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ON THE MAGNETIC ANOMALIES AND THEIR SECULAR VARIATIONS AROUND MAEYAMA ON SIMABARA PENINSULA*†

BY

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ABSTRACT

A magnetic survey was carried out by the writer in 1923 at 87 points around volcanic mountain Maeyama near the Volcano Unzen, and the magnetic anomalies due to the mountain were examined. Since then, 29 years had passed without any remarkable volcanic or seismic activity on Simabara Peninsula, until in 1952 when the writer carried out a second survey in the same district. A careful comparison of the results of these two surveys shows that the magnetic anomalies have remained almost unchanged, but that the magnetization of the mountain block appears to have slightly progressed.

1. Introduction

As magnetic anomalies due to volcanic mountains have had definite influence on the results of general magnetic surveys in several cases in our country, it is practically necessary to examine the nature of the magnetization of volcanic mountains. Further, some relations between great earthquakes and geomagnetic anomalies have been suspected by geophysicists since early times in Japan. If some tectonic as well as volcanic earthquakes were caused by changes in the states of magma underground, then these changes would definitely be accompanied by a variation in temperature, which would give rise to the time variation of the local magnetic anomaly. In this respect, time variation observations of the magnetic field have been taken to be a necessary factor in the study of seismology, especially for the purpose of possible earthquake prediction. In this connexion, there arise two fundamental problems: 1) What is the nature of the magnetization of volcanic mountains? and 2) How does the magnetic anomaly vary with time, not only when the earthquake or the volcano is active, but also when it is calm?

* Contribution to Geophysical Papers dedicated to Prof. M. Hasegawa on his sixtieth birthday.

† A more detailed description on the survey will be published in Japanese in "Tikyu Buturi" Vol. 9 in the near future.

As early as 1904, A. Tanakadate suggested in his report (1) " A Magnetic Survey of Japan " that magnetic anomalies observed at a few points around Mt. Fuji could be well explained by assuming that the mountain was magnetized almost in the direction of magnetic meridian. In 1923, the present writer performed exact measurments of 3 magnetic components at 87 points around a volcanic hill, Maeyama, located on Simabara Peninsula and concluded that the hill was magnetized by induction almost in the same direction as that of the magnetic field. (The report (2) was published in Japanese.) It has now been established by many workers (3) in this field that the volcanic mountain is induced almost in the same direction as that of the present magnetic field.

We now have many reports on the existence of anomalous magnetic variations in cases of volcanic eruptions and of large earthquakes. Among them two reports (the one by T. Nagata (4) about anomalous magnetic variation immediately before and after the formation of a volcano, Usu in Hokkaido and the other by T. Rikitake (5) about the magnetic observations around Mt. Mihara, an active volcano) are of special importance inasmuch as they elucidate the relation between volcanic eruption and time variation of the magnetic field.

A somewhat remarkable earthquake occurred near Simabara Peninsula in December, 1922. But since the magnetic survey around Maeyama Hill, there had been neither earthquakes nor volcanic eruptions to consider. As it seemed interesting to the writer to examine how the anomaly of the magnetic field suffered from change during this period, he undertook a survey again in 1952 in the same region as before. From the results (6) of magnetic observations by the Hydrographic Office in Japan in 1922, 1933, 1942 and 1950 at the writer's station No. 3, it can be seen that there were no remarkable fluctuations in the magnetic secular variation in this region throughout the period.

The writer's second survey was carried out from August 2 to September 8 in 1952 in cooperation with Mr. T. Ogawa and Mr. M. Yasuhara. A magnetometer of the Hydrographic Office type was used and the three elements were measured at as nearly the same points as those selected in the former case. Among the 58 stations, 39 were within a few meters, 17 were within ten meters and only 2 were about fifty meters from the former stations. The name numbers of these stations which succeeded the former ones are expressed in Fig. 5.

2. The corrections

a) *Instrumental corrections.* Instrumental corrections were obtained through a comparison carried out on Oct. 7–8, 1952 at the Kakioka Geomagnetic Observatory, and were 6′.90 for the declination, −1′.20 for the dip, and none for the horizontal intensity.

b) *Correction of daily variation.* For this purpose, the records of daily changes at the Aso Observatory ($\lambda = 131°00' \mathrm{E}$, $\varphi = 32°54' \mathrm{N}$) were utilized, as the Aso Observatory is situated on nearly the same latitude as that of Maeyama. The deficiencies of those records were supplied by hourly values observed at the Kakioka Observatory ($\lambda = 140°10' \mathrm{E}$, $\varphi = 36°15' \mathrm{N}$).

c) *Correction of day-to-day variation.* As the day-to-day variations at Kakioka and Aso were very similar, it can be assumed that the value at Maeyama may also be similar to them. To apply these corrections the writer takes values at 0 o'clock on August 16 as standard, when it was most quiet. By this correction, the secular variation and the magnetic disturbances such as magnetic storms can be eliminated.

d) *Reduction to the central point* ($\lambda = 130°20'.50 \mathrm{E}$, $\varphi = 32°46'.00 \mathrm{N}$). In order to know the exact anomalies, it is necessary to reduce the values from each point to those at a standard point. The writer selected it at the nearly central point of Maeyama. According to the Geographical Survey Institute, the distributions of each magnetic element in the whole Japan at 1950. 0 are as follows (**7**) :

$$\left.\begin{aligned} D &= 6°\,51'.8+23'.58\,\Delta\varphi-6'.48\,\Delta\lambda-0'.420\,(\Delta\varphi)^2+0'.162\,\Delta\varphi\Delta\lambda-0'.672\,(\Delta\lambda)^2\,, \\ H &= 29898^{\gamma}-400^{\gamma}.3\,\Delta\varphi-72^{\gamma}.2\,\Delta\lambda-9^{\gamma}.75\,(\Delta\varphi)^2+12^{\gamma}.88\,\Delta\varphi\Delta\lambda-3^{\gamma}.48\,(\Delta\lambda)^2\,, \\ I &= 50°\,43'.9+72'.48\,\Delta\varphi-9'.36\,\Delta\lambda-0'.744\,(\Delta\varphi)^2-0'.138\,\Delta\varphi\Delta\lambda+0'.066\,(\Delta\lambda)^2\,, \end{aligned}\right\} \quad (1)$$

where $\Delta\varphi = \varphi - 37°$ $\Delta\lambda = \lambda - 138°$ (in degree), and west in D, north in H, and down in I, are taken as positive respectively.

From these, we can take the following rates at the central point :

$$\frac{\partial D}{\partial \varphi} = 0'.431\,, \qquad \frac{\partial D}{\partial \lambda} = 0'.052\,,$$

$$\frac{\partial H}{\partial \varphi} = -6^{\gamma}.94\,, \qquad \frac{\partial H}{\partial \lambda} = -1^{\gamma}.22\,,$$

$$\frac{\partial I}{\partial \varphi} = 1'.33\,, \qquad \frac{\partial I}{\partial \lambda} = -0'.163 \qquad \text{(per minute)}.$$

These can be reduced to the values at the central point.

e) *Altitude correction.* Of the altitude correction, the writer applies Dr. Tanakadate's formula (**8**). From the above expressions (1), we obtain the three elements and the three components at that point as follows :

$$D = 5°\,20'.1\,, \qquad H = 32182^{\gamma}\,, \qquad I = 46°\,35'.0\,,$$

$$N = 32043^{\gamma}\,, \qquad W = 2992^{\gamma}\,, \qquad V = -34012^{\gamma}\,,$$

where we take north, west and upward as positive for the components respectively. The obtained rates of the three elements are as follows :

Table I. Corrected observed values.

