7. *Changes in the Vertical Intensity of Geomagnetism that Accompanied the Eruption of Miyakezima, in 1940.*

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1. *Introduction.*

Soon after the eruption of Komagatake, Hokkaido, in 1929, S. M. Nakamura[1] executed a magnetic survey around the volcano, using a dip-circle. Since then, the survey was repeated once every year until 1937, with the remarkable discovery that a conspicuous change, sometimes amounting to thirty minutes in the magnetic dip, occurs with the activity of the volcano.

Y. Kato[2] has pointed out, by means of a bold and ingenious contouring technic, that these changes in magnetic dip are closely related to the topographic changes caused by the eruption. After studying the results of six magnetic surveys made since 1882, each covering the whole of Japan, he[3] discovered also some changes in the magnetic elements that seem to have been related to the activities of Azumayasan during 1893~96, of Adatarasan during 1899~1900, of Zaosan during 1918~25 and 1894~97, of Ususan and Tarumaisan in 1893, 1909~19, of Komagatake, Hokkaido, during 1919~24, and of Sakurazima and Asosan in 1914.

In the recent eruption of the volcanic island, Miyakezima, on July 12, the writers executed magnetic surveys of the island, using a vertical intensity magnetometer, with the object of detecting changes in the vertical intensity of geomagnetism that usually accompany eruptions, all eventually to furnish some clue for elucidating the mechanism of volcanic eruptions.

The writers will begin with a short note on the recent eruption of Miyakezima. This island volcano, situated about 100 km south of Tokyo, belongs to the Huzi volcanic chain, and is one of the seven islands of

1) S. T. NAKAMURA, *Proc. Imp. Acad.*, **11** (1935), 102.
2) Y. KATO, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 1, **27** (1938), No. 1.
3) *loc. cit.*, *Disin*, **5** (1933), 156, 573.

Idu Province. The island, which is circular, about 8km in diameter, is a cone-shaped stratified double volcano, having a somma, and a central cone called Oyama, standing about 800 m above sea level. It is of basaltic augite andesite and olivine two-pyroxene andesite. Before the recent eruption, there were three craters on the central cone, each 300m∼500m in diameter, lying side by side in an E—W direction. The volcano was dormant until the recent eruption.

The recent activity began on July 12, 1940, with a sort of fissure eruption on the eastern slope of the island. A number of craterlets were opened in two lines from a height of about 500m down to the sea, where a new cinder cone, 60 m high, was formed, filling up the bay of Akabakke. This new hill, afterwards named Hyôtanyama, consists of ashes, scoriae, bombs, and lava bearing large phenocrysts of anorthite.

From the craters on the slope of the island, molten lava poured out and flowed down the valleys, forming two lava streams. They are of basaltic block lava, without any visible phenocrysts. One of the lava flows, the northern, flowed into the sea, burying the hamlet of Simasita on the northern shore of Akabakke bay, and joined Hyotanyama, a broad lava field, forming a new land, 800m wide and 1km long, projecting into the sea. Besides these lava flows, scoriae, ashes, and bombs were projected from the craterlets just mentioned in such quantities that the topography of the neighbourhood was completely altered.

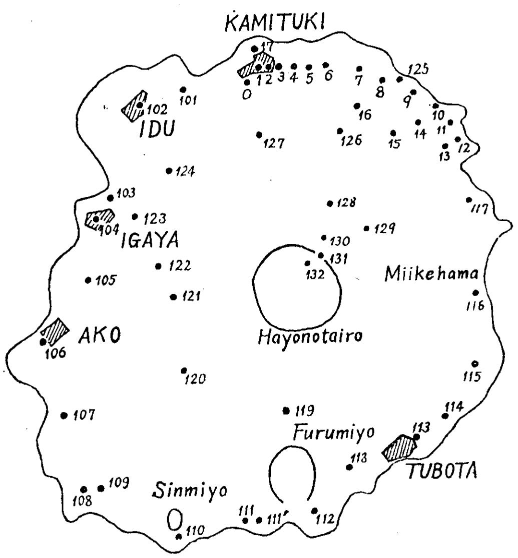
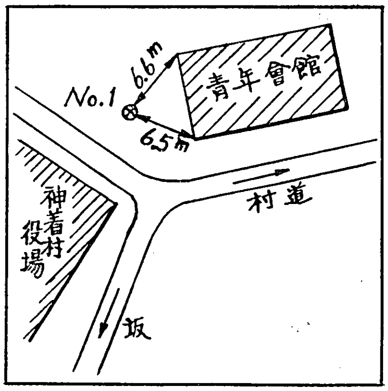
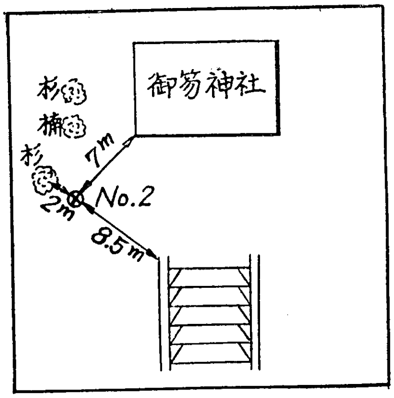


Fig. 1. Positions of stations.

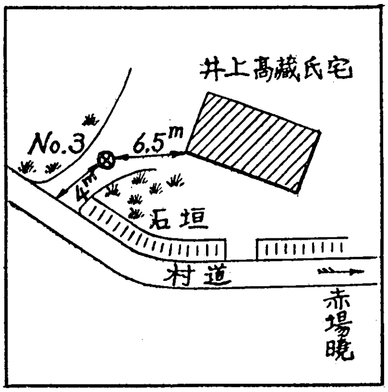
These eruptions from the eastern slope of the island ceased in the evening of July 13, the day following the outbreak, but from July 14, activity shifted to the central cone, Oyama. This eruption of the central cone, however, developed very gradually, attaining maximum violence on and after July 25, and continued till the early part of August. Filling up the old craters on the central cone, a lava flow and a cinder cone, 50m high, had formed, besides accumulations of ashes, scoriae, and bombs.



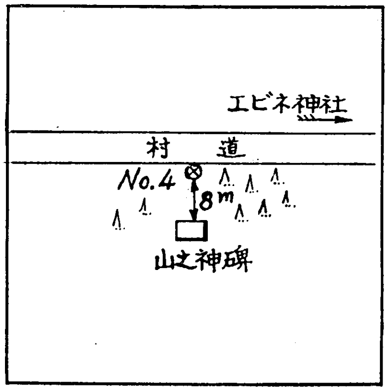
Station No. 1. Kamituki-m.
Young Men's Hall.



Station No. 2. Kamituki-m.
Osyaku shrine.



Station No. 3. Kamituki-m.
Mr. T. Inoue's garden.



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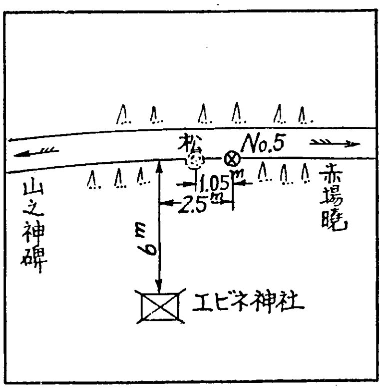
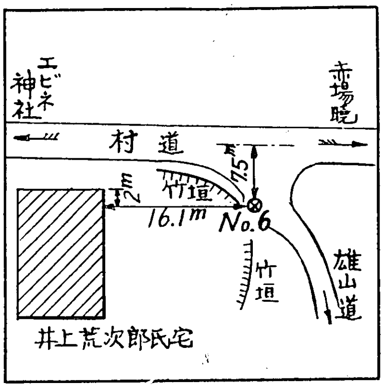
Yamanokami.

