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Determining the Amount of Man-Induced Geomagnetic Disturbances

by

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Abstract

To grasp the amount of man-induced geomagnetic disturbances, observations must be made at some points to establish comparative geomagnetic observations before and after the occurrence of man-induced geomagnetic disturbances. A difference between measurements before and after the occurrence must be identified and defined as the amount of man-induced geomagnetic disturbances in which natural variation is not included. Problems to this method are that it requires a great deal of labor to analyze observational data and perform calculations and that the criteria for evaluating the results of calculations are not established yet. This paper describes the analysis software that we have developed to analyze the man-induced geomagnetic disturbances caused by a magnetic moment which is unchanged and fixed. If this software is used to process observational data, it is expected that the problems mentioned above will be resolved.

1. Introduction

Man-induced disturbances, which are a considerable impediment to geomagnetic observations, have been increasing more than ever in recent years. Causes and types of man-induced disturbances are various and many. If a magnetic body moves or if an electric current leaks to the ground, it is difficult to clarify how geomagnetic field disturbances occur. If a fixed magnetic body is the cause of a geomagnetic field disturbance, it is relatively easy to grasp the effects of geomagnetic field disturbances. In the latter case, analysis methods using only total geomagnetic force values were proposed by Ozima et al. (1993) and Tokumoto et al. (1994).

In their studies, however, data were analyzed and calculations were performed for individual cases of man-induced disturbances. With this approach to man-induced disturbances, it is difficult to evaluate the results of disturbances based on common criteria as a whole, the overall efficiency of data processing decreases, and it takes a great deal of time and labor to do analytical work. Given this background, there is an increasing need for a standardized analysis software program that will allow us to process data quickly and efficiently and to evaluate disturbances on common criteria.

In the above study conducted by Ozima et al., only total magnetic force values were measured. Although their observation and analysis methods are simple and easy to use, there are cases in which the accuracy of analysis results will deteriorate depending on the arrangement of observation points. Specifically, if only total magnetic force values are measured, especially the level of sensitivity with which geomagnetic disturbances affecting east and west components are reflected in measured values becomes low. If geomagnetic component values are also measured during comparative observations, it is possible to increase the accuracy of data analysis. At Fixed-Point Observatories like the Kakioka Magnetic Observatory and both of its branches (Memambetsu and Kanoya), geomagnetic component values are also continuously measured. Introducing a fluxgate magnetometer to these comparative observatories to collect data on man-induced disturbances will be much easier than introducing it to field observation points.

With all these considered, we upgraded the method used by Tokumoto et al., so data can be analyzed using geomagnetic component values in addition to total magnetic force values. It should be noted, however, that this method assumes that the cause of man-induced geomagnetic disturbances is a single magnetic moment at a fixed position. This paper describes the upgraded method and the analysis software that we have developed based on the method.

2. Observation Conditions

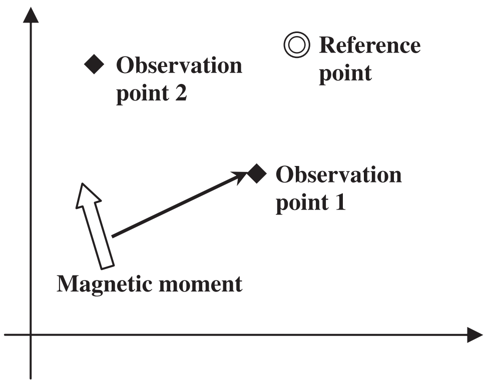

Fig. 1 Arrangement of observation points

A lot of overlap in what is described in this chapter and in the next chapter is intended to help the reader obtain a better understanding of the process of analyzing the effect of man-induced geomagnetic disturbances based on geomagnetic component values. It should be noted, however, that there is a slight difference in the symbols used in this chapter and those used in the next chapter.

Suppose that there are a number of geomagnetic observation points in a certain spatial domain and man-induced disturbances occur in this domain. There are three observation points here. One point is called a reference point and other two points are called observation points, as shown in Figure 1. A reference point is where a geomagnetic component value is continuously measured. At observation points, only a total magnetic force value is measured or only a component value is measured or both total magnetic force and component values are measured or only horizontal components are measured. For clarity, the observation point where only a total magnetic force value is measured is called a total magnetic force observation point, and the observation point where three components are measured is called a component observation point.