No.	*D*	*H*	*I*	*F*	*N*	*W*	*V*
1	5° 35.5	32318	46° 39.9	47092	32164	3149	34253
3	26.0	32287	21.5	46783	32142	3057	33856
4	32.6	32393	26.0	47001	32241	3129	34056
5	20.5	32388	17.0	46864	32247	3015	33872
6	34.4	32200	32.4	46813	32048	3127	33980
8	17.6	32234	23.4	46733	32096	2974	33837
9	26.2	32325	30.7	46970	32180	3063	34078
10	21.8	31920	47° 11.7	46975	31780	2984	34464
11	23.8	32239	46° 33.9	46891	32096	3032	34050
13	11.7	32376	20.3	46894	32243	2932	33925
14	37.4	32614	45° 57.7	46917	32456	3196	33727
15	45.0	32571	46° 12.2	47061	32407	3263	33969
16	52.6	32532	06.7	46927	32361	3331	33820
17	57.2	32457	06.5	46816	32282	3366	33738
18	53.7	32247	12.4	46596	32077	3312	33635
19	6° 07.6	32196	45° 55.5	46285	32012	3436	33253
20	5° 46.3	32345	46° 02.8	46603	32181	3253	33549
21	17.6	32456	45° 57.9	46693	32318	3994	33568
22	33.0	32358	46° 08.0	46694	32206	3130	33664
23	20.4	32496	45° 50.4	46646	32355	3024	33463
31	33.9	32369	46° 07.9	46708	32217	3139	33674
32	52.5	32365	23.3	46922	32195	3313	33973
33	42.0	32564	04.1	46936	32403	3234	33802
34	41.8	32463	07.4	46837	32303	3222	33761
35	44.8	32586	12.9	47092	32422	3263	33998
36	53.4	32383	05.0	46686	32212	3323	33629
37	6° 16.0	32410	38.0	47200	32217	3538	34312
38	5° 55.8	32505	08.6	46915	32331	3358	33829
39	44.3	32362	19.8	46867	32200	3236	33901
40	15.5	32328	25.1	46894	23192	2963	33970
41	28.3	32444	14.0	46903	32296	3094	33871
42	22.5	32495	17.9	47033	32353	3044	34002
43	21.9	32445	09.3	46838	32303	3034	33780
44	09.0	32522	45° 43.0	46580	32391	2919	33346
45	11.1	32178	46° 41.7	46915	32046	2908	34141
46	29.7	32312	26.3	46888	32163	3094	33976
47	21.0	32263	32.0	46898	32122	3008	34038
48	26.0	32343	29.7	46982	32197	3063	34076
49	26.5	32298	26.4	46869	32153	3063	33964
55	44.1	32296	08.2	46607	32134	3227	33604
57	55.9	32364	20.1	46874	32191	3345	33909
58	53.9	32338	17.9	46805	32166	3323	33838
59	53.1	32323	20.9	46826	32153	3314	33881
60	6° 01.3	32421	11.8	46839	32243	3401	33805
61	5° 50.5	32439	16.1	46926	32271	3302	33908
62	45.7	32545	15.1	47064	32380	3267	33999
63	33.3	32575	13.2	47080	32422	3153	33992
64	6° 05.1	32455	18.7	46986	32272	3440	33976
65	5° 42.9	32625	09.2	47097	32463	3249	33966
66	13.7	32792	45° 49.5	47058	32656	2988	33750
67	00.0	32867	48.9	47156	32742	2865	33816
68	05.4	32781	47.5	47013	32651	2908	33699
69	31.0	32689	58.0	47029	32537	3143	33811
70	11.3	32436	46° 22.6	47014	32303	2933	34034
71	44.6	32435	31.3	47138	32272	3246	34205
72	51.9	32476	25.6	47115	32306	3319	34135
74	48.4	32353	25.4	46934	32187	3273	34002
77	48.6	32384	18.4	46879	32217	3278	33896
mean	5° 38.0	32430.3	46° 13.95	46885.9	32275.3	3183.4	33858.8

$$\frac{\partial D}{\partial z} = -0'.205\,, \quad \frac{\partial H}{\partial z} = -15^{\gamma}.5\,, \quad \frac{\partial I}{\partial z} = -0'.085 \qquad \text{(per km.)}.$$

Therefore the magnitude of each element will increase as the points will descend.

3. The distribution of the corrected observed values

The corrected elements and their components are shown in Table I, where the vertical component is reckoned positive downward.

The differences of each value from some standard one are set forth in Figs. 1 to 3. At a glance we can see that they are very similar to the corresponding figures obtained at 1923. 50 (**9**).

In the first place, the distribution of the declination, as expressed in Fig. 1, may be divided into four quadrants by two lines drawn in the N–S and E–W directions. In the NE and SW quadrants they are in general smaller than the mean value, while in the SE and NW quadrants they are greater.

In the distribution of the horizontal intensity as shown in Fig. 2, in the northern and the southern parts they are greater than the mean and in the western and eastern parts they are smaller. In the distribution of the inclination or dip as shown in Fig. 3, at the northern and southern feet of the mountain they are smaller than the mean and in the distant and the eastern parts they are greater. In the case of

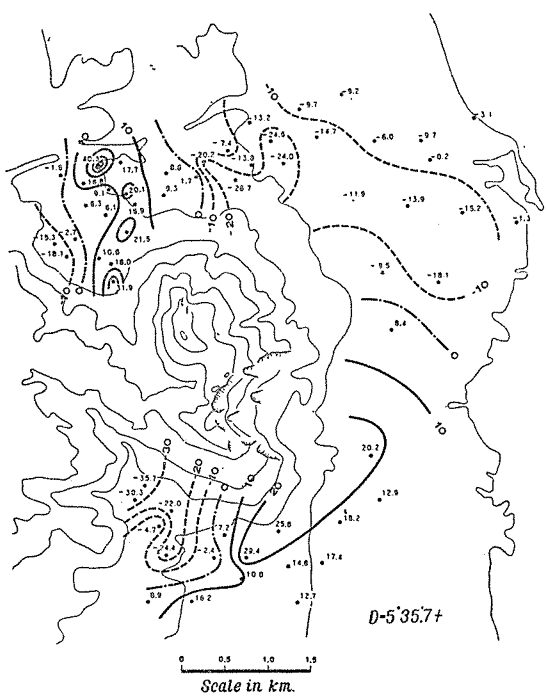

Fig. 1. Distribution of the declination at 1952. 63.