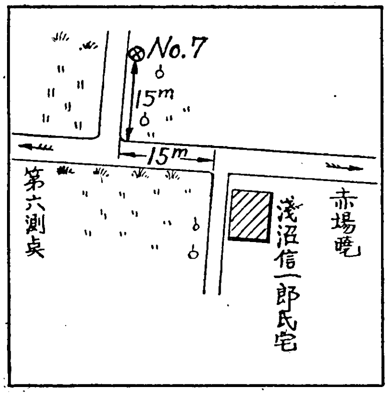


Station No. 5. Kamituki-m.
Ebine shrine.



Station No. 6. Kamituki-m.
Mr. A. Inoue's garden.

Fig. 2a.



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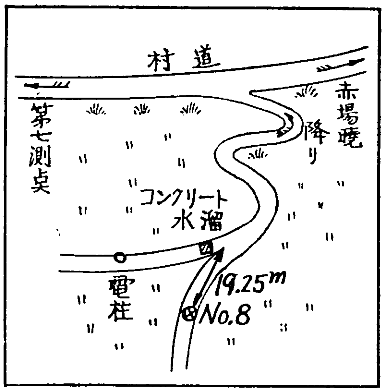
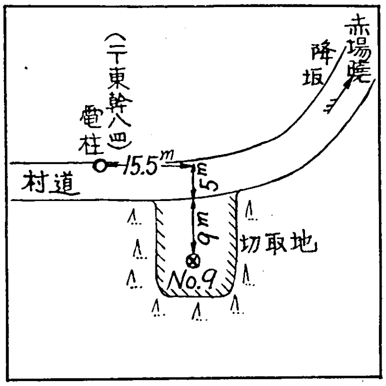
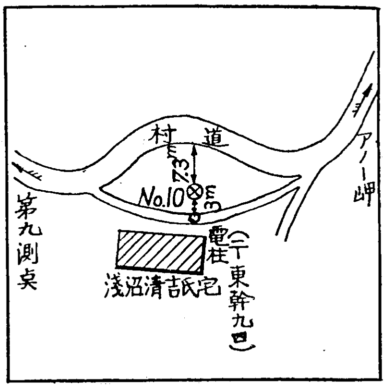
Nadaado.



Station No. 8. Kamituki-m.
Minowa.



Station No. 9. Kamituki-M.
Hôdai.



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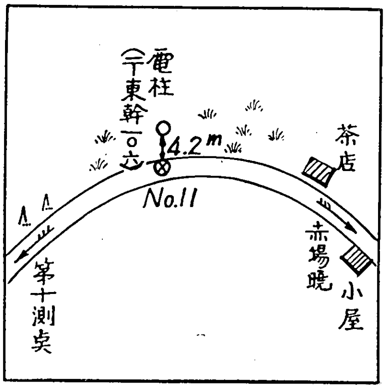
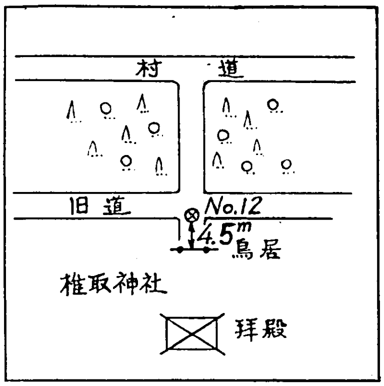
Kamanosiri.

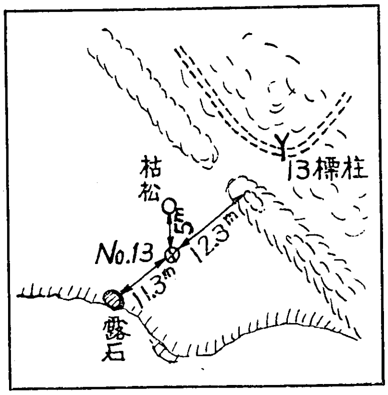


Station No. 11. Kamituki-m.
Cape of Nisiano.

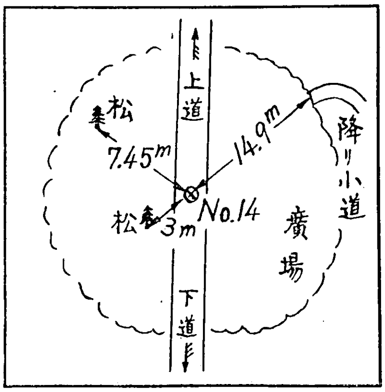


Station No. 12. Kamituki-m.
Siitori shrine.

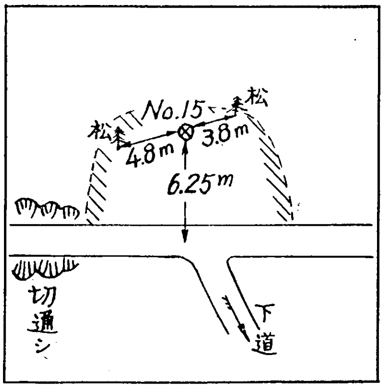
Fig. 2b.



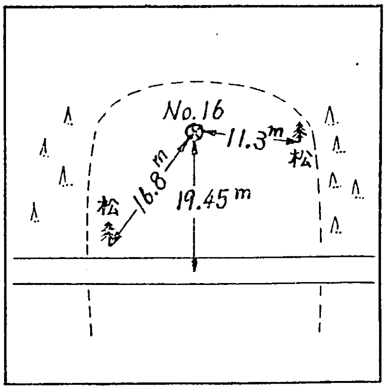
Station No. 13. Kamituki-m.
The new lava flow.



Station No. 14. Kamituki-m.
Takenoo.



Station No. 15. Kamituki-m.
Uemiti.



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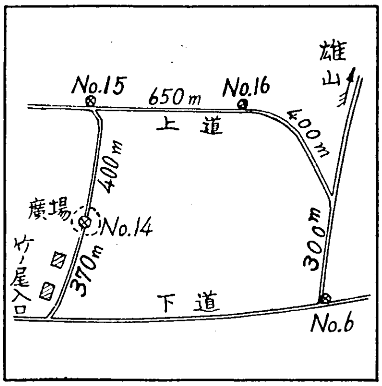
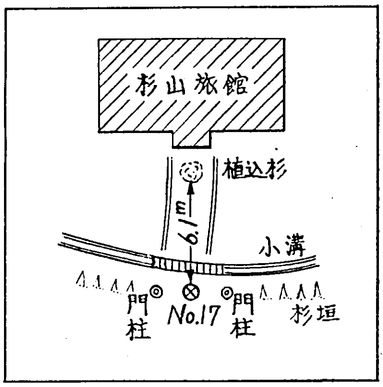
Nadaado Ue.

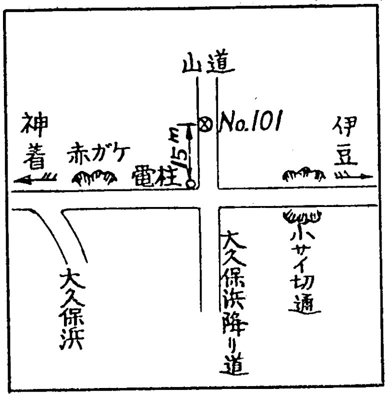


Stations Nos. 6, 14, 15, 16.