Calculation conditions are defined as follows:

1. A source of disturbance is a magnetic moment at a single point.
2. Values of all components are measured at a reference point.
3. A total magnetic force value or a component value is measured at observation points.
4. The relative positions of a reference point, observation points and a source of man-induced disturbance are known.
5. The geomagnetic variation at a reference point and each observation point is the same for each component.
6. Point-to-point differences between a reference point and each observation point are minimal.
7. Data before and after the occurrence of a man-induced disturbance are provided.

We will elaborate on each of the above conditions as follows:

Condition 1: A magnetic moment does not have a volume and, therefore, observation points can be as close as possible to a source of disturbance. In real-life conditions, however, a source of disturbance has a certain volume. It is thought that the reasonable relationship between observation points and a source of disturbance can be established if observation points are set at a certain distance from a source of disturbance.

Conditions 2, 3 and 4: Types of data acquired by observation or by measurement are described. If only a total magnetic force value is measured using a proton magnetometer at observation points, the time and labor needed for observation work can be curtailed, and measurements will somewhat stabilize.

Condition 5: This means that point-to-point differences do not change. Point-to-point differences mentioned here concern three component values. Strictly speaking, however, total magnetic force values may apparently vary at a reference point and observation points.

Condition 6: If a point-to-point difference is known as described later, this postulation is unnecessary. If the value of a point-to-point difference is unknown, it must be as small as negligible except in special cases, as indicated by the formula shown in the next chapter. In the case of three component values, a point-to-point difference is an unnecessary condition because it is canceled out as described in Chapter 3.

Condition 7: A total magnetic force value or each component value must be measured twice: before and after man-induced geomagnetic disturbances occur. Specifically, if a total magnetic force was measured at one observation point before the occurrence of a disturbance, it must be measured again after the occurrence of the disturbance.

3. Calculation Method

Because the potential of dipole magnetic moment $\boldsymbol{M}$ is $\phi_m = \frac{(\boldsymbol{M} \cdot \boldsymbol{r})}{4\pi\mu_0 r^3}$, the density of a magnetic flux that forms at the position $\boldsymbol{r}$ can be expressed as follows, providing that a natural magnetic field is $\boldsymbol{F}$:

$$F - \mu_0 grad(\phi_m)$$
$$= F + \frac{1}{4\pi}\{-\frac{M}{r^3} + \frac{3(M \cdot r)r}{r^5}\}$$

Because $\boldsymbol{r}$ is a known value, a disturbing component is represented in the form of a linear expression of $\boldsymbol{M}$.

What will become of geomagnetic component values at observations points and a reference point before and after the occurrence of man-induced disturbance? Symbols are defined as follows:

F_i, X_i, Y_i, Z_i:

Total geomagnetic force value and component value at observation points and a reference point (i=0) before the occurrence of disturbance

F'_i, X'_i, Y'_i, Z'_i:

Total geomagnetic force value and component value at observation points and a reference point (i=0) after the occurrence of disturbance

${}_sx_i$, ${}_sy_i$, ${}_sz_i$:

Point-to-point difference between observation points and a reference point

x, y, z:

Natural variation of geomagnetism

${}_dx_i$, ${}_dy_i$, ${}_dz_i$:

Disturbances at observation points and a reference point (i=0)

Geomagnetic component values before the occurrence of a disturbance are as follows:

Before disturbance

Observation point $(X_0+{}_sx_i,\ Y_0+{}_sy_i,\ Z_0+{}_sz_i)$

Reference point $(X_0,\ Y_0,\ Z_0)$

Geomagnetic component values after the occurrence of a disturbance are as follows:

After disturbance

Observation point

$(X_0+{}_sx_i+x+{}_dx_i,\ Y_0+{}_sy_i+y+{}_dy_i,\ Z_0+{}_sz_i+z+{}_dz_i)$

Reference point

$(X_0+x+{}_dx_0,\ Y_0+y+{}_dy_0,\ Z_0+z+{}_dz_0)$

Differences between component values at each observation point and a reference point before and after the occurrence of disturbance are as follows:

