·5 and 18′·5 in excess of the mean observed values respectively. It is notable that the differences between the calculated and the observed mean values of the dip in the two volcanoes are very much smaller than the dip anomalies already referred to. It will be more logical to consider that the present surveys were conducted at a large number of stations regardless of whether they were situated on concave or convex topographies, with the result that the dip anomalies due to these complicated topographies have automatically cancelled one another. Consequently, the major part of the dip anomalies of Asama and Sirane

15) *Bull. Hydrog. Dep.*, **8** (1936).

is believed to be caused, not by the active volcanoes themselves nor by the presence of abnormal magnetic substances under the ground, but by the complex topography around the stations.

On the other hand, H. Nagaoka[16] is of the opinion that, even should the origin of the magnetic disturbances actually exist in Asama itself, if it has any particular relation to the surface topography, the two causes, the one due to the topography and the other to the magnetic material under the surface, cannot be separated. It is hoped that a definite explanation of this phenomenon will be found after the study now in progress of the physical properties of the rocks of Volcano Asama is completed.

3. Dip Anomaly and the Eötvös Quantities.

If the excess or defect mass that causes the gravity anomaly gives rise at the same time to magnetic anomalies, and then it is homogeneously magnetized, it is well known that there exists the following relation between the gravitational and the magnetic potentials:

$$P = J\frac{dW}{di}$$

P = the magnetic potential.

W = the gravitational potential.

J = intensity of magnetization.

i = direction of magnetization.

$$\frac{\partial P}{\partial x} = X, \qquad \frac{\partial P}{\partial y} = Y, \qquad \frac{\partial P}{\partial z} = Z, \tag{2}$$

where x, y, z are taken in the direction of magnetic north, magnetic east, and toward ground, and X, Y, Z are the two components of the horizontal intensity and the vertical intensity.

The three components of the normal values of the magnetic intensity at Asama, which are determined by the magnetic intensity distribution in Japan, as given by the Hydrographic Department, are represented by X_0, Y_0 and Z_0. At Asama the values of the dip are generally far larger than the dip anomaly, which enables us to make this calculation. That is,

$$\frac{Z_0+Z}{\sqrt{(X_0+X)^2+(Y_0+Y)^2}} - \frac{Z_0}{\sqrt{X_0^2+Y_0^2}} \leqslant \frac{Z_0}{\sqrt{X_0^2+Y_0^2}}.$$

16) H. NAGAOKA, *loc. cit.*

Therefore, as already stated, for the present purpose, the calculated value of dip θ_c may be regarded as being to equal to the mean value of dip (θ_0), so that the dip anomaly $\Delta\theta$ already mentioned, which is looked upon as due to the potential P, is expressed by the formula

$$\Delta\theta=\frac{\sqrt{X_0^2+Y_0^2}\,Z-\sqrt{X^2+Y^2}\,Z_0}{\sqrt{X^2+Y^2}\{\sqrt{X_0^2+Y_0^2}+\sqrt{X^2+Y^2}\}}\times\frac{X_0^2+Y_0^2}{X_0^2+Y_0^2+Z_0^2} \qquad (3)$$

Formula (4) is the result of replacing X, Y, Z in formula (3) by the gravitational potential, W, namely,

$$\Delta\theta=\frac{\frac{1}{G.f(s)}\left[\left\{\sqrt{X_0^2+Y_0^2}\left(\alpha\frac{\partial^2W}{\partial x\partial z}+\beta\frac{\partial^2W}{\partial y\partial z}+\gamma\frac{\partial^2W}{\partial z^2}\right)\right\}-Z_0\left\{\left(\alpha\frac{\partial^2W}{\partial x^2}+\beta\frac{\partial^2W}{\partial x\partial y}+\gamma\frac{\partial^2W}{\partial x\partial z}\right)^2+\left(\alpha\frac{\partial^2W}{\partial x\partial y}+\beta\frac{\partial^2W}{\partial y^2}+\gamma\frac{\partial^2W}{\partial y\partial z}\right)^2\right\}^{\frac{1}{2}}\right]}{\sqrt{X_0^2+Y_0^2}\left[\sqrt{X_0^2+Y_0^2}+\frac{1}{G.f(s)}\left\{\left(\alpha\frac{\partial^2W}{\partial x^2}+\beta\frac{\partial^2W}{\partial x\partial y}+\gamma\frac{\partial^2W}{\partial x\partial z}\right)^2+\left(\alpha\frac{\partial^2W}{\partial x\partial y}+\beta\frac{\partial^2W}{\partial y^2}+\gamma\frac{\partial^2W}{\partial y\partial z}\right)^2\right\}^{\frac{1}{2}}\right]}\times\cos^2\theta_0 \qquad (4)$$

where

$$G=\text{gravity constant}$$

$$f(s)=\text{density distribution}$$

$$\sqrt{\frac{X_0^2+Y_0^2}{X_0^2+Y_0^2+Z_0^2}}=\cos\theta_0$$

and

$$\alpha=J\frac{\partial x}{\partial i},\qquad \beta=J\frac{\partial y}{\partial i},\qquad \gamma=J\frac{\partial z}{\partial i}.$$