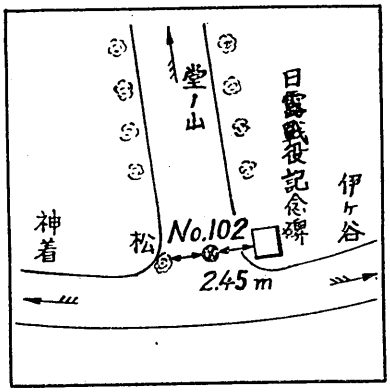


Station No. 17. Kamituki-m.
Sugiyama Hotel.

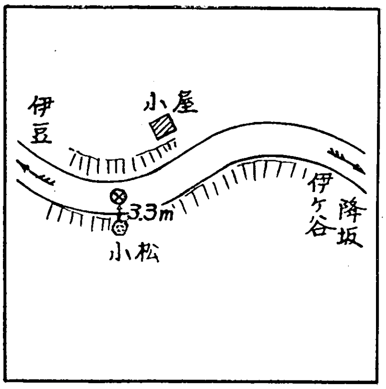
Fig. 2c.



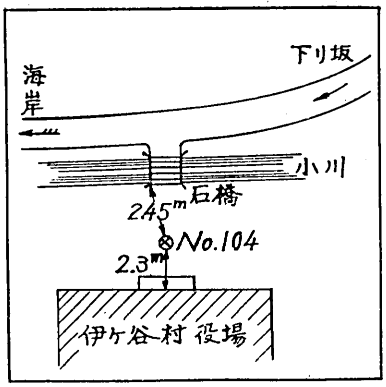
Station No. 101. Kamituki-m.
Okubohama.



Station No. 102. Idu-m.
Monument.



Station No. 103. Igaya-m.



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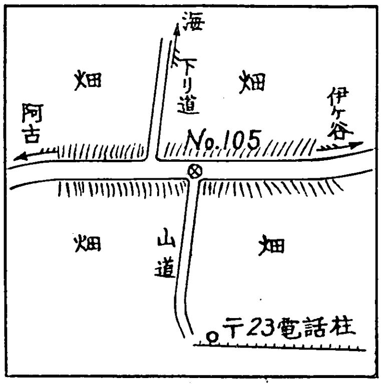
Public Office.



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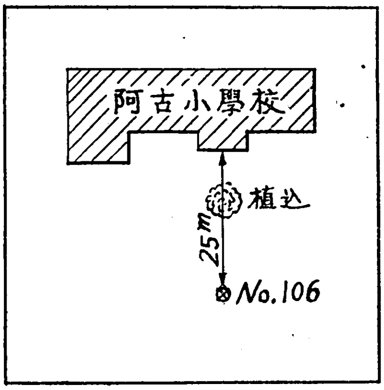
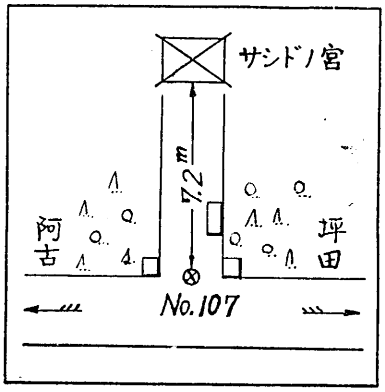


Station No. 106. Ako-m.
Primary School.

Fig. 2d.



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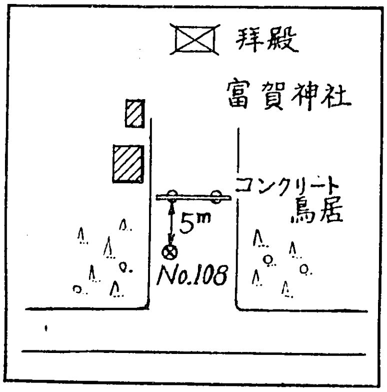
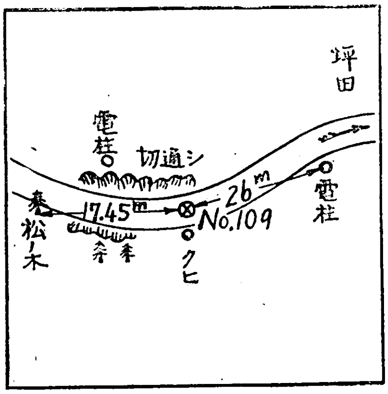
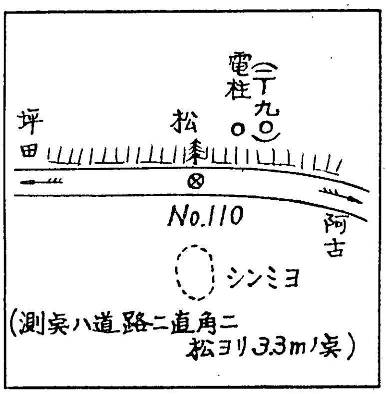
Sabinohama.



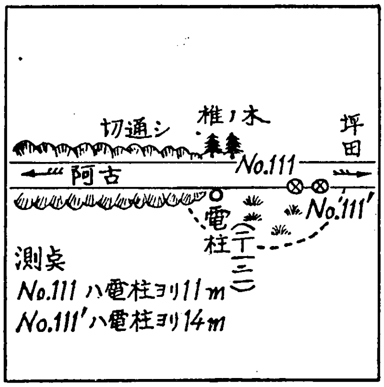
Station No. 108. Ako-m.
Toga shrine.



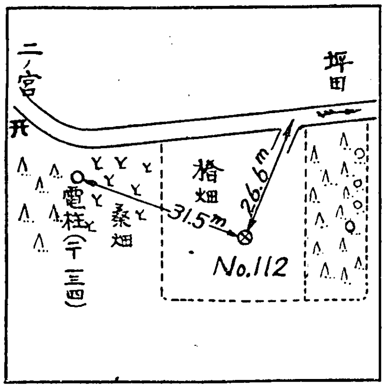
Station No. 109. Ako-m.
Upw. of Toga shrine.



Station No. 110. Ako-m.
Sinmiyo.

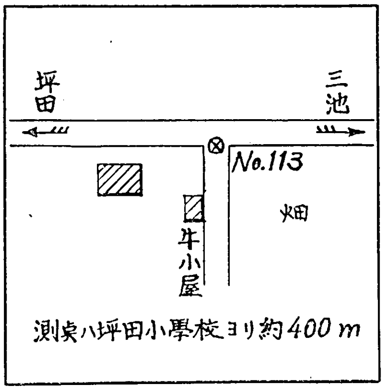


Stations Nos. 111 and 111'.
Boundary bet. Ako & Tubota.

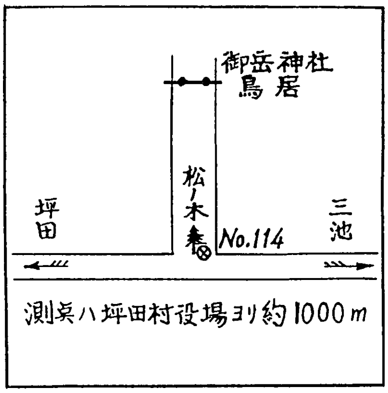


Station No. 112. Tubota-m.
Ninomiya.