Before disturbance

$({}_sx_i,\ {}_sy_i,\ {}_sz_i)$

After disturbance

$({}_sx_i+{}_dx_i-{}_dx_0,\ {}_sy_i+{}_dy_i-{}_dy_0,\ {}_sz_i+{}_dz_i-{}_dz_0)$

If differences are further condensed,

$({}_dx_i-{}_dx_0,\ {}_dy_i-{}_dy_0,\ {}_dz_i-{}_dz_0)$

Point-to-point differences disappear, and a difference in the amount of the disturbance to which each point was subjected can be obtained. These differences can be rewritten based on the values measured at each observation point and a reference point as follows:

$(X'_i-X'_0-X_i+X_0,\ Y'_i-Y'_0-Y_i+Y_0,$
$Z'_i-Z'_0-Z_i+Z_0) \equiv \boldsymbol{d}_i$

These values are known values. A magnetic field that is formed by a magnetic moment is expressed as follows:

$$A(r) = \frac{1}{4\pi r^5}\begin{pmatrix} -r^2+3x^2 & 3xy & 3xz \\ 3yx & -r^2+3y^2 & 3yz \\ 3zx & 3zy & -r^2+3z^2 \end{pmatrix}$$

$$M = \begin{pmatrix} M_x \\ M_y \\ M_z \end{pmatrix}$$

$$\beta(r_1, r_2) \equiv A(r_1) - A(r_2)$$

Therefore, the magnetic field becomes $\boldsymbol{A}(\boldsymbol{r})\boldsymbol{M}$ and the difference in the amount of the disturbance at observations points and a reference point can be calculated with the formula shown below:

$$\beta(r_i^{'}, r_0^{'})M \quad (= d_i)$$

The above formula is based on $\boldsymbol{r}_i^{'} = \boldsymbol{r}_i - \boldsymbol{r}_d$ $\boldsymbol{r}_0^{'} = \boldsymbol{r}_0 - \boldsymbol{r}_d$ in where $\boldsymbol{r}_d$ is the position of a magnetic moment. Assuming that $\boldsymbol{r}_d$ is also a known value, these can be considered part of the linear expression of $\boldsymbol{M}$. $\beta(\boldsymbol{r}_i^{'}, \boldsymbol{r}_0^{'})$ is hereinafter abbreviated as β_i. With the above formula, $\boldsymbol{M}$ can be calculated if there is one observation point. If there are a number of observation points, $\boldsymbol{M}$ can be calculated using the least square method. Ultimately, we have

$$\begin{pmatrix} \sum \beta_i^{(1)} \bullet \beta_i^{(1)} & \sum \beta_i^{(1)} \bullet \beta_i^{(2)} & \sum \beta_i^{(1)} \bullet \beta_i^{(3)} \\ \sum \beta_i^{(2)} \bullet \beta_i^{(1)} & \sum \beta_i^{(2)} \bullet \beta_i^{(2)} & \sum \beta_i^{(2)} \bullet \beta_i^{(3)} \\ \sum \beta_i^{(3)} \bullet \beta_i^{(1)} & \sum \beta_i^{(3)} \bullet \beta_i^{(2)} & \sum \beta_i^{(3)} \bullet \beta_i^{(3)} \end{pmatrix} M$$
$$= \sum \beta_i^T d_i$$

and $\boldsymbol{M}$ can be obtained using the above equation. Here, $\beta_i^{(j)} \cdot \beta_i^{(k)}$ etc., are the inner products of j- and k-column vectors.