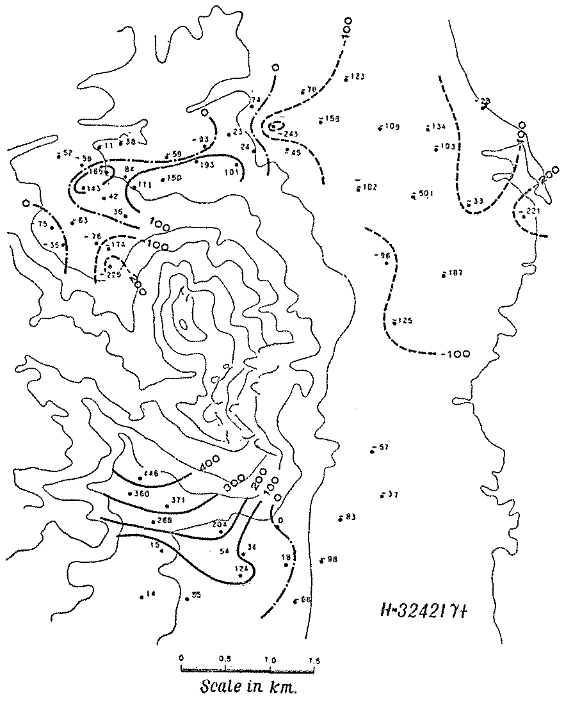

Fig. 2. Distribution of the horizontal intensity at 1952. 63.

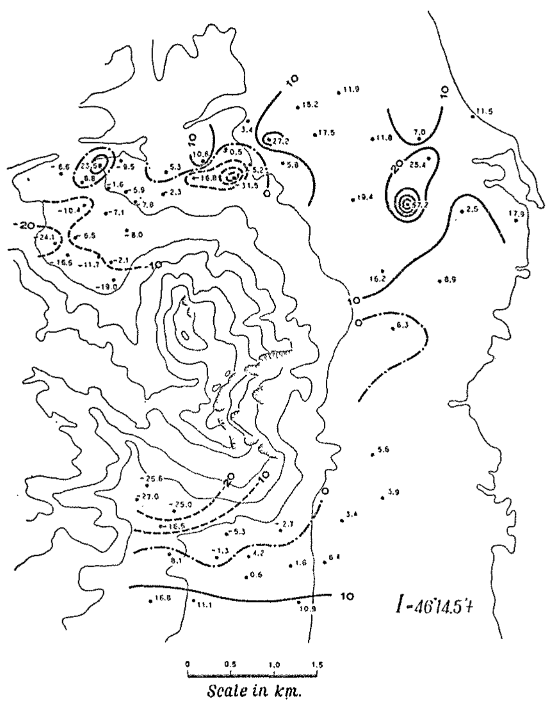

Fig. 3. Distribution of the inclination at 1952. 63.

inclination, the result seems to be apparently contradictory to the general feature described by the buried magnetic body underneath the mountain, but it must be supposed that the positive anomalic region of dip must be enclosed within the inner boundary of the observed region.

From these three figures we can suppose that the mountain block of Maeyama is magnetized almost parallel to the earths' magnetic field.

4. The magnetic anomalies of the first and second order

Two observations about the general magnetic distribution in the whole Japanese region at 1950.0 have been made, namely, one by the Geographic Survey Institute (G. S. I.) and the other by the Hydrographic Office (H. G. O.) (**10**). The differences between the writer's observed values and the results derived from the above general expressions, may be seen as the anomalies of the earth magnetism. They can be called the magnetic anomalies of the first order and they include both the regional anomalies in the western Kyushu and local ones around Maeyama. The values of each element at the central point deduced from two general expressions are as follows:

	D	H	I	F	N	W	V
G. S. I.	5° 24′. 2	32228$^\gamma$	46° 38′. 1	46935$^\gamma$	32085$^\gamma$	3035$^\gamma$	34122$^\gamma$
H.G.O.	5° 24. 4	32327	46° 20. 9	46832	32183	3046	33885

From this table it will be seen that the values of D are nearly equal, but the values of H and I are different, and the three components also are different from each other. Therefore two different anomalies of the first order will be obtained, but the differences are common to every point. We cannot distinguish how much of it will belong to regional and how much to local, so that we cannot judge which will be better. While the survey of the H. G. O. included the writer's point No. 3, that of G. S. I. did not have a point in Simabara Peninsula. Consequently the values in the expression of H. G. O. include values in Simabara Peninsula, but those of G. I. S. do not. Therefore the expressions of G. I. S. are more convenient in ascertaining regional and local anomalies. The differences between the observed values and those of G. S. I. are called magnetic anomalies of the first order.

In these anomalies we can see that the western components are in general superior to the eastern ones, so we can understand that the anomalies of the first order contain both local anomalies due to Maeyama and regional anomalies which include general western components. The regional anomalies are perhaps due to the great mountain block called Unzen, situated to the westward of Maeyama. If this is true, for obtaining the local anomalies due to Maeyama it is nescessary to get rid of the regional anomalies which are also perhaps predominant in the south and upward components.

Table II. Anomaly of the second order.

No.	D''	H''	I''	N''	W''	V''
1	−0.2	90	1.8	79	−10	131
3	−9.7	59	−16.6	57	−102	−266
4	−3.1	165	−12.1	156	−30	−66
5	−15.2	160	−21.1	162	−144	−250
6	−1.3	−28	−5.7	−37	−32	−142
8	−18.1	6	−14.7	11	−185	−285
9	−9.5	97	−7.4	95	−96	−44
10	−13.9	−308	33.6	−305	−175	342
11	−11.9	11	−4.2	11	−127	−72
13	−24.0	148	−17.8	158	−227	−197
14	1.7	386	−40.4	371	37	−395
15	9.3	343	−25.9	322	104	−153
16	16.9	304	−31.4	276	172	−302
17	21.5	229	−31.6	197	207	−384
18	18.0	19	−25.7	−8	153	−487
19	31.9	−32	−42.6	−73	277	−869
20	10.6	117	−35.3	96	94	−573
21	−18.1	228	−40.2	233	−165	−554
22	−2.7	130	−30.1	121	−29	−458
23	−15.3	268	−47.7	270	−135	−659
31	−1.8	141	−30.2	132	−20	−458
32	16.8	137	−14.8	110	154	−149
33	6.3	336	−34.0	318	65	−320
34	6.1	235	−30.7	218	63	−361
35	9.1	358	−25.2	337	104	−124
36	17.7	155	−33.1	127	164	−493
37	40.3	182	−0.1	132	379	190
38	20.1	277	−29.5	246	199	−293
39	8.6	134	−18.3	115	77	−221
40	−20.2	100	−13.0	107	−196	−152
41	−7.4	216	−24.1	211	−65	−251
42	−13.2	267	−20.2	268	−115	−120
43	−13.8	217	−28.8	218	−125	−342
44	−26.7	294	−55.1	306	−240	−776
45	−24.6	−50	3.6	−39	−251	19
46	−6.0	84	−11.8	78	−65	−146
47	−14.7	35	−6.1	37	−151	−84
48	−9.7	115	−8.4	112	−96	−46
49	−9.2	70	−11.7	68	−96	−158
55	8.4	68	−29.9	49	68	−518
57	20.2	136	−18.0	106	186	−213
58	18.2	110	−20.2	81	164	−284
59	17.4	95	−17.2	68	155	−241
60	25.6	193	−26.3	158	242	−317
61	14.8	211	−22.0	186	143	−214
62	10.0	317	−23.0	295	108	−123
63	−2.4	347	−24.9	337	−6	−130
64	29.4	227	−19.4	187	281	−146
65	7.2	397	−28.9	378	90	−156
66	−22.0	564	−48.6	571	−171	−372
67	−35.7	639	−49.2	657	−294	−306
68	−30.3	553	−50.6	566	−251	−423
69	−4.7	461	−40.1	452	−16	−311
70	−24.4	208	−15.5	218	−226	−88
71	8.9	207	−6.8	187	87	83
72	16.2	248	−12.5	221	160	13
74	12.7	125	−12.7	102	114	−120
77	12.9	156	−19.7	132	119	−226

Fig. 4. Horizontal anomaly
1952. 63
(The second order)
Full line: Observed.
Broken line: Calculated.