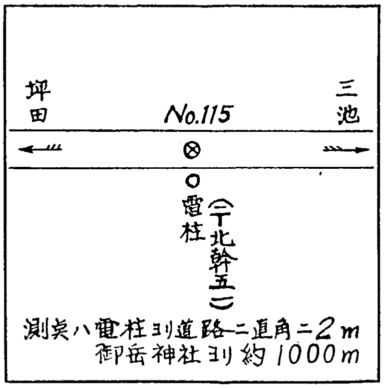
Fig. 2e.



Station No. 113. Tubota-m.



Station No. 114. Tubota-m.
Mitake shrine.



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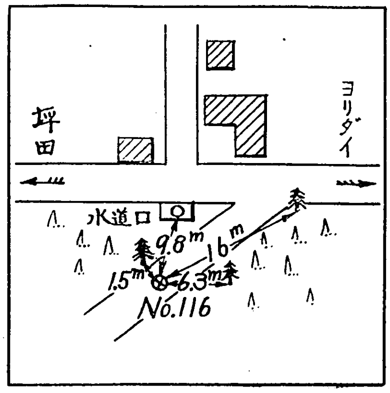
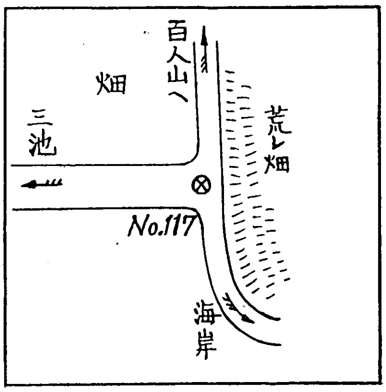
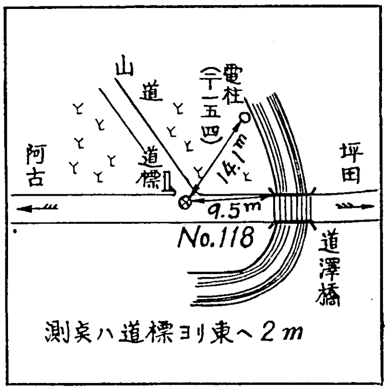


Station No. 116. Tubota-m.
Miikehama.

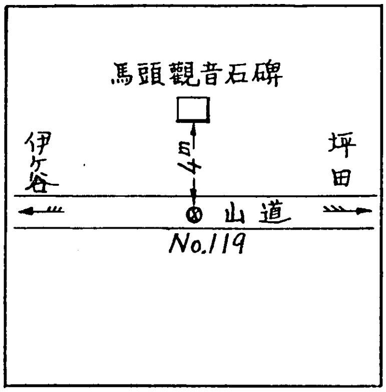


Station No. 117. Tubota-m.
Yoridaisawa.

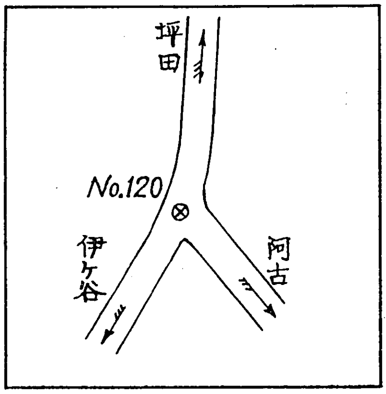


Station No. 118. Tubota-m.
Entrance to Goyômiti.

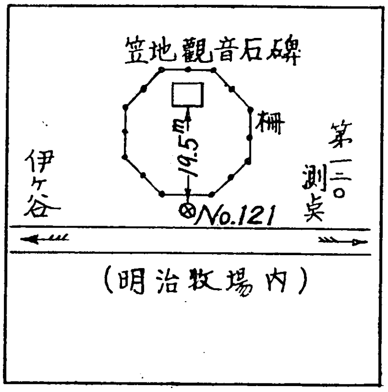
Fig. 2f.



Station No. 119. Tubota-m.
Batô Kannon.



Station No. 120. Branch point of Ako and Igaya-m.



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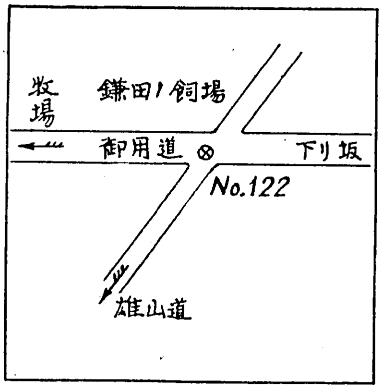
Kasadidaira.



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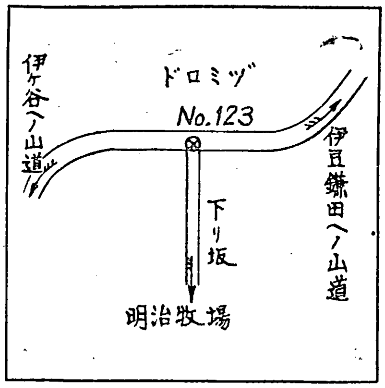
Kamata.



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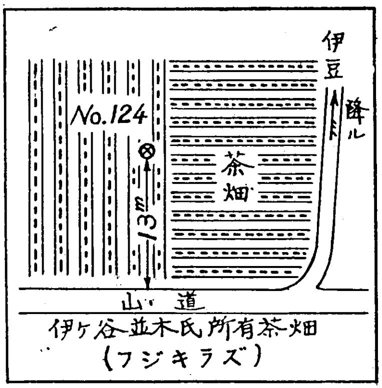
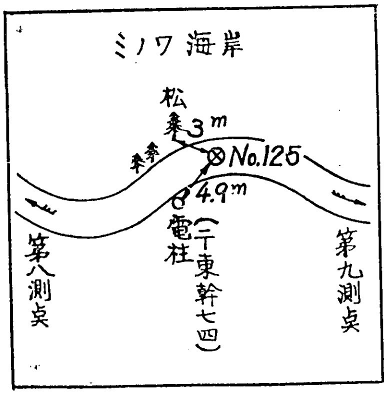
Doromidu.

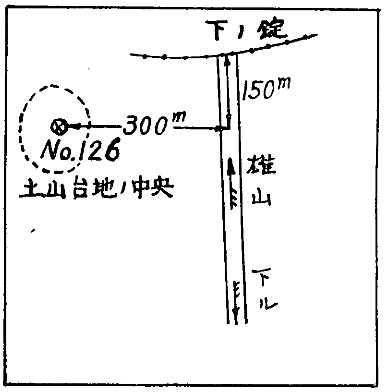


Station No. 124. Igaya-m.
Huzikirazu.

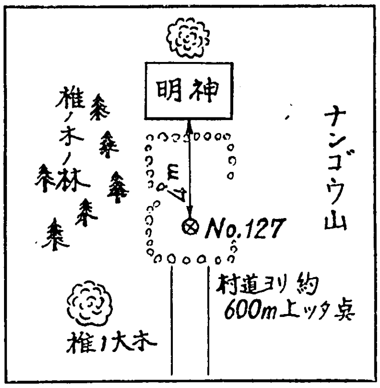
Fig. 2g.