Hence in formula (4), the intensity of magnetization was obtained experimentally and the density distribution, from the gravity surveys. Although there is no method of obtaining $\frac{\partial^2W}{\partial z^2}$ in the general case, if the problem is treated as a two dimensional one, all the Eötvös quantities required for the purpose are determined by torsion balance surveys. The results of the torsion balance surveys of Volcano Asama, in 1936, have been reported in the previous papers[17]. The present magnetic surveys were conducted at the same 22 stations where the torsion balance surveys were made.

17) T. MINAKAMI, *Bull. Earthq. Res. Inst.*, **15** (1937), 50.

While study of the forthgoing two quantities, together with a comparison of the results, will be made on another occasion, in this paper the two kinds of quantities are compared only for the limited regions A, B as shown in Fig 6. A glance at these Figs. 6 and Table III will make clear the remarkable difference in the magnetic and gravitational characters of the two regions; that is, not only are

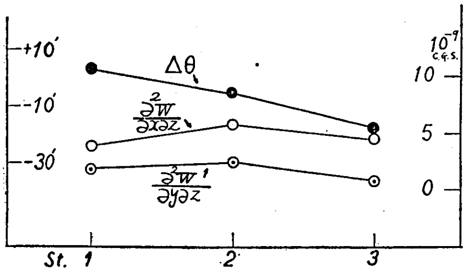

Fig. 6 a. Dip anomalies and Eötvös quantities in the region A.

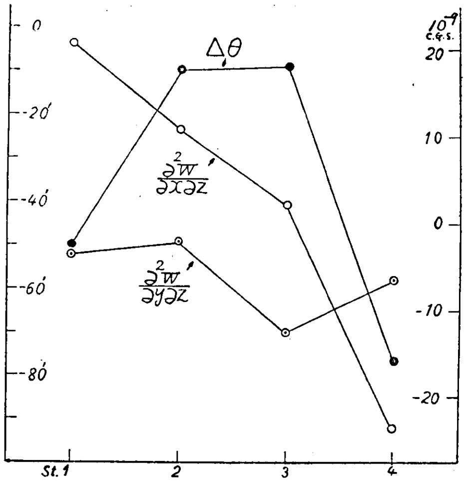

Fig. 6 b. Dip anomalies and Eötvös quantities in the region B.

Table III.

(a) (Observations in the A region)

Station	$\frac{\partial^2 W}{\partial x \partial z}$	$\frac{\partial^2 W}{\partial y \partial z}$	$\frac{\partial^2 W}{\partial y^2}-\frac{\partial^2 W}{\partial x^2}$	$2\frac{\partial^2 W}{\partial x \partial y}$	θ_i	$\Delta\theta_i$
Sengataki club	8·07	3·88	−12·22	0·35	49°43′·1	+ 3′·1
Sengataki lectur hall	11·79	5·13	− 8·98	−0·85	49°34′·8	− 5′·5
Kutukake	9·91	1·48	−12·31	6·05	49°21′·2	−19′·1

(b) (Observations in the B region)

Station	$\frac{\partial^2 W}{\partial x \partial z}$	$\frac{\partial^2 W}{\partial y \partial z}$	$\frac{\partial^2 W}{\partial y^2}-\frac{\partial^2 W}{\partial x^2}$	$2\frac{\partial^2 W}{\partial x \partial y}$	θ_i	$\Delta\theta_i$
Asama-kan	20·91	− 7·17	−16·90	−1·61	48°50′·4	− 49′·9
Yunotaira	11·57	− 4·20	− 5·12	−0·44	49° 5′·5	− 10′·2
Tenguno-rozi	4·26	−25·06	− 9·20	2·82	49°28′·9	− 11′ 4
Yunotaira Obs.	−26·91	−14·91	−10·90	−1·33	48°23′·4	−1°16′·9

the second derivatives of the gravitational potential and the dip anomalies at the three stations in region A almost similar to each other, but also the changes in dip anomalies in region A are parallel to those of the Eötvös quantities. On the other hand, these quantities in region B, at four stations, different much from each other and are distinctly larger than those of region A, but the similar tendency in both regions to parallelism of the magnetic anomalies and Eötvös quantities are obvious. Moreover, although region A has a very simple topography, region B has the most complicated topography in Volcano Asama, extending over Kurohu-Yama and Gippa-Yama, the first somma, and the deep valley of the Zyabori river, whereas the parallelism of the two kinds of quantities in the two regions A, B, is almost similar.