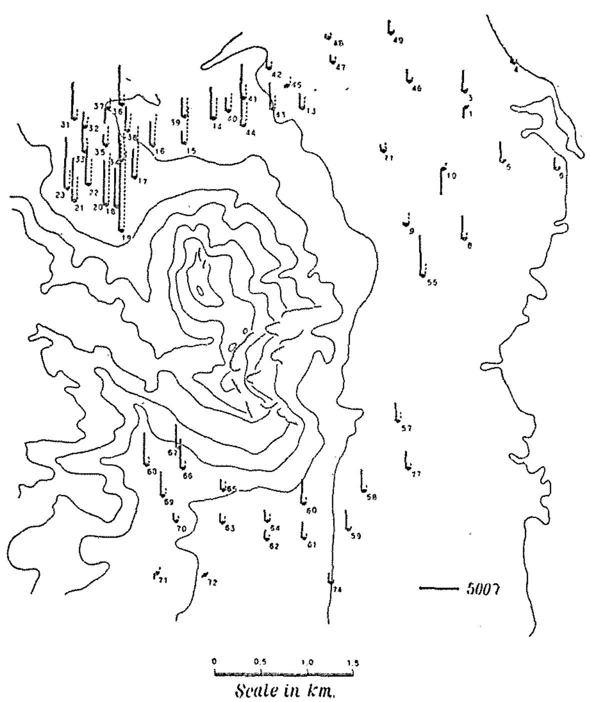

Fig. 5. Vertical anomaly
1952. 63
(The second order)
Full line: Observed.
Broken line: Calculated.

But since these components are unknown numerically and moreover their values are supposed to be nearly equal at all points, they will be overlooked for a while. But the declination and westward components of the anomalies due to Maeyama must be symmetrical with respect to the magnetic axis which nearly runs from south to north. Therefore the regional anomlies due to Unzen block can be avoided by obtaining differences between the observed values and their means. Now, it is not unreasonable to consider that the differences from their means in D and W, and differences from G. I. S. in H, I, N, and V are the anomalies due to Maeyama in general, and they are called anomalies of the second order and tabulated in Table II. Figs. 4 and 5 represent their horizontal and vertical vectors respectively in full lines. The horizontal vectors denote elegantly the magnetic lines of Maeyama which is magnetized approximately in the same direction as the earth's magnetic field. The vertical anomalies are almost all directed upward as if they agreed with the direction of the magnetic field due to Maeyama, supposed to be magnetized by the induction of the earth field as explained hereafter.

5. The local anomalies due to Maeyama

As stated above, it is very natural that the magnetic anomalies of the second order should be due to Maeyama, but it is impossible to calculate the magnetic field numerically unless the geometrical form of Maeyama is known. In the previous case, the writer explained the distributions of anomalies through the assumption of a simple magnet underneath Maeyama. But in this case he considered that it is more reasonable to assume that the form of Maeyama is an oblate spheroid whose minor axis is vertical. Königsberger (**11**) obtained the formulae to express the magnetic anomalies due to an oblate spheroid, by the induction of the field. Taking the x axis to magnetic north, y axis to east and z axis to downward, as positive, the formulae are as follows:

$$\frac{\Delta H}{H} = \frac{K}{1-KL} 3V_0 \tan I \frac{xz}{\sqrt{X}\sqrt{a^2+\nu}(b^2+\nu)} + \frac{K}{1-KM} 3V_0 \left[\frac{\sqrt{a^2+\nu}\,x^2}{\sqrt{X}(b^2+\nu)^2} - \frac{1}{2e^3}\left(\tan^{-1} l - \frac{l}{1+l^2}\right)\right],$$

$$\Delta D = \frac{K}{1-KL} 3V_0 \tan I \frac{yz}{\sqrt{X}\sqrt{a^2+\nu}(b^2+\nu)} + \frac{K}{1-KM} 4V_0 \frac{\sqrt{a^2+\nu}}{\sqrt{X}(b^2+\nu)^2} xy,$$

$$\frac{\Delta V}{V} = \frac{K}{1-KL} 3V_0 \left[\frac{z^2}{\sqrt{X}(a^2+\nu)^{\frac{3}{2}}} - \frac{l-\tan^{-1} l}{e^3}\right] + \frac{K}{1-KM} \frac{3V_0}{\tan I} \frac{xz}{\sqrt{X}\sqrt{a^2+\nu}(b^2+\nu)},$$

where $2a$ is the length of the minor axis, $2b$ the length of the major axis and K magnetic susceptibility, and

$$e=\sqrt{b^2-a^2},\ u=\frac{e}{a},\ l=\frac{e}{\sqrt{a^2+\nu}},\ V_0=\frac{4}{3}\pi ab^2,$$

$$X=(x^2+y^2+z^2)^2+(b^2-a^2)\left[(b^2-a^2)-2\{z^2-(x^2+y^2\}\right],$$

$$\nu=\frac{1}{2}(x^2+y^2+z^2-a^2-b^2+\sqrt{X}),$$

$$L=-4\pi\frac{1+u^2}{u^3}(u-\tan^{-1}u),$$

$$M=-4\pi\frac{1+u^2}{u^3}\tan^{-1}\frac{u^3}{1+u^2}.$$

It is reasonable to obtain the magnitudes and azimuths of a and b, and the position of the centre of the spheroid by the method of least squares, as there are many observed values. Since, however, the procedure is too complicated, the writer has used the following method.

In the first place, the writer assumed that the centre of the spheroid coincided with the geographic centre of Maeyama which had been taken as the central point in §2. In the second place the writer selected ten of the observed stations which seemed to be normal, and compared the magnetic susceptibilities K deduced respectively from ΔH, ΔD and ΔV through varying the major axis b or the minor axis a and the depth of the centre of the spheroid. That is, (1) asuming that a is 0.7 km and the centre of the spheroid is on the sea level, the writer finds that the probable value of b is 1.4 km in the case when the three values of K obtained from ΔH, ΔD and ΔV are nearly equal, (2) assuming that b is 1.4 km and the upper surface of the spheroid almost coincides with the mountain surface whose top is supposed to be at 700 meters high above the sea level, it seems that the probable value of a is 0.7 km. One representative of these considerations is given in Fig. 6. It was concluded that the major axis $2b$ is equal to 2.8 km, minor axis $2a$ to 1.4 km and the centre of the spheroid is at the sea level.