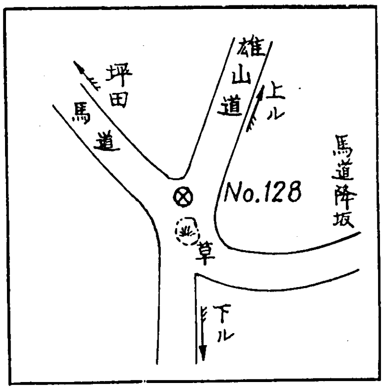
Station No. 125. Kamituki-m. Minowa.



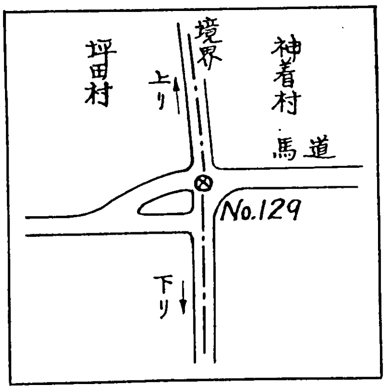
Station No. 126. Kamituki-m. Kazahaya. (Sumiya no tairo)



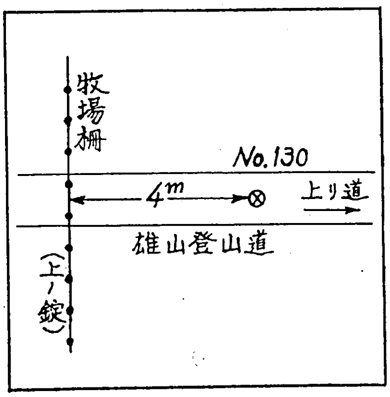
Station No. 127. Kamituki-m. Nango shrine.



Station No. 128. Kamituki-m. Umamiti.

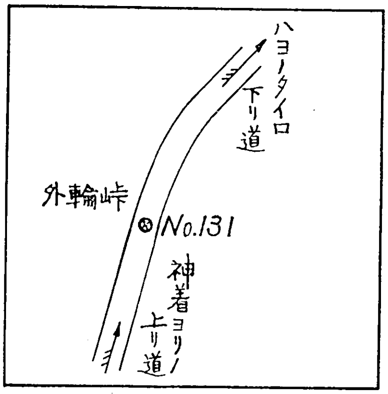


Station No. 129. Boundary of Kamituki-m. and Tubota-m.

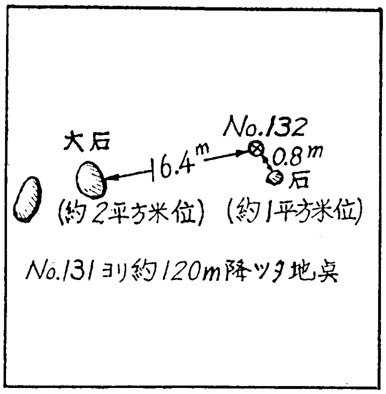


Station No. 130. Tubota-m. Ue no Zyô.

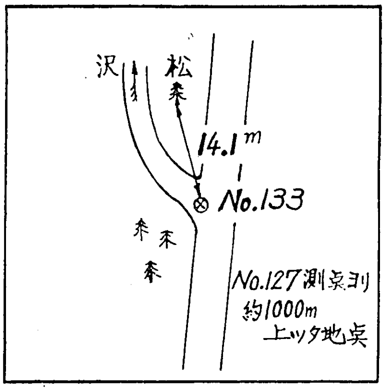
Fig. 2h.



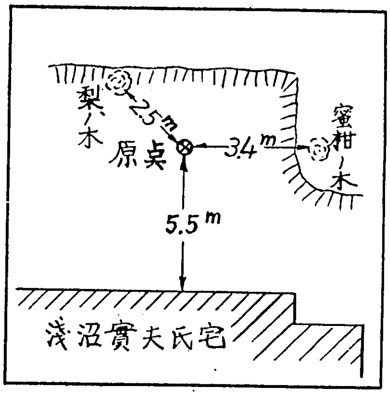
Station No. 131. A pass on the somma.



Station No. 132. Hayonotairo.



Station No. 133. Kamituki-m. Attakayama.



Station No. 0. Kamituki-m. Mr. Asanuma's garden.

Fig. 2i.

2. *Survey.*

The writers attempt here to describe the requisites in geomagnetic surveys that are made with the object of detecting changes in the distribution of the magnetic elements. The first requisite in such surveys is to have the observing stations distributed as close to one another, and in the most uniform distances apart, possible, because the greater the number of stations, the more minutely can the changes in the distribution be detected. In the surveys cited above, the number of stations were so few, being only 10 even in the case of Komagatake, that scarcely anything could be learned of what happened under the ground. Since, on the other hand, increase in the number of stations means increased time and cost, there is a limit in some cases to the number of stations that can be used. The writers think that for a volcano, several scores of stations are necessary.

The second requisite is that the stations shall be occupied exactly in the same way for each survey. Not only the horizontal positions, but the height of the instrument also must be the same as that in previous surveys. In volcanic regions, it is not seldom that a difference in position of only a few decimeters will result in so large a difference in the magnetic dip as several scores of minutes. In this respect, such places must be selected for stations as represent the mean topography of its neighbourhood. Ridges, valleys, and edges of lava flows must be avoided. It is best to make measurements at three or four points, a few meters distant from one another, to certify that the magnetic gradient is not large. Station marks must, preferably, be a group of pegs, otherwise they are lost after a few years. Every possible care must be taken to keep the station marks intact, because the accuracy of the re-survey depends entirely on whether the station marks exist or not.

As to the instrument, the best is a vertical intensity variometer or an earth inductor. With a dip circle, an error of 1~2 minutes is unavoidable, even in the best of conditions. Under bad conditions, such as rain, snow, wind, or ash precipitation, unexpectedly large errors are liable to be introduced into the observed values. If the probable error of a survey is 3′, the probable error in the difference of two surveys will amount to 5′, which, in the case of a vertical intensity variometer, corresponds to an error of 50 gammas.

The effects of magnetic storms and of the daily variation must be considered, especially when the changes sought are not large. With a station instrument that records continuously the variations in the magnetic elements, the troubles just enumerated are inmaterial, so that it is adequate for ascertaining the existence of magnetic variations that accompany the eruption of a volcano. As a matter of fact, T. Minakami[4] and T. Nagata[5] observed changes in dip and declination at volcano Asama with station instruments.

3. *Stations and Instruments.*

In the present survey, there were 50 stations, the reason for this comparatively small number being that the survey could then be completed in a short time, during which period the condition of the eruption and the

4) *Bull. Earthq. Res. Inst.*, **13** (1935), 799.
5) *Disin*, **10** (1938), 221.

conditions of the phenomena underneath the volcano may be regarded as having been alike. The distribution of stations in the island is shown in Fig. 1. The numerals denote the serial numbers of the stations. For lack of roads, the stations, to our regret, are somewhat scanty on the southeastern side of the island, notwithstanding our desire for uniform distribution. In the reconaissance work, due attention was paid to the geology as well as to the topography of the sites, selected for the stations. With a view to shortening the time required for survey, the magnitude of the space gradient in the geomagnetism was not measured at all the stations, but every caution was taken to occupy exactly the same position in every measurement. The distances of the station peg from the corners of neighbouring buildings, trees, etc., were measured in anticipation of possible accidents by which the station marks may get lost. Sketch maps were made of each station, and photographs taken. These are shown in Figs. 2 a∼2 i and in Pl. I, Fig. 3.