4. Data Processing and Evaluation

The calculation method shown in the previous chapter assumes that the position of a magnetic moment is known. Therefore, the position and magnitude of a magnetic moment cannot be estimated simultaneously. If the position of a magnetic moment (position of a source of disturbance) is unknown or indefinite and if the position and the magnitude must be identified simultaneously, the position of a magnetic moment must usually be moved in small steps to find a position where there is the closest value to a measured value. Therefore, the computational load varies greatly depending on the presence or absence of positional information. Admitting this theoretical imperfection and computational disadvantage, we thought that the function of searching for the position of a magnetic moment is definitely required. The integration of this function was considered to be a definite requirement based on the considerations described below:

(1) There are cases in which the positions of the sources of man-induced disturbances cannot be identified in real-life conditions.
(2) Information on the positions of magnetic moments will enable us to evaluate calculation results from different perspectives.
(3) There is the potential to apply the method of searching for the position of magnetic moment to a monitoring system of man-induced geomagnetic disturbances.

We will here discuss how information on magnetic moments should be evaluated. First, it is conceivable to calculate a sum of squares (hereinafter called a residual) of a difference between the calculated and measured values of the amount of disturbance (or a measured value) at an observation point by using the position and magnitude of a magnetic moment measured. If a measured value can be reproduced completely, the residual becomes zero. In this sense, the position and magnitude of a magnetic moment can be considered the indicators to be used to make an absolute judgment.

Next, the accuracy of the position of an observation point and the accuracy of a measured value must be considered (positions of observation points and measured values are sometimes referred to simply as parameters). By collating the results of calculation using initial parameters with the measurements made at displaced observation points or the measurements containing errors, it may be possible to verify the degree of reliability. The accuracy of measured values varies depending on the performance of geomagnetism observation equipment or how measured values are handled (for example, how many measurements are used to calculate the average). The accuracy of positions also varies depending on the type of equipment used to measure the positions of observation points or whether or not the positions of observation points are measured on a map. The amount of variation of a magnetic moment relative to errors contained in parameters can be defined as one indicator.

These two indicators are related to one another. For example, not only a magnetic moment but also a residual varies depending on errors contained in a measured value or the position of an observation point. A slight fluctuation in parameters may cause a small residual to become large. A residual should be as small as possible, and it should not become large even if parameters fluctuate (within the limits of measurement accuracy). To achieve this, it is necessary to arrange observation points according to a well planned configuration.

The software developed is provided with a function of showing the residual above and the amount of difference resulting from errors contained in individual parameters. The residual is simply defined as the total of residuals at individual observation points. Because the number of observation points and the amount of disturbance measured at observation points change each time comparative observations are made, comparing data obtained by simply dividing measured values by the number of observation points (averaging) was considered inappropriate. Therefore, data cannot be evaluated by simply comparing the results obtained using this software with the residuals obtained from other comparative observations. The amount of difference resulting from errors contained in parameters is not necessarily a good evaluation indicator because it is not always proportional to a change in magnetic moment and errors of individual parameters are correlated, not independent. If the amount of difference is shown for all parameters, the volume of information to be shown will be too large, making it difficult to grasp the overall picture. Therefore, only the square roots of sums of squares are shown. It should be pointed out here that values, large or small, must not be associated directly with the degree of reliability of magnetic moment values. Even if magnetic moment values measured are correct, they never become zero. It should be used as a judging indicator in a case, for example, if a large residual is detected at a certain observation point and if it becomes smaller after the position of that observation point is displaced in comparison with other parameters, it should be judged that although a measured value is correct, the position setting (measurement) of an observation point might have been wrong.

5. Cases of Man-Induced Geomagnetic Disturbances

There have been some reports of the results of the comparative man-induced geomagnetic disturbance observations. Of such reports, four reports showing the influence quantities of total magnetic force were selected, and their data were calculated again using the upgraded (developed) method. Vector components are eastward, northward, and upward, respectively.

Regrettably, many of these reports did not show sort of the residuals for estimating the result of calculation. This is thought to be attributed to the fact that the purpose of these surveys was to verify whether or not the disturbance reached an absolute observation room. In our study, values given in reported cases were used to calculate residuals, and the calculated residuals were compared with those calculated using the upgraded (developed) method.

Case 1: Survey of disturbance caused by the replacement of a utility pole with a new one (Shimizu 1994)

In the survey of a disturbance caused by the replacement of utility poles with new ones on the premises of the Kanoya Branch, it was assumed after considering the special characteristics of the utility poles that a magnetic moment works only in a vertical direction, and the height of a position of a magnetic moment was defined as 3.4 m from the gravity point of a utility pole. It was concluded based on the result of observation made at a point 10 m from the utility pole located along a survey line that the magnetic moment in the vertical direction is Mv=3.0e5 [cgsemu].