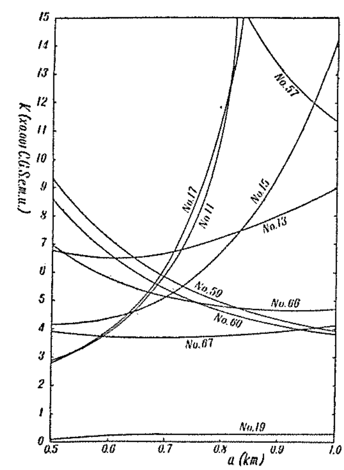

Fig. 6. Relation between the magnetic susceptibility (K) by H and the minor axis (a) of the oblate spheroid, at 10 stations.

With these values, the anomalies of each point are calculated, but in this case the x-axis is taken to the magnetic north which is westward by about 5°30′ to the geographical north.

Comparing the observed and calculated values, magnetic susceptibilities are obtained, the extreme values having been rejected, and the means for each element are as follows:

$$\text{from} \quad \Delta D \quad K_D = 0.0051 \text{ C. G. S. E. M. U.} \quad (33)$$
$$\Delta H \quad K_H = 0.0062 \quad ,, \quad (30)$$
$$\Delta V \quad K_V = 0.0058 \quad ,, \quad (26)$$

The numbers in the bracket denote the numbers of stations which were utilized. The mean value of K is 0.0057 C. G. S. E. M. U. and it is supposed to be the probable value. The calculated anomalies of each point with this value of K, are represented in Figs. 4 and 5 with dotted lines. But ΔN and ΔW in the figures refer to the geographical north and west. We can observe a fairly good agreement in both arrows. That is to say, it seems that the writer's assumptions are not incorrect.

6. The secular variations of the magnetic anomalies due to Maeyama

The writer's principal purpose of the second survey was to study the secular variations of the magnetic anomalies during the past twenty-nine years.

The variations of each observed element between 1923. 50 and 1952. 63 are tabulated in Table III, and expressed in Figs. 7, 8, 9 and 10. Their means are obtained from them excluding six points which have extreme values.

What part of them may be attributed to regional and what part of them may be attributed to local anomalies must be ascertained. The writer applied the following method.

The magnetic anomalies in both epochs must be due to the mountain block of Maeyama and other local substances, and any appreciable essential differences of their features have not been recognised. Therefore there must be a simple relation between the deviations of the same element at each point from some standard values which may be different at each epoch. From this reason the writer takes the second order anomalies expressed in Table II as abscissa, and the corresponding values at 1923. 50 as ordinate in Figs. 11, 12 and 13. For convenience, the differences between the observed values and their mean, expressed in the Table IV (12) in the previous paper, were used as the latter values. The following equations were obtained for each element, but 8 points for D or H, 13 points for V which have extreme values have been excluded.

$$\text{For } D \quad y = 0.94\,x + 0.'23 \pm 2.'48\,,$$
$$H \quad y = 0.94\,x - 169^{\gamma} \pm 27.^{\gamma}5\,,$$
$$V \quad y = 0.90\,x + 246^{\gamma} \pm 44.^{\gamma}5\,,$$

in minute for D and in γ for H and V. The constant terms in these equations can be considered as the corrections of the mean values which are taken as ordinates. Then the corrected mean values or the standard values at 1923.50 are as follows:

Table III_1. Secular variation of the declination (1923.50–1952.63).

No.	D_2 (1952.63)	D_1 (1923.50)	d (D_2-D_1)	d-d_m
1	5° 35.5	4° 55.6	39.9	1.7
3	26.0	45.3	40.7	2.5
4	32.6	58.4	34.2	−4.0
5	20.5	41.6	38.9	0.7
6	34.4	5° 00.0	34.4	−3.8
8	17.6	4° 45.8	31.8	−6.4
9	26.2	38.8	47.4	9.2
10	21.8	44.6	37.2	−1.0
11	23.8	44.5	39 3	1.1
13	11.7	39.2	32.5	−5.7
14	37.4	5° 01.8	35.6	−2.6
15	45.0	03.6	41.4	3.2
16	52.6	11.3	41.3	3.1
17	57.2	18.8	38.4	0.2
18	53.7	17.5	36.2	−2.0
19	6° 07.6	29.8	37.8	−0.4
20	5° 46.3	06.9	39.4	1.2
21	17.6	27.5	50.1	11.9
22	33.0	4° 53.7	39.3	1.1
23	20.4	40.7	39.7	1.5
31	33.9	5° 05.8	28.1	−10.1
32	52.5	09.5	43.0	4.8
33	42.0	04.9	37.1	−1.1
34	41.8	08.1	33.7	−4.5
35	44.8	10.6	34.2	−4.0
36	53.4	16.4	37.0	−1.2
37	6° 16.0	02.2	73.8	35.6
38	5° 55.8	07.6	48.2	10.0
39	44.3	4° 58.5	45.8	7.6
40	15.5	58.1	17.4	−20.8
41	28.3	49.6	38.7	0.5
42	22.5	50.4	32.1	−6.1
43	21.9	16.5	65.4	27.2
44	09.0	35.6	33.4	−4.8
45	11.1	24.3	46.8	8.6
46	29.7	50.5	39.2	1.0
47	21.0	45.2	35.8	−2.4
48	26.0	47.9	38.1	−0.1
49	26.5	42.8	43.7	5.5
55	44.1	5° 08.8	35.3	−2.9
57	55.9	08.5	47.4	9.2
58	53.9	12.9	41.0	2.8
59	53.1	08.9	44.2	6.0
60	6° 01.3	17.6	43.7	5.5
61	5° 50.5	14.1	36.4	−1.8
62	45.7	10.9	34.8	−3.4
63	33.3	4° 55.9	37.4	−0.8
64	6° 05.1	31.8	33.3	−4.9
65	5° 42.9	5° 00.9	42.0	3.8
66	13.7	4° 37.1	36.6	−1.6
67	00.0	23.0	37.0	−1.2
68	05.4	31.3	34.1	−4.1
69	31.0	56.2	34.8	−3.4
70	11.3	57.6	13.7	−24.5
71	44.6	5° 08.6	36.0	−2.2
72	51.9	17.3	34.6	−3.6
74	48.4	09.0	39.4	1.2
77	48.6	11.2	37.4	−0.8
			d_m=38.16	

Table III_2. Secular variation of the horizontal intensity.