A vertical intensity magnetometer, designed by one of the writers, was used in the present survey. The magnetometer can be modified by a simple procedure into a horizontal intensity variometer. The moving magnet system of the instrument was reconstructed just before the outburst of Miyakezima, the compensation adjustment for temperature not yet being complete. In these circumstances it was decided to determine the temperature coefficient of the instrument in the field, and to correct the reading according to the coefficient thus determined. Although our instrument is capable of being adjusted to any sensitivity, it was kept sealed during the intervals from the beginning of the first survey to the end of the second, in order that neither sensitivity nor the zero-point shall suffer the slightest change. The sensitivity of the instrument was adjusted to 82·5 gamma/division at the beginning of the first survey, under the expectation that in such a volcanic island as Miyakezima, which is built up of basaltic lava and ashes, the magnetic anomaly would sometimes be very large. The total range that can be measured without using a compensating magnet amounts thus to 8000 gammas, so that the compensating magnet, the moment of which is 210 c.g.s., was not necessary for any of the stations except No. 130. The sensitivity of the instrument was measured by means of a Helmholtz coil several times during the surveys.

4. *Corrections.*

(a) Correction for the air temperature. As just mentioned, because the temperature compensation adjustment of the moving system of the magnetometer was incomplete, the temperature coefficient was determined in the field. The magnetometer was installed at a station, and its readings and those of the thermometer attached to the instrument were taken from time to time. The following is an example of such readings. In order to avoid the effect of diurnal variation, several series of such readings were taken at various times of the day. The most probable temperature coefficient thus determined and adopted was 47·8 gamma/1°C, or 0·58 div./1°C, converted into the sensitivity used

Table I.

July 17 Fine.

Reading (E)	Temperature	Time	Remarks
20·8	26·°0C	6^h 10^m	
22·4	27· 0	30	
22·7	27· 3	45	
22·9	27· 5	7 00	Sensitivity 13·31 gamma/div.
24·3	29· 0	16	
33·0	32· 2	45	
32·2	31· 0	8 00	
35.2	32· 5	10	

during the surveys. The compensation was excessive, that is, the reading increased with the temperature. Since the temperature variation during the survey was 6～7°C at the most, an error of 10 gamma/div. in the determination of the temperature coefficient introduces into the observed values only an error of less than 60～70 gammas, the same order of error as that from the diurnal variation. Since the changes in the vertical intensity detected by the present surveys reaches ten times this amount, the general situation of the change would scarcely be affected even if there were an error of this order in the adopted temperature coefficient.

(b) Changes in vertical intensity at the reference station. In such magnetic surveys as this, it is a common practice to make measurements every day at one and the same station that has been selected for the reference station, both before and after the measurements have been made at the other stations. The reason for this procedure was to ascertain whether or not changes had occurred in the zero value and sensitivity of the magnetometer during the day's journey. Since, in the present case, the vertical intensity is expected to change at the reference station as well as at other stations, it is necessary to know the extent to which the vertical intensity has changed at the reference station.

For this purpose, the mean values of the daily morning and evening readings, each corrected for temperature, were plotted against time. The result showed, as indicated in Fig. 4, in which the oridinate is arbitrary, that the vertical intensity at the reference station decreased for the period July 20～25, and then increased. It is interesting that this tendency was also discovered in variations in the magnetic dip observed by T. Nagata[6] and T. Minakami[7] at Hôdai, 1·5 km east of our reference station. Similar variations were also observed by T. Hagiwara[8] in the earth current at Kamituki. The decrease of 55 gammas in the vertical intensity, shown in Fig. 4, corresponds to a decrease of 9′ in the dip.

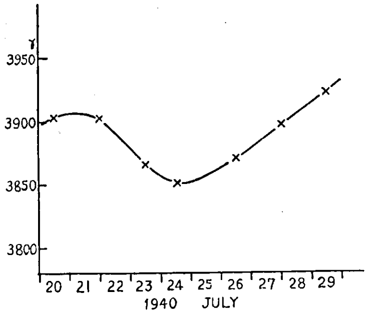


Fig. 4. Change in the vertical intensity of geomagnetism at the reference station.

Since the vertical intensity at the reference station was already subject to variations as stated above, it was decided to denote the vertical intensity at the various stations by values relative to the value of the reference station at 0^h on July 25. The difference of the morning and evening values at the reference station, which still remains after the correction is made for temperature, is mainly due to the diurnal variation in geomagnetism. This difference was accordingly distributed to the observed values of that day in proportion to the time elapsed.

(c) Geomagnetic storms. The first survey was made during the period July 20～24, and the second during the period July 26～29, the stations being occupied in entirely the same order as that in the first survey. During these periods of surveys there was fortunately no magnetic storm greater than 50 gammas. Since in the present surveys, the magnetometer, as mentioned above, was adjusted to a very low sensitivity, there is no need to take any account of such small magnetic storms.

5. *Results of the surveys.*

The results of the surveys are shown in Fig. 5 and in Table II. These values are already corrected for temperature and diurnal variation. In Fig. 5 are given the result of the of the first survey. In the figure,

6) *Disin*, **12** (1940), 12.
7) *Ditto*, 18.
8) *Ditto*, 44.

contour lines are drawn at intervals of 1500 gammas. The negative parts are shaded by a fine mesh, and the parts greater than 3000 gammas by thick diagonal lines.

In volcanic regions, there are usually so many intense local anomalies that the contour-lines given in Fig. 5, being based on only 50 measurements, do not necessarily show the real anomalies. Considering however that due attention was paid to selecting the positions of the stations, the writers believe that they represent to some extent the general trend of the disribution of the vertical intensity of the earth's magnetism. It is interesting that the contour-lines curve inward at the old explosion craters

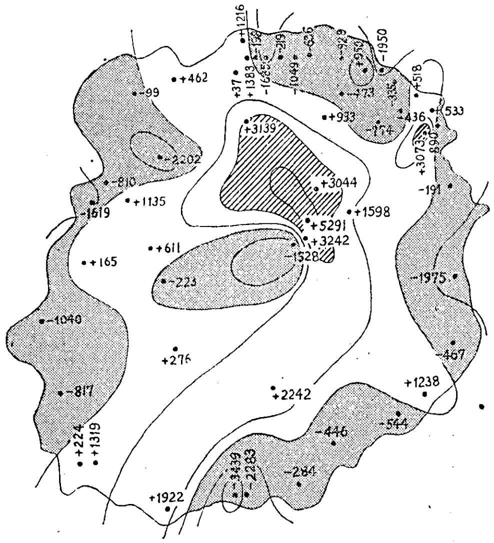


Fig. 5. Distribution of vertical intensity. Unit=γ.

Table II.