On the other hand, if the position was set to (0, 0, 3.4) [m], M was found to be (-1.2 e-4, 4.7e-5, 5.0e-4) [Am^2] using the upgraded (developed) method and the measurements given by a proton magnetometer set at a height of 2.5 m. In this case, the residual was enormously large at 3 to 4 observation points, and the overall residual exceeded 1,000. The residual was recalculated without using the measurements at 4 points (WNW5, WNW10, W5, and WSW5) where the residual

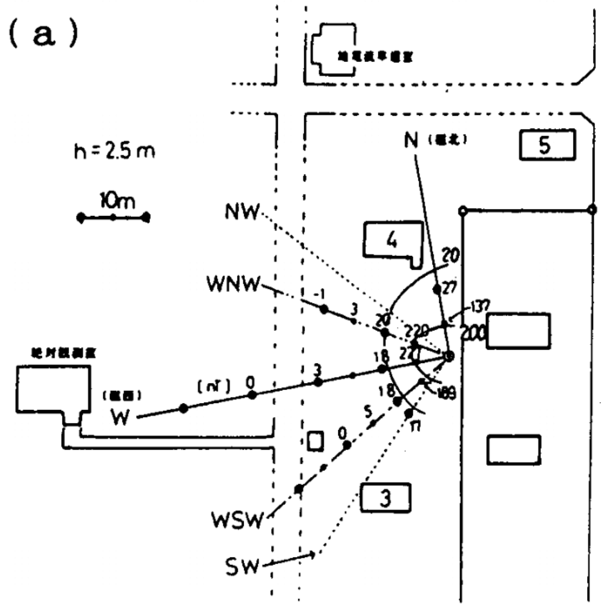

Fig. 2 Arrangement of observation points (case 1) Data extracted from the material prepared by Shimizu (1994)

Table 1 Residuals at each observation point

	(A)	(B)	(C)
N5	42.8	0.6	0.9
N10	1.7	9.6	9.7
WNW5	155.0	-	0.6
WNW10	187.6	-	8.4
WNW15	55.9	16.5	8.4
WNW20	29.1	15.4	10.2
W5	603.9	-	0.2
W10	65.3	3.3	3.2
W15	16.4	1.3	0.1
W20	0.0	1.7	3.2
W30	0.5	0.1	0.0
W40	0.5	0.3	0.2
WSW5	120.9	-	0.1
WSW10	19.3	2.5	0.0
WSW15	1.2	0.3	0.2
WSW20	4.6	2.2	2.0
WSW25	4.6	3.3	3.1
WSW30	2.8	2.3	2.1
SW10	52.3	7.1	3.7
Residual(total)	1364.4	66.5	56.5

exceeded 100. The result of recalculation shows that the residual decreased to about 70. This residual value is smaller than the value (about 300) obtained by removing the residuals at 4 observation points. Therefore, the value should be considered reasonable and valid. Because only a slight positional displacement causes the amount of disturbance to change greatly at short range of 5 m or less from a utility pole, it is not exactly wrong to judge that large errors observed are associated with this relationship between the amount of disturbance and a positional displacement.

By using all observation points without removing some of them, the magnetic moment and positions were calculated, and it was found that the position is (-1.7, 1.3, 3.4), M is (-1.5e-05, 6.7e-05, 2.4e-04), and the residual is a little less than 60. An examination of these values shows that a difference between the amount of disturbance and actual measurement is not so large. The positions of utility poles are clear and definite so a critical factor is how the result of calculation, i.e., the position of a source of disturbance (-1.7, 1.3, 3.4) should be interpreted. If it is interpreted as being within the acceptable error span of positional measurement, it should be regarded as a value based on which measured values can be well accounted for. Otherwise, if it is interpreted as being outside the acceptable error span of positional measurement, it should not be adopted even if the residual is small. We will then examine the measured values at each observation point. With the position of a magnetic moment defined as (0, 0, 3.4), we will here examine the measured values at observation points where large residuals were observed. Possibilities are that there was accidentally another source of disturbance there, that a point-to-point difference was large in that location, etc. For each case, the residual at each observation point is shown in Table 1. In this table, (A) is a case in which the position of a magnetic moment is (0, 0, 3.4), (B) is a case in which calculations were performed by removing data at the observation points shown as blanks, and (C) is a case in which calculations were performed by defining the position as (-1.7, 1.3, 3.4).