No.	H_2 (1952. 63)	H_1 (1923. 50)	h (H_2-H_1)	h-h_m
1	32318	31919	399	−34
3	32287	31738	549	116
4	32393	31833	560	127
5	32388	31814	574	141
6	32200	31864	336	−97
8	32234	31849	385	−48
9	32325	31866	459	26
10	31920	31390	530	97
11	32239	31740	499	66
13	32376	31904	472	39
14	32614	32141	473	40
15	32571	32108	463	30
16	32532	32074	458	25
17	32457	32014	443	10
18	32247	31910	337	−96
19	32196	31730	466	33
20	32345	31859	486	53
21	32456	32024	432	−1
22	32358	31918	440	7
23	32496	32084	412	−21
31	32369	32056	313	−120
32	32365	31950	415	−18
33	32564	32165	399	−34
34	32463	32028	435	2
35	32586	32152	434	1
36	32383	31905	478	45
37	32410	31968	442	9
38	32505	32104	401	−32
39	32362	31953	409	−24
40	32328	31782	546	113
41	32444	31988	456	23
42	32495	31985	510	77
43	32445	32015	430	−3
44	32522	32110	412	−21
45	32178	31754	424	−9
46	32312	31966	346	−87
47	32263	31901	362	−71
48	32343	32064	279	−154
49	32298	31945	353	−80
55	32296	31924	372	−61
57	32364	32025	339	−94
58	32338	31874	464	31
59	32323	31913	410	−23
60	32421	32034	387	−46
61	32439	32014	425	−8
62	32545	32155	390	−43
63	32575	32150	425	−8
64	32455	32077	378	−55
65	32625	32221	404	−29
66	32792	32384	408	−25
67	32867	32398	469	36
68	32781	32387	394	−39
69	32689	32062	627	194
70	32436	32018	418	−15
71	32435	31997	438	5
72	32476	32064	412	−21
74	32353	31938	415	−18
77	32384	31925	459	26
			h_m=432.5	

Table III_3. Secular variation of the inclination (1923.50–1952.63).

No.	I_2 (1952.63)	I_1 (1923.50)	i (I_2–I_1)	i–i_m
1	46° 39.9	46° 52.6	−12.7	0.1
3	21.5	35.8	−14.3	−1.5
4	26.0	39.4	−13.4	−0.6
5	17.0	31.0	−14.0	−1.2
6	32.4	42.9	−10.5	2.3
8	23.4	39.0	−15.6	−2.8
9	30.7	40.0	−9.3	3.5
10	47° 11.7	47° 23.6	−12.9	−0.1
11	46° 33.9	46° 48.7	−14.8	−2.0
13	20.3	35.6	−15.3	−2.8
14	45° 57.7	10.9	−13.2	−0.4
15	46° 12.2	28.5	−16.3	−3.8
16	06.7	16.4	−9.7	3.1
17	06.5	21.2	−14.7	−1.9
18	12.4	05.7	6.7	19.5
19	45° 55.5	16.8	−21.3	−8.5
20	46° 02.8	15.5	−12.7	0.1
21	45° 57.9	06.2	−8.3	4.5
22	46° 08.0	21.7	−13.7	−0.9
23	45° 50.4	03.2	−12.8	0.0
31	46° 07.9	27.2	−19.3	−6.5
32	23.3	34.2	−10.9	1.9
33	04.1	13.7	−9.6	3.2
34	07.4	23.1	−15.7	−2.9
35	12.9	22.9	−10.0	2.8
36	05.0	26.4	−21.4	−8.6
37	38.0	18.3	19.7	32.5
38	08.6	21.4	−12.8	0.0
39	19.8	31.1	−11.3	1.5
40	25.1	35.9	−10.8	2.0
41	14.0	23.3	−9.3	3.5
42	17.9	38.5	−20.6	−7.8
43	09.3	24.7	−15.4	−2.6
44	45° 43.0	07.4	−24.4	−11.6
45	46° 41.7	44.9	−3.2	9.6
46	26.3	33.4	−7.1	5.7
47	32.0	41.5	−9.5	3.3
48	29.7	40.4	−10.7	2.1
49	26.4	29.9	−3.5	9.3
55	08.2	24.7	−16.5	−3.7
57	20.1	22.9	−2.8	10.0
58	17.9	32.4	−14.5	−1.7
59	20.9	35.2	−14.3	−1.5
60	11.8	27.1	−15.3	−2.5
61	16.1	37.3	−21.2	−8.4
62	15.1	29.6	−14.5	−1.7
63	13.2	20.7	−7.5	5.3
64	18.7	27.8	−9.1	3.7
65	09.2	23.2	−14.0	−1.2
66	45° 49.5	06.6	−17.1	−4.3
67	48.9	11.0	−22.1	−9.3
68	47.5	00.9	−13.4	−0.6
69	58.0	09.3	−11.3	1.5
70	46° 22.6	29.0	−6.4	6.4
71	31.3	47.7	−16.4	−3.6
72	25.6	36.0	−10.4	2.4
74	25.4	40.7	−15.3	−2.5
77	18.4	32.6	−14.2	−1.4
			$i_m = -12.83$	

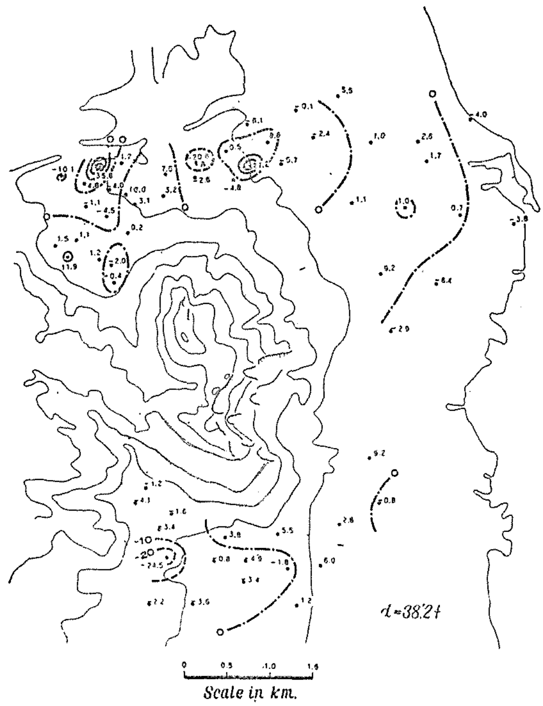

Fig. 7. Secular variation of the declination. (1923. 50–1952. 63)

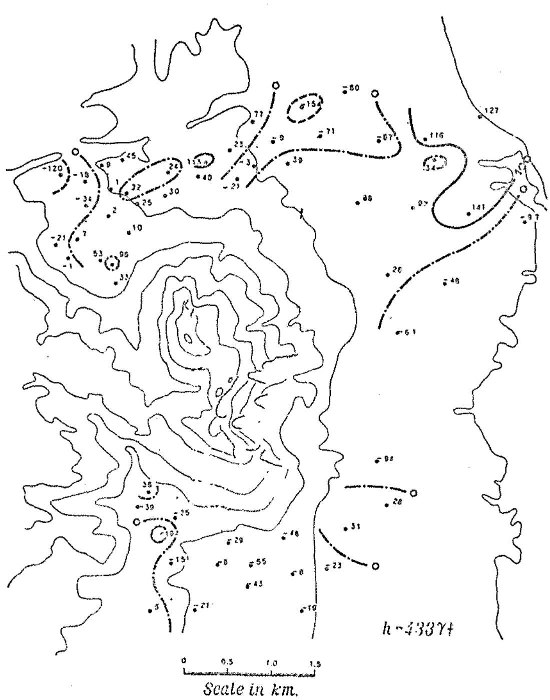

Fig. 8. Secular variation of the horizontal intensity. (1923. 50–1952. 63)