In order to further elucidate the gravitational and magnetic properties of Asama, it is hoped that it will be possible to measure the gravity $\left(\frac{\partial W}{\partial z}\right)$ and the other components of the terrestrial magnetism of Volcano Asama.

4. Accuracy of the Present Surveys.

It being known that according to the nature of the instrument, an error of one minute is unavoidable in the values indicated by the dip circle, every care was taken in the present surveys to reduce errors to the minimum, with which object, in the present surveys, the accuracy of observations were tested three times at the station near our Volcano Observatory.

The results of these tests made on October 15 are shown in Table IV, in which in the case of end A of a magnetized needle pointing N,

Table IV.

No.	time	$\theta_i \pm \frac{m.g.\Delta l}{M} \cos\theta_i$	θ_i	$\theta_0 - \theta_i = \Delta\theta_i$
	h m			
1	13 13·0	50° 46′·9	49° 38′·0	−0′·4
2	13 26·0	48° 29′·0	49° 37′·9	−0′·5
3	13 32·0	50° 46′·7	49° 39′·1	+0′·7
4	13 39·5	48° 31′·4	49° 39′·2	+0′·8
5	13 50·0	50° 46′·8	49° 37′·7	−0′·7
6	14 00·0	48° 28′·5	49° 39′·5	+1′·1
7	14 8·0	50° 50′·5	49° 38′·1	−0′·3
8	14 16·0	48° 25′·6		

mean $\theta_0 = 49°38'·4 \pm 0'·4$

m; mass of needle. Δl; deviation of center of gravity.
g; acceleration of gravity. M; magnetic moment of needle.

the values of observation are represented in No. 1, 3, 5, 7, and in the case of the other end B magnetized to point N are shown in No. 2, 4, 6, 8. With the exception of the 6th value, the residuals in the same table are less than one minute, and the probable error of the mean value is only $\pm 0'{\cdot}4$. But, in the measurment of inversion once only, an error of observation of $1'$ may be admissible.

Although the present surveys lasted a fairly long period of time, namely, during the period from May to November, 1937, no corrections of any kind have been made to present results, for the reason that the corrections were of such minute quantities as not to affect the results. On the other hand, one of our main objects is to know the extent to which volcanic activity causes variations in magnetism, when the results must be given the corrections due to daily variations, magnetic storm and the other causes. Moreover, whether or not the lava reservoir, as postulated by H. Nagaoka, really does exist in the neighbourhood of Asama, the distribution of time variations in terrestial magnetism which may be found by comparing the present results with those of observations repeated at intervals should throw some light on this problem.

5. Conclusion.

In this paper, the results are reported of magnetic dip surveys made at 76 stations around the crater of Asama, and it is pointed out that the magnetic dip is affected to a remarkable degree by the topography.

In conducting these surveys, it was fully realized that in observations of this kind, it it neccesary not only to execute the work as accurately as possible, but also, to have as many stations as possible in order to study the underground structure from measurments of gravity and of terrestrial magnetism.

As to the explanation of the dip anomaly, this is scarcely possible until the permeability of the lavas of Asama has been determined. Since the mountain consists of many kinds of lava and lavas that were ejected at various periods, it is natural to expect the presence of lavas of different permeabilities according to the part of Asama whence it is derived. On the other hand, the study of the permeability of Asama is related to the problem how lava of high temperature of about 1000°C at the time of ejection, came to be magnetized with its cooling.

For observing Volcano Asama, besides a variometer for the vertical intensity of magnetism designed by H. Nagaoka[18], at each of two stations, a declination-variometer also at each of the two stations, and a dip-variometer designed by T. Nagata[19] at one station were set up during the year.

18) H. NAGAOKA, *loc. cit.*

19) T. NAGATA, *Bull. Earthq. Res. Inst.*, **15** (1937), 185.

In conclusion, the writer wishes to express his hearty thanks to the Hydrographic Department for the loan of the dip circle and other courtesies shown. He also acknowledges his great indebtedness to the Foundation for the Promotion of Scientific and Industrial Research of Japan, with whose grant the present surveys were made possible.