Nos. of Station	Locality		I	II	II—I
	(Kamitukimura)	(神着村)			
0	Mr. Asanuma's garden	淺沼方庭	+ 37 γ	+ 8 γ	− 29 γ
1	Young Men's Hall	青年會館	+1383	—	—
2	Osyaku shrine	御笏神社	− 198	− 188	+ 10
3	Mr. Inoue's garden	井上高藏方庭	−1685	—	—
4	Yamanokami	山神碑前	− 219	− 79	+ 140
5	Ebine shrine	エビネ神社前	−1049	—	—
6	Mr. A. Inoue's garden	井上荒次郎方前	− 636	− 570	+ 66
7	Nadaado	ナダアド	− 929	—	—
8	Minowa	三ノ輪入口	+ 950	+ 941	− 9
9	Hôdai	砲臺	− 335	− 347	− 12
10	Kamanosiri	釜ノ尻	+ 518	+ 545	+ 27
11	Cape of Nisiano	西アノー岬	+ 533	+ 512	− 21
12	Siitori shrine	椎取神社前	− 890	− 880	+ 10
13	Beside the new lava flow	新熔岩脇	+3073	—	—
14	Takenoo	竹ノ尾	− 436	− 240	+ 196
15	Uemiti	上道	− 774	− 818	− 44

(*to be continued.*)

Table II. (*Continued.*)

Nos. of Station	Locality		I	II	II−I
16	Nadaado Ue	ナダアド眞上	− 473 γ	− 434 γ	+ 39 γ
17	Sugiyama Hotel	杉山旅館	+1216	+1140	− 76
101	Okubohama	大久保濱上	+ 462	+ 454	− 8
	(Idumura)	(伊豆村)			
102	Monument	伊豆村	− 99	− 79	+ 20
	(Igayamura)	(伊ケ谷村)			
103	Igayamura	伊ケ谷へ下り口	− 810	− 777	+ 33
104	Public Office	伊ケ谷役場	−1619	—	—
105	Igayamura	伊ケ谷阿古間	+ 165	+ 152	− 13
	(Akomurna)	(阿古村)			
106	Ako Primary school	阿古小學校	−1040	− 950	+ 90
107	Sabinohama	錆ノ濱	− 817	− 835	− 18
108	Toga shrine	富賀神社	+ 224	+ 206	− 18
109	Upward of Toga shrine	富賀神社上	+1319	—	—
110	Sinmiyo	新ミヨ	+1922	+1907	− 15
111	Boundary btw. Ako and Tubota	坪田，阿古境	−3439	—	—
111′	Do.	同上	−2283	−2305	− 22
	(Tubotamura)	(坪田村)			
112	Ninomiya	二ノ宮	− 284	− 203	+ 81
113	Tubotamura	坪田村	− 544	− 529	+ 15
114	Mitake shrine	御岳神社	+1238	+1337	+ 99
115	Btw. 114 and 116	御岳，三池間	− 467	− 509	− 42
116	Miikehama	三池濱	−1975	−2033	− 58
117	Yoridaisawa	ヨリダイ澤	− 191	− 207	− 16
118	Entrance to Goyomiti	御用道入口	− 446	− 387	+ 59
119	Bato Kannon	馬頭觀音前	+2242	+1734	− 508
120	Branch pt. of Ako and Tubota	坪田阿古分岐點	+ 276	+ 214	− 62
121	Kasadidaira	笠地平	− 223	− 360	− 137
	(Igayamura)	(伊ケ谷村)			
122	Kamata	鎌田飼場	+ 611	+ 416	− 195
123	Doromidu	泥水	+1135	+1040	− 95
124	Huzikirazu	藤不切	−2202	−2293	− 91
	(Kamitukimura)	(神着村)			
125	Minowa	三ノ輪	−1950	−1751	+ 199
126	Kazahaya	風早	+ 933	−1045	+ 112
127	Nango shrine	南郷祠	+3139	+3130	− 9
128	Umamiti	雄山馬道	+3044	+2893	− 151
129	Boundary of Kamituki and Tubota	坪田，神着境界	+1598	—	—
	(Tubotamura)	(坪田村)			
130	Ue no Zyo	上ノ錠	+5291	+5061	− 230
131	Pass on Somma	外輪頂上	+3242	+3029	− 213
132	Hayonotairo	八丁平	−1528	−1741	− 213

of Miikehama, Midutamari, Hurumiyo, etc., and at the attrio of Hayonotairo, as also that the positive anomalies on the northern slope of the volcano coincides with the region of activity in 1874.

The difference in the first and second surveys is shown in Fig. 6. The parts in which the differences are less than -100 gammas, and those in which the variations exceed $+100$ gammas are shaded differently. It is remarkable that the figure shows a large negative area of oval shape, extending from the center to the southern half of the island, and also a small positive zone of elliptic shape at the northern part of the island. The maximum and minimum values of these variations are 120 and 500 gammas respectively.

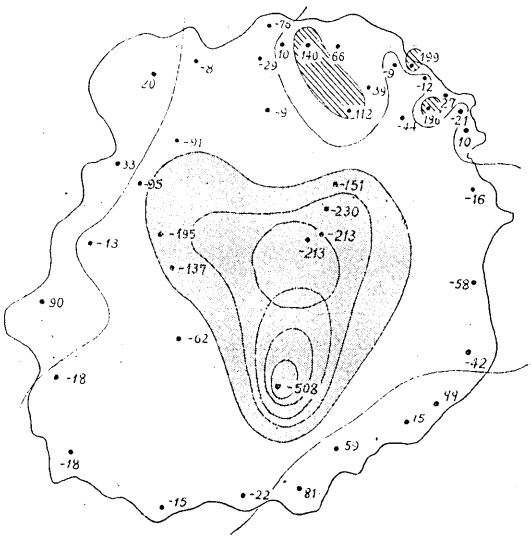


Fig. 6. Changes in the vertical intensity (II—I) Unit=γ.

6. *Interpretation of the result.*

We shall now consider the changes in the condition under the volcano that have caused these changes in the vertical intensity of geomagnetism. Miyakezima is a conical volcanic island. Since the coastline of the island is nearly circular, 8 km in diameter, and its height about 800 m above sea level, the island is aptly represented by a cone of gradient 1 in 5. We take the origin of the coordinate at the summit, the x-axis to the north, and the y-axis to the east, and the z-axis downward. We shall assume that a spherical part of radius R, of which the centre is at $x=0$, $y=0$, and $z=t$ km, has been heated and thus lost its magnetic properties. Because rocks have comparatively small susceptibility, it is obvious that the above assumption is equivalent, in the first approximation, to assuming that the susceptibility of the surrounding rocks is zero, while that of the spherical part changes from zero to $-k$. The change in the geomagnetic elements that ought to be observed at a point $(x,\ y,\ z=\frac{1}{5}\sqrt{x^2+y^2})$ on the surface of the cone is given by

$$\left.\begin{aligned}
\varDelta Z&=\frac{\frac{4}{3}\pi kR^3}{1+\frac{4}{3}\pi k}\frac{V_0}{r^5}\left[x^2+y^2-2(t-z)^2+3\frac{H_0}{V_0}x(t-z)\right],\\
\varDelta X&=\frac{\frac{4}{3}\pi kR^3}{1+\frac{4}{3}\pi k}\frac{H_0}{r^5}\left[-2x^2+y^2+(t-z)^2+3\frac{V_0}{H_0}x(t-z)\right],\\
\varDelta Y&=\frac{\frac{4}{3}\pi kR^3}{1+\frac{4}{3}\pi k}\frac{H_0}{r^5}\left[-3xy+3\frac{V_0}{H_0}y(t-z)\right],
\end{aligned}\right\}\qquad(1)$$

where $r^2=x^2+y^2+(t-z)^2$; H_0, V_0 are the horizontal and vertical intensities of the original earth's magnetic field, $\varDelta X$, $\varDelta Y$, $\varDelta Z$, the x-, y-, and z-components of the change in the geomagnetism, and $z^2=\frac{1}{25}(x^2+y^2)$.

With this formula, it is easy to calculate the variations respectively in the magnetic declination, dip, horizontal, and vertical intensities.