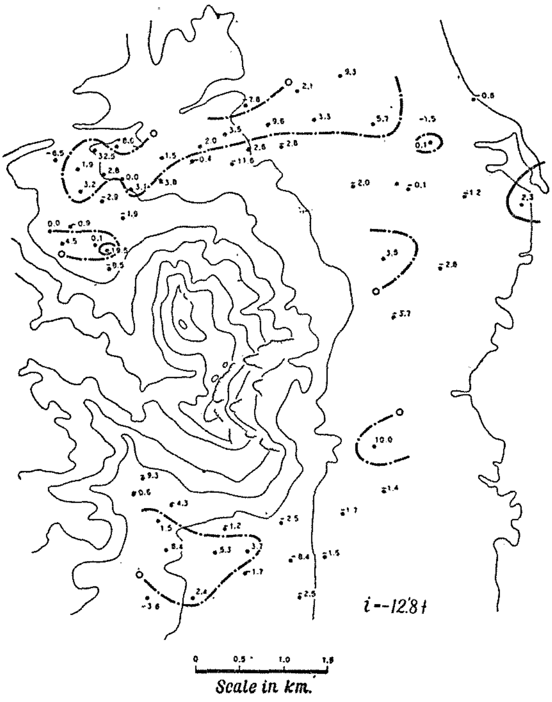

Fig. 9. Secular variation of the inclination. (1923. 50–1952. 63)

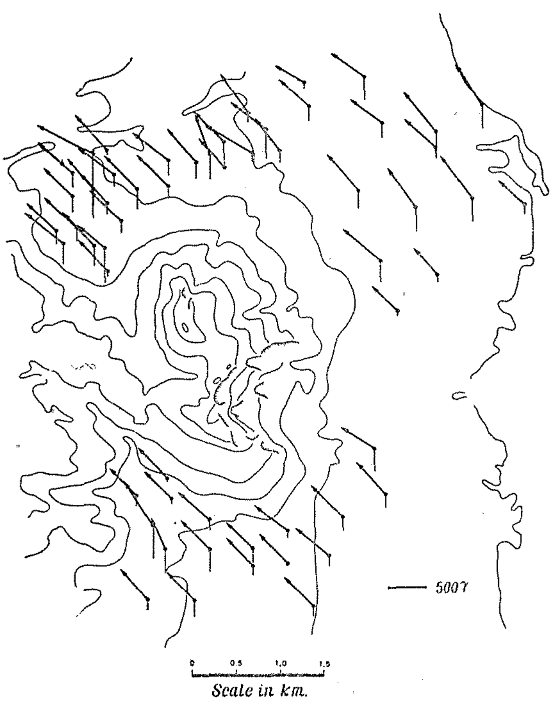

Fig. 10. Secular variation of the horizontal and the vertical components. (1923. 50–1952. 63)

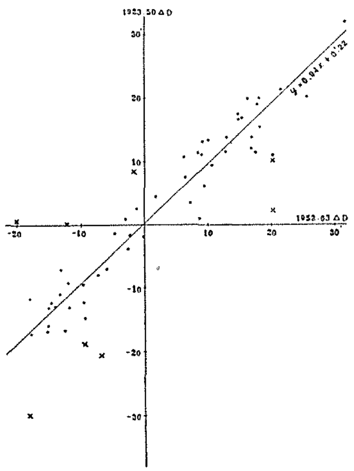

Fig. 11. Relation between the anomalies of the declination at 1952. 63 and those at 1923. 50.

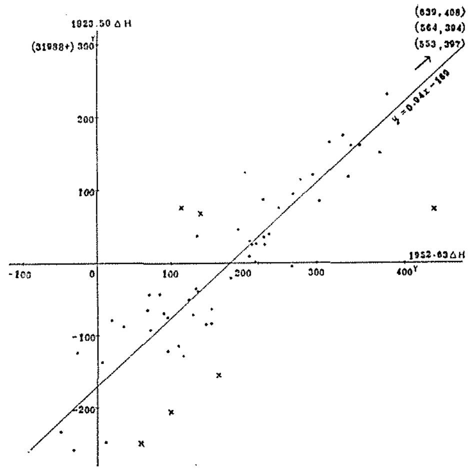

Fig. 12. Relation between the anomalies of the horizontal intensity at 1952. 63 and those at 1923. 50.

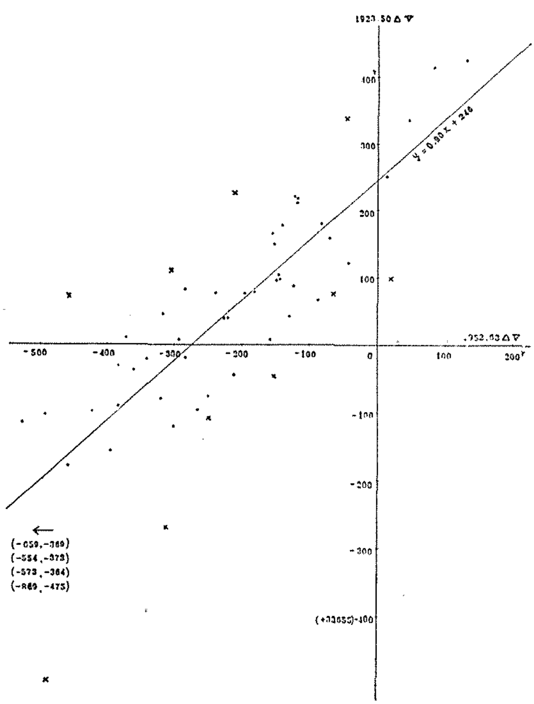

Fig. 13. Relation between the anomalies of the vertical component at 1952. 63 and those at 1923. 50.

Table IV_1. The variations of the anomalies (D).

No.	1952.63	1933.50	diff.	No.	1952.63	1923.50	diff.
1	−0.2	−2.1	1.9	41	−7.4	−8.1	0.7
3	−9.7	−12.4	2.7	42	−13.2	−7.3	−5.9
4	−3.1	0.7	−3.8	43	−13.8	−41.2	27.4
5	−15.2	−16.1	0.9	44	−26.7	−22.1	−4.6
6	−1.3	2.3	−3.6	45	−24.6	−33.4	8.8
8	−18.1	−11.9	−6.2	46	−6.0	−7.2	1.2
9	−9.5	−18.9	9.4	47	−14.7	−12.5	−2.2
10	−13.9	−13.1	−0.8	48	−9.7	−9.8	0.1
11	−11.9	−13.2	1.3	49	−9.2	−14.9	5.7
13	−24.0	−18.5	−5.5	55	8.4	11.1	−2.7
14	1.7	4.1	−2.4	57	20.2	10.8	9.4
15	9.3	5.9	3.4	58	18.2	15.2	3.0
16	16.9	13.6	3.3	59	17.4	11.2	6.2
17	21.5	21.1	0.4	60	25.6	19.9	5.7
18	18.0	19.8	−1.8	61	14.8	16.4	−1.6
19	31.9	32.1	−0.2	62	10.0	13.2	−3.2
20	10.6	9.2	1.4	63	−2.4	−1.8	−0.6
21	−18.1	−30.2	12.1	64	29.4	34.1	−4.7
22	−2.7	−4.0	1.3	65	7.2	3.2	4.0
23	−15.3	−17.0	1.7	66	−22.0	−20.6	−1.4
31	−1.8	8.1	−9.9	67	−35.7	−34.7	−1.0
32	16.8	11.8	5.0	68	−30.3	−26.4	−3.9
33	6.3	7.2	−0.9	69	−4.7	−1.5	−3.2
34	6.1	10.4	−4.3	70	−24.4	−0.1	−24.3
35	9.1	12.9	−3.8	71	8.9	10.9	−2.0
36	17.7	18.7	−1.0	72	16.2	19.6	−3.4
37	40.3	4.5	35.8	74	12.7	11.3	1.4
38	20.1	9.9	10.2	77	12.9	13.5	−0.6
39	8.6	0.8	7.8				
40	−20.2	0.4	−20.6				

Table IV_2. The variations of the anomalies (H).

