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Observation of the Geomagnetic Total Force at Kusatsu-Shirane Volcano

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Abstract

After the small explosions at Kusatsu-Shirane Volcano in 1976, repeat measurement of the geomagnetic total force by proton-precession magnetometer has been carried out continuously every year at the observation points in and around the volcanic active regions. During the period from October 1982 to May 1984, the activity of Kusatsu-Shirane Volcano was enhanced in association with the frequent occurrence of volcanic earthquakes and five small steam explosions. In the present paper, the relationship between the volcanism and the long-term magnetic variation will be discussed based on the observation from 1976 to 1985. We confirm that the systematic spatial distribution of variations of the geomagnetic total force around the volcanic active regions could be interpreted by magnetization or demagnetization of the material beneath the volcanic active regions resulted from the volcanic thermal effect.

1. Introduction

The first magnetic observation at Kusatsu-Shirane Volcano was carried out by Yasui, Ohchi and others in the occasion of the Special Volcanological Observation of the Japan Meteorological Agency (abbreviated as JMA hereafter) in 1967. The purpose of the observation was to recognize basic characteristics on Kusatsu-Shirane Volcano during its quiet period. In that observation, the dip-angle of the geomagnetic field was measured at the several observation points [Ohchi, 1971].

In March, 1976, small steam explosions occurred at Mizugama, which was one of the active regions of Kusatsu-Shirane Volcano. In association with those explosions, staff of Kakioka Magnetic Observatory measured the geomagnetic total force