Case 2: Test field on the Kakioka premises (Fukui et al. 1998)

Comparative observations of man-induced geomagnetic disturbances made as part of training activities were reported. Because a magnet with a known magnetic moment was placed on a test field, both measured values and calculation results are neat and orderly. According to the report prepared by Fukui et al., some groups of three points were selected, a magnetic moment was calculated for each group, and the average of all magnetic moments was calculated. While all the observation points are used simultaneously for the upgraded (developed) method, the magnitude of a magnetic moment obtained were in good agreement with those shown in the report by Fukui et al. Variation in the positions of magnetic moments (original point for this case) is on the order of several tens of centimeters. This shows that reliable results can be obtained with a reasonably small number of observation points if the level of accuracy of positions and that of measured values are high.

Case 3: Disturbance caused by a building (Fukui et al. 2000).

The disturbance caused by the JA building northwest of the Kanoya Branch was surveyed. Calculations were performed using the upgraded (developed) method, and it was found that there are very large residuals at two to three observation points as pointed out in the report. By removing data on these observation points, recalculations were made, and approximately the same magnetic moment value was obtained. Calculations to find components and position of magnetic moment were also performed and the height became about 11 m, which does not agree with real-life conditions. The building is a steel-frame, single-story building of 40 m (20 m in size. To be exact, therefore, it does not meet the requirement that “a source of disturbance must be a magnetic moment at a single point,” which is specified in Chapter 2. Observation Condition 1. By removing some points close to the building, recalculations were performed, and the position of the magnetic moment was (-5.8, -7.7, 1.1). Although it is not outside the building, it is away from the center of the building. A magnetic moment is not always in the center of a building for reasons of a building structure, locations of steel material, etc. To further investigate this matter, information on each steel material, such as magnetic susceptibility, is required.

At some observation points, the positions of measurement seem too close to the building if the size of the building is considered. Although a difference was examined between a case in which all these observation points are included and a case in which they are excluded, it was difficult to verify whether or not the observation points arranged close to the building are affected by the size of the building. However, it is inferred that measurements at the observation points close to the building are affected by the factor that “a source of disturbance is not a magnetic moment at a single point” if we consider the following three points: (1) The overall residual becomes small if the observation points close to the building are excluded. (2)

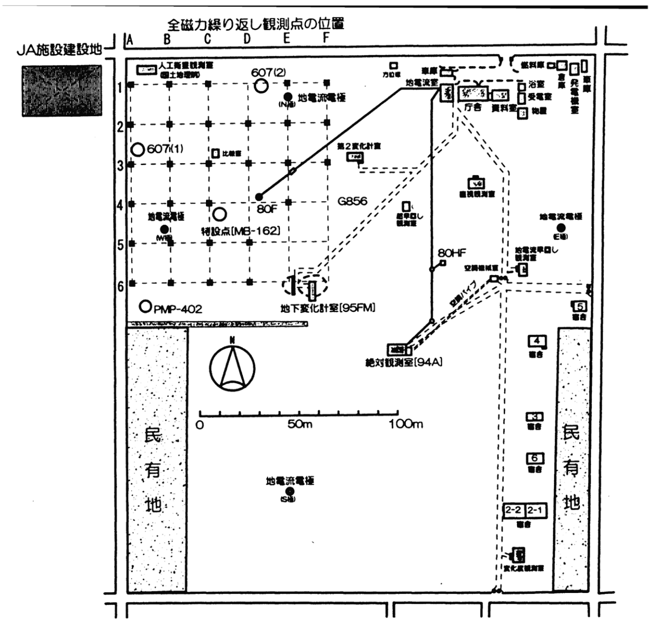

Fig. 3 Arrangement of observation points (case 3)
Data extracted from the material prepared by Fukui et al. (2000)

The position of a magnetic moment is inside the building. (3) If the observation points close to the building are included, slight residuals remain at those observation points close to the building.

Case 4: Disturbance caused by a linear source of disturbance (Nakajima et al. 2001)

Steel plates were laid on the road over a distance of 200 m during the sewage pipe installation work done at a location northwest of the Kakioka Magnetic Observatory. Although it is considered a linear source of disturbance, not a point source, the results of observation of geomagnetic component values were included in data obtained concerning this disturbance source and, therefore, they were compared with the geomagnetic component values measured using the upgraded (developed) method.

Geomagnetic component values were measured by a flux-gate magnetometer and an Overhauser magnetometer installed at a location about 200 m south-southeast of the work site. A point of installation at 90FM was defined as a reference point. 17 total magnetic force points were established. The amount of disturbance at these points was small. The amount of disturbance exceeded several nT at four observation points near the work site. Therefore, it was difficult to increase the accuracy.

The calculation results show that the position of a horizontal plane was slightly northwest of the steel plates and the orientation of the magnetic moment was about 45 degrees northeast. If only total magnetic force values are used, the height was about 3m. If both total magnetic force values and component values are used, it was about 10 m (30 m at 90FM). In both cases, the height was unnatural. In the report, however, the height of observation points is not shown. In performing calculations, positions of observation points were acquired from contour lines on a map and, therefore, the level of accuracy is not very high. In case 4, although the residual is not large (3 to 5) it should be taken into consideration

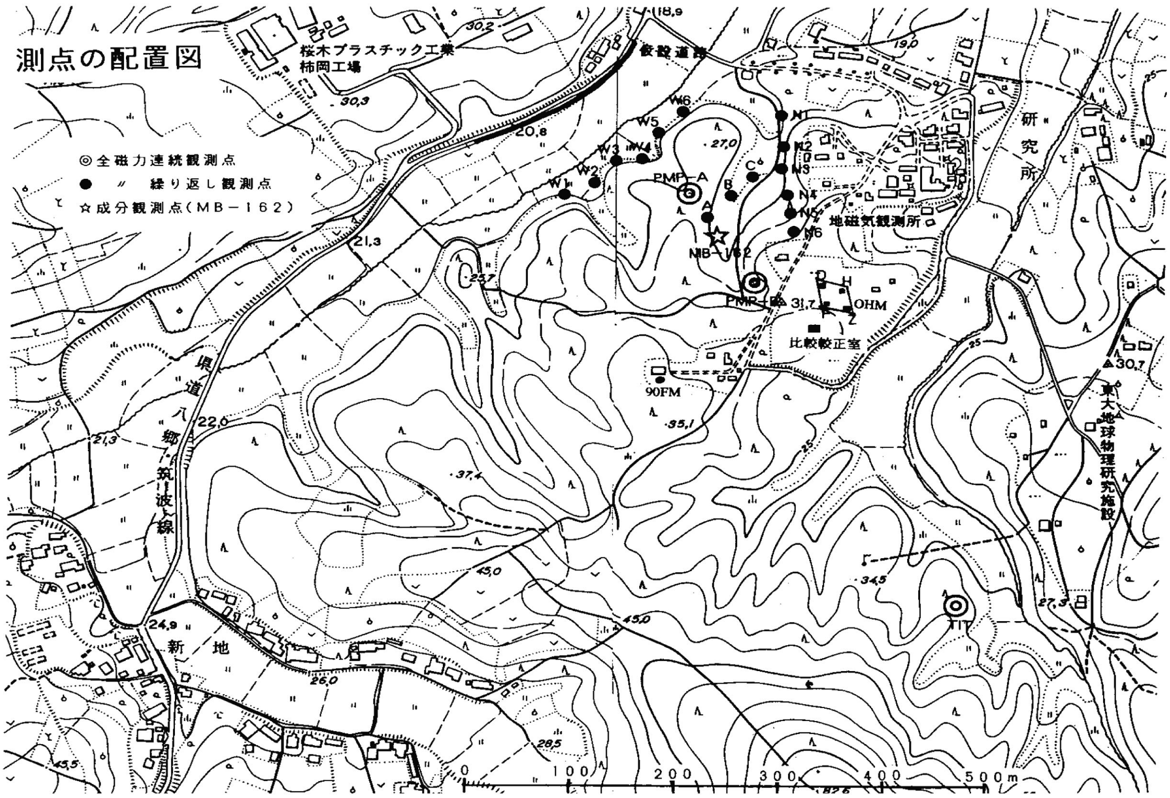

Fig. 4 Arrangement of observation points (case 4)
Data extracted from the material prepared by Nakajima et al. (2001)

that the amount of disturbance at each observation point was small from the beginning. Calculations were also performed with the position of a magnetic moment fixed to the position of the steel plates. The residual was approximately on the same level and did not increase, the orientation of the magnetic moment was approximately equal to that of the steel plates (about 35 degrees east-northeast), and the Z-component of the magnetic moment was smaller by a factor of 10 than the horizontal component. It is thought that these results well account for the actual conditions. In case 4, although the measured value at the W1 point relatively closer to the steel plates was slightly different from the calculated value, a specific effect associable with the linear source of disturbance could not be found.

In all cases described, we think that measured values can be well accounted for based on the magnetic moments obtained. Although a person who handles data should examine data from various perspectives and make an ultimate judgment, recalculating data on past cases is a good training activity for those concerned with research in geomagnetic disturbances.

6. Conclusion

Data analysis using the method discussed in this paper is accompanied by three problems: (1) A great deal of time and labor must be used. (2) The degree of reliability of the results of data analysis can be defined only vaguely. (3) It is difficult to reproduce the process of data processing. Using the upgraded (developed) method, it is possible to evaluate data from various perspectives by repeatedly performing a data processing cycle (examining calculation results, changing parameters, performing recalculations, and examining the calculation results again) easily.

Variation in a magnetic moment caused by residuals and parameter errors was introduced as an evaluation indicator. Although this indicator has a number of ambiguities, it is expected to enable us to share information on man-induced geomagnetic disturbances and to analyze them relative to a magnetic moment based on a common understanding. In analyzing data to study man-induced geomagnetic disturbances, measured values are checked by examining the relationships between a distance from a source of disturbance and the amount of disturbance, which decays by the power of 3 of a distance; measured values are not adopted as is. Using this approach, observation points must be established along a survey line extending from a source of disturbance. This imposes considerable restrictions on observations. Additionally, this conventional approach is used to check existing conditions, not to analyze data acquired from measurement. The indicator, therefore, is more straightforward because conditions of geomagnetic disturbance are identified and analyzed at the same time. Using the upgraded (developed) method discussed in this paper, calculations were performed with a focus on decreasing the residual. If the method was applied to past cases, we found that there are conditions other than the residual that must be met. For example, the range in which magnetic moments exist, the orientation of components, etc. To check to see if these conditions are met, the operator changed parameters and performed recalculations on his or her own judgment. However, the efficiency can be improved if this process of changing parameters and performing recalculations is integrated into a set of restricting conditions in advance. If a source of disturbance is a car, the range of search can be narrowed down to a line as a magnetic moment is always on the road.

If it is known in advance that a certain point is affected by man-induced geomagnetic disturbances, a plan can be prepared as to the placement of observation points for comparative observations. If the position and magnitude of a magnetic moment can be estimated to some degree, such as a building (based on the amount of steel material used), it is possible to make more detailed predictions. Key points are that there is a measurable amount of geomagnetic disturbance and that variation in the amount of geomagnetic disturbance is minimal (the magnetic gradient of geomagnetic disturbance is small) although the positions of observation points somewhat fluctuate.

It is feasible to analyze man-induced disturbances in real time by using data on geomagnetic observations. If a series of conditions from passing of a truck with steel materials, unloading of steel materials and passing of a truck again can be analyzed with a high degree of accuracy, there is a good prospect for doing data correction work efficiently.

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