No.	1952.63	1923.50	diff.	No.	1952.63	1923.50	diff.
1	90	100	−10	19	−32	−89	57
3	59	−81	140	20	117	40	77
4	165	14	151	21	228	205	23
5	160	−5	165	22	130	99	31
6	−28	45	−73	23	268	265	3
8	6	30	−24	31	141	237	−96
9	97	47	50	32	137	131	6
10	−308	−429	121	33	336	346	−10
11	11	−79	90	34	235	209	26
13	148	85	63	35	358	333	25
14	386	322	64	36	155	86	69
15	343	289	54	37	182	149	33
16	304	255	49	38	277	285	−8
17	229	195	34	39	134	134	0
18	19	91	−72	40	100	−37	137

Continued

No.	1952. 63	1923. 50	diff.	No.	1952. 63	1923. 50	diff.
41	216	169	47	62	317	336	-19
42	267	166	101	63	347	331	16
43	217	196	21	64	227	256	-31
44	294	291	3	65	397	402	-5
45	-50	-65	15	66	564	565	-1
46	84	147	-63	67	639	579	60
47	35	82	-47	68	553	568	-15
48	115	245	-130	69	461	243	218
49	70	126	-56	70	208	199	9
55	68	105	-37	71	207	178	29
57	136	206	-70	72	248	245	3
58	110	55	55	74	125	119	6
59	95	94	1	77	156	106	50
60	193	215	-22				
61	211	195	16				

Table IV_3. The variations of the anomalies (V).

No.	1952. 63	1923. 50	diff.	No.	1952. 63	1923. 50	diff.
1	131	180	-49	41	-251	-324	73
3	-266	-344	78	42	-120	-29	-91
4	-66	-172	106	43	-342	-269	-73
5	-250	-357	107	44	-776	-507	-269
6	-142	-70	-72	45	19	-148	167
8	-285	-163	-122	46	-146	-150	4
9	-44	-125	81	47	-84	-67	-17
10	342	227	115	48	-46	93	-139
11	-72	-88	16	49	-158	-241	83
13	-197	-172	-25	55	-518	-364	-154
14	-395	-406	11	57	-213	-293	80
15	-153	-97	-56	58	-284	-267	-17
16	-302	-369	67	59	-241	-170	-71
17	-384	-338	-46	60	-317	-201	-116
18	-487	-748	261	61	-214	-21	-193
19	-869	-721	-148	62	-123	-26	-97
20	-573	-610	37	63	-130	-205	75
21	-554	-619	65	64	-146	-143	-3
22	-458	-430	-28	65	-156	-82	-74
23	-659	-615	-44	66	-372	-238	-134
31	-448	-176	-272	67	-306	-137	-169
32	-149	-151	2	68	-423	-346	-77
33	-320	-327	7	69	-311	-520	209
34	-361	-286	-75	70	-88	-181	93
35	-124	-160	36	71	83	167	-84
36	-493	-351	-142	72	13	6	7
37	190	-443	633	74	-120	-36	-84
38	-293	-241	-52	77	-226	-208	-18
39	-221	-208	-13				
40	-152	-295	143				

$$D_m = 4° \ 57.'5 + 0.'2 = 4° \ 57.'7$$

$$H_m = 31988^\gamma - 169^\gamma = 31819^\gamma$$

$$V_m = 33655^\gamma + 246^\gamma = 33901^\gamma$$

Making use of these standards, the preceding equations may be written as follows:

For D $\quad y_2 = 0.94\, x_2$,

H $\quad y_2 = 0.94\, x_2$,

V $\quad y_2 = 0.90\, x_2$.

y_2 must be the second order anomaly at 1923.50, since x_2 is the second order anomaly at 1952.63.

The coefficients of the above equations have an interesting meaning, that is, they represent the ratios of the second order anomalies at 1923.50 to those at 1952.63. The fact that their values are very near to unity means that these two groups of anomalies are nearly equal. But their values are a little smaller than unity, and this means that the anomalies at 1923.50 are smaller than those at 1952.63, indicating that the anomalies have somewhat increased in the past twenty-nine years. The mean value of the three coefficients is 0.927 and it means that the increment is about one-thirteenth of the previous value. But, since the probable errors are rather large, as shown in the above, the increments are not so accurate as the numerical values express.

The anomalies at both epochs and their differences are expressed in Table IV. The coefficients of the equations which express the relations of those differences and the anomalies at 1952.63, are 0.06, 0.06 and 0.10 respectively. The distributions of the differences are very similar to Figs. 1, 2 and 5 respectively This means that these anomalies have been added in the past twenty-nine years by about one-thirteenth of the previous ones.

Finally, it is noticeable that these relations are perfectly independent of the distribution of the magnetic bodies beneath Maeyama which the writer assumed as an oblate spheroid in expressing the magnetic anomalies themselves, and also independent of the standard values with which the writer obtained the anomalies.

7. Conclusion

1. There were almost similar magnetic anomalies around Maeyama at 1952,63 as at 1923.50.
2. To explain these anomalies, the writer assumes an oblate spheroid whose centre is situated at the sea level and at nearly the geographycal centre of Maeyama, the minor axis of which is vertical and equal to 1.4 km, and the major axis of which is horizontal and equal to 2.8 km. The magnetic field around Maeyama seems

to be due to magnetic induction by the earth's magnetic field. The magnetic susceptibility of Maeyama is about 0.0057 C. G. S. E. M. U..

3. To deduce the magnetic susceptibility, the position and the dimensions of the spheroid are modified in several cases, and the above position and dimensions are presented as most probable. Therefore these geometical forms will suggest the form of Maeyama as that of a volcano.
4. In a general view, the magnetic anomalies due to Maeyama have almost not changed for the past 29 years.
5. But the tendency of the variation of the magnetic anomalies is positive, and the increment of the magnetic susceptibility is about one-thirteenth for that internal.
6. As Simabara Peninsula has been calm in seismic and in volcanic aspects for the past 29 years, so it has also been calm in its magnetic nature. It rather proceeds somewhat in magnetization and, to speak without reserve, the temperature of the rock beneath the mountain seems to descend and the stability of it also seems to proceed, in some degree.

In conclusion, the writer wishes to express his sincere thanks to the late Prof. T. Sida and Prof. M. Hasegawa for their guidance. His cordial thanks are also due to Dr. M. Ota for his well-intended aid in the comparison of the instruments and in other cases. The writer also wishes to express his hearty thanks to the members of the Kakioka Geomagnetic Observatory and the Aso Volcanic Observatory for placing their observed records at his disposal.

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