According to measurements made by the Hydrographic Department of the Imperial Japanese Navy,[9] the geomagnetic elements at the following stations in Miyakezima are

Locality		δ	i	H_0	Epoch
Okubohama	(大久保濱)	5° 22′	46° 11′	31408 γ	Jan. 28, 1933
Akabakke	(赤 場 曉)	3 52	44 01	31346	
Ako	(阿 古)	3 49	48 18	29396	
Tubota	(坪 田)	5 41	48 01	30213	

It may therefore be safely assumed that $H_0=V_0=30000\gamma$, $i=45°$, in the formula just given. The susceptibilities of all the rocks of Miyakezima, as measured by Nagata,[10] are nearly 2×10^{-3}. Adopting this value for k, and assuming $t=3$ km, $R=2{\cdot}7$ km., $\varDelta Z$, $\varDelta H$, and $\varDelta i$[11] were evaluated with results as shown in Figs. 7 and 8. $\varDelta Z$, $\varDelta H$., and $\varDelta i$ are symmetric with respect to the x-axis.

9) *Bull. Hydr. Dep. Imp. Jap. Navy*, **8** (1936), 316

10) *Disin*, **12** (1940), 524.

11) $\varDelta i=\cos^2 i_0\left(\frac{\varDelta V}{H_0}-\frac{\varDelta H\cdot V_0}{H_0^2}\right)=\frac{1}{2H_0}(\varDelta V-\varDelta H)$

Comparing Figs. 7 and Fig. 6, it is surprising that the two figures are very similar, not only in regard to the distribution of positive and

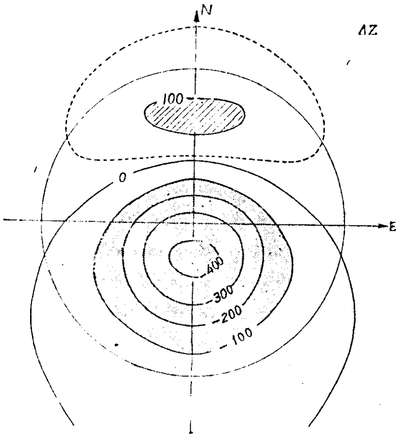


Fig. 7. ΔZ. Unit=γ.

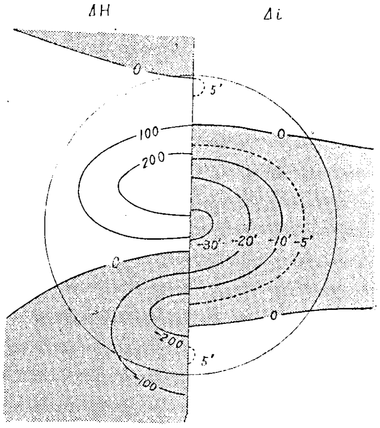


Fig. 8. ΔH and Δi. Unit=γ.

negative areas, but also in regard to their values. It may be said that the measured change in the vertical intensity is thus satisfactorily explained. The results of the surveys show therefore that a spherical part, 3 km beneath the summit of the volcano, had become heated above the Curie point about July 25, that is, between the time of our first and second surveys. We shall now compare this consideration with the development of the eruption. As already mentioned, the fissure eruption that took place on the eastern slope of the island ceased entirely in the evening of July 13, but on July 15, the activity shifted to the central cone Oyama. This central cone eruption developed, however, very slowly. On July 18, when the writers descended to the bottom of Oana, the largest of the three craters on the central cone, the eruption was still in its very in itial stage; only hot gases being seen rising with a hissing noise from a new pit opened in the NE corner of the crater bottom of Oana. Since, at this time, no solid material was being ejected, the centre of the crater bottom of Oana could be reached quite safely. This new pit however gradually enlarged, and on July 20 began to throw up lava blocks. Two more new craters then opened SW of the first crater, and, when the writers ascended the volcano on July 25, a beautiful day, they saw fountains of incandescent lava rising high into the sky from a lava pool in the westernmost crater. The central cone eruption was thus in a developing stage until July 25, after which the eruption attained maximum violence, a large cinder cone, 50 m high, having arisen later from the site of the lava fountain just mentioned.

The underground conditions may be regarded as having then been all "set" for the eruption. That is, underneath the central cone, the rocks seem to have been gradually melting, or magma had been stoping up until July 25, when the melting or stoping had completed. Our surveys were executed, fortuitously, during the most favourable time for observation imaginable.

Simultaneously with these underground changes, the seismicity of the island had shown marked changes. According to micro-seismic observations made by Minakami,[12] the volcanic earthquakes ceased after July 25, and in lieu of the earthquakes, volcanic tremors of large amplitude were observed on that day and since. This is very interesting, seeing that a volcanic earthquake is caused by the stoping or intrusion of magma, whereas volcanic tremors are caused by superficial activities in the crater.

Since in equations 1, the value of k^3R, not R, is determined from the observed changes in the vertical intensity of geomagnetism, there is something arbitary about the radius R of the spherical part stated above. According to Nagata,[13] the basalt of Miyakezima has thermo-remanent magnetism in the direction of the present geomagnetic field, the intensity of magnetisation being 10 to 20 times that due to the induced magnetism. If this is so, even in the depth of the volcano, we have to take for k the value $2\times10^{-2}\sim4\times10^{-2}$, R decreasing accordingly to $1{\cdot}2\sim1{\cdot}0$ km.

The magnetic dip, as measured by Minakami,[14] has shown marked decrease at all of his stations in the island. Seeing that the change in magnetic dip, as calculated under the present assumption, predicts decrease in dip for almost the entire island, as shown in Fig. 8, the results of Minakami's survey seem to be in good accordance with the results of our survey.

In conclusion, the writers wish to express their cordial thanks to the Officials of the Division of Scientific Research in the Ministry of Education for the financial aid granted them for a series of investigations, of which this study is a part.

12) *Disin*, **12** (1940), 492.
13) *Disin*, **12** (1940), 524.
14) *Disin*, **12** (1940), 507.

Station No. 117.

Station No. 105.

(震研彙報 第十九號 圖版 高橋・平能)

Station No. 110.

Station No. 124.

Fig. 3.

7. 三宅島の噴火に伴つた垂直磁力の變化（概要）

地震研究所 高橋龍太郎
平能金太郎

昭和 15 年 7 月 12 日三宅島の噴火に際し，筆者等は垂直磁力計を用ひて噴火に伴つて起つた垂直磁力の變化の測定を行つた．三宅全島に分布された測點の數は 50 である．本文中第 1 圖に測點の位置及び番號を示した．第 4 圖は 7 月 20〜24 日に行つた第 1 回測定の結果であり，第 5 圖は第 1 回測定と，其れに引續いて 7 月 26〜30 日に行はれた第 2 回測定との差を示す．此等の變化は山頂下 3 km の點を中心とする半徑 1〜2.7 km の球狀部分が其の感應磁氣或は熱殘留磁氣を失つたものとすれば，變化の分布は勿論，其の量に至るまで非常にうまく説明がつく．磁氣を失つた原因は岩漿の上昇とか或は又他の原因によつて其の部分の岩石の溫度が上昇したとか考へればよい．此の考は同時に荻原，水上，永田理學士等によつて行はれた地磁氣の伏角や地震，微動等の觀測結果ともよく調和する．

本研究は文部省科學研究費によつて爲されたものである事を記し，玆に深謝の意を表す．