Table I.

station	height	latitude	longitude	station	height	latitude	longitude
1	1405 m	36°24′14″	138°34′17″	34	790 m	36°19′19″	138°28′38″
2	1530	24′10″	34′50″	35		19′21″	24′39″
3	1392	25′25″	33′43″	36	810	19′19″	25′22″
4	1410	25′ 2″	34′ 8″	37	765	18′59″	27′26″
5	1400	24′33″	34′14″	38	855	19′49″	27′28″
6	1390	23′46″	34′32″	39	820	20′ 5″	26′46″
7	1590	24′17″	33′40″	40	1110	21′20″	28′ 3″
8	1655	24′25″	33′56″	41	1265	22′ 4″	28′27″
9	1630	24′19″	33′52″	42	1395	22′38″	28′47″
10	1400	23′36″	35′00″	43	1560	23′10″	29′39″
11	1205	22′52″	35′30″	44	1640	23′36″	29′57″
12	1060	22′26″	35′24″	45	2020	23′56″	29′59″
13	1020	21′42″	35′24″	46	2030	24′ 9″	30′ 5″
14	1370	25′38″	33′26″	47	1990	23′41″	30′ 7″
15	1375	23′53″	34′18″	48	2005	23′36″	30′13″
16	1660	24′17″	33′26″	49	1345	26′ 1″	33′ 6″
17	1810	24′ 6″	32′54″	50	1315	26′35″	32′17″
18	2060	24′ 2″	32′41″	51	1332	26′ 9″	33′10″
19	2220	23′54″	32′14″	52	1346	26′11″	32′56″
20	2390	24′ 2″	31′43″	53	1315	26′33″	32′30″
21	2560	24′24″	31′35″	54	1245	26′11″	34′42″
22	2555	24′ 7″	31′27″	55	1320	25′35″	34′26″
23	2485	24′ 1″	31′25″	56	1375	24′59″	34′26″
24	1310	23′25″	34′11″	57	1220	21′33″	32′30″
25	1290	22′46″	34′ 6″	58	1370	22′13″	32′19″
26	1250	21′25″	33′34″	59	1600	23′ 4″	31′51″
27	1215	21′47″	32′54″	60	1800	23′28″	31′40″
28	1110	21′ 2″	32′28″	61	2100	23′49″	31′13″
29	1065	20′54″	32′42″	62	2180	23′54″	29′47″
30	1012	20′21″	33′ 2″	63	2300	24′ 1″	29′23″
31	974	20′18″	31′51″	64	2160	23′ 3″	29′ 9″
32	935	20′ 8″	30′43″	65	1540	21′16″	27′17″
33	858	19′57″	29′25″	66	950	21′35″	26′46″

(to be continued.)

Table I. (*continued.*)

station	height	latitude	longitude	station	height	latitude	longitude
67	950 m	36°21′16″	138°26′46″	72	1175 m	36°27′30″	138°32′32″
68		21′35″	35′46″	73	1150	28′ 1″	32′ 8″
69	985	20′24″	35′ 1″	74	1110	28′32″	31′37″
70	955	26′39″	35′21″	75	1045	29′11″	30′56″
71	1255	25′13″	32′30″	76	1220	28′24″	26′48″

Table II.

station	date	time	dip (θ_i)	anomaly ($\Delta\theta_i$)
		h m		
1	June, 11	14 20	49° 31′·2	− 12′·7
2	〃	17 5	49° 40′·4	− 3′·5
3	〃 12	13 25	50° 17′·5	+ 33′·6
4	〃	14 54	50° 21′·5	+ 37′·6
5	〃	16 5	49° 32′·8	− 11′·1
6	〃	17 28	49° 54′·1	+ 10′·2
7	〃 14	11 55	49° 42′·6	− 1′·3
8	〃	13 17	50° 41′·5	+ 57′·6
9	〃	14 26	50° 1′·5	+ 17′·6
10	〃 18	9 45	49° 48′·5	+ 4′·6
11	〃	11 10	49° 43′·1	− 0′·8
12	〃	12 21	49° 39′·1	− 4′·8
13	〃	13 34	49° 34′·8	− 9′·1
14	〃	15 1	50° 36′·1	+ 52′·2
15	〃	17 10	49° 31′·6	− 12′·3
16	〃 19	9 29	50° 9′·6	+ 25′·7
17	〃	10 29	50° 17′·9	+ 34′·0
18	〃	11 37	50° 8′·7	+ 24′·8
19	〃	12 56	51° 14′·5	+1° 30′·6
20	〃	14 18	52° 20′·2	+2° 36′·3
21	〃	16 22	52° 53′·7	+3° 9′·8
22	〃	17 6	53° 5′·5	+3° 21′·6
23	〃 23	12 28	50° 9′·3	+ 25′·4
24	〃	13 52	49° 31′·4	− 12′·5
25	〃	14 54	49° 39′·9	− 4′·0
26	〃	16 4	49° 13′·7	− 30′·2
27	〃	17 5	49° 22′·7	− 21′·2
28	〃	18 8	49° 36′·4	− 7′·5
29	〃 24	9 22	49° 26′·8	− 17′·1

(*to be continued.*)

Table I1. (*continued.*)

station	date	time	dip (θ_i)	anomaly ($\Delta\theta_i$)
		h m		
30	June, 24	10 53	49° 3′·1	− 40′·8
31	〃	12 28	49° 26′·8	− 17′·1
32	〃	14 14	49° 34′·7	− 9′·2
33	〃	15 55	48° 59′·5	− 44′·4
34	〃	15 55	49° 36′·3	− 7′·6
35	〃 28	18 19	50° 4′·6	+ 20′·7
36	〃	12 20	49° 33′·4	− 10′·5
37	〃	14 3	49° 43′·4	− 0′·5
38	〃	15 37	49° 57′·7	+ 3′·8
39	〃	16 55	49° 29′·3	− 14′·6
40	〃 30	12 5	49° 31′·1	− 12′·8
41	〃	13 36	49° 8′·0	− 35′·9
42	〃	15 1	48° 50′ 4	− 53′·5
43	July, 1	16 0	46° 29′·1	−3° 14′·8
44	〃	15 0	48° 23′·4	−1° 20′·5
45	〃	8 35	49° 5′·5	− 38′·4
46	〃	10 1	49° 55′·1	+ 7′·2
47	〃	11 13	48° 51′·9	− 52′·0
48	〃	12 0	49° 28′·9	− 15′·0
49	〃 8	13 53	49° 17′·8	− 26′·1
50	〃	15 0	48° 34′·4	−1° 9′·5
51	〃 9	14 31	49° 19′·3	− 24′·6
52	〃	16 1	50° 12′·5	+ 28′·6
53	〃	15 36	50° 2′·3	+ 18′·4
54	〃 11	16 51	49° 50′·7	+ 6′·8
55	〃	16 1	49° 23′·3	− 20′·6
56	〃	15 10	49° 44′·8	+ 0′·9
57	Sept., 5	9 35	49° 33′·7	− 10′·2
58	〃	10 35	49° 51′·2	+ 7′·3
59	〃	12 3	49° 48′·6	+ 4′·7
60	〃	13 51	49° 34′·2	− 9′·7
61	〃	15 21	50° 20′·8	+ 36′·9
62	〃 6	8 30	50° 11′·3	+ 29′·4
63	〃	11 4	51° 4′·9	+1° 21′·0
64	〃	13 5	53° 15′·5	+3° 31′·6
65	〃	14 20	51° 57′·0	+2° 13′·1
66	〃	15 58	49° 28′·3	− 15′·6
67	〃 7	10 26	50° 38′·3	+ 54′·4
68	〃 14	12 47	49° 20′·4	− 23′·5

(*to be continued.*)

Table II. (*continued.*)

station	date	time (h m)	dip (θ_i)	anomaly ($\varDelta\theta_i$)
69	Sept., 14	13 25	49° 38′.3	− 5′·6
70	〃	14 34	49° 21′·2	− 22′·7
71	Nov., 7	10 11	49° 42′·7	− 1′·2
72	〃	11 5	50° 2′·2	+ 18′·3
73	〃	12 11	49° 30′·1	− 13′·8
74	〃	13 30	49° 37′·8	− 6′·1
75	〃	14 27	49° 52′·6	+ 8′·7
76	8	8 31	49° 59′·0	+ 15′·1

9. 淺間火山の磁氣測量(其の 1)

地震研究所 水 上 武

淺間火山の火口を中心として，76點に於いて磁氣伏角の測定を行ひ地形の影響の著しい事を指摘した．尙又伏角の異常と重力偏差の關係を示し，兩者は略平行する事を示した．磁氣の他の成分の測定並に重力の測定を行ふと共に山體を形成する熔岩の物理的性質の究明は，今後の淺間火山の研究に於いて最も望ましいものの一つである．

今回，測定を施行するに當り，伏角計の使用を許可され，且種々便宜を與へられたる海軍水路部に對し，且又日本學術振興會の補助により，測定を行ひ得た事に對し共に，厚く感謝の意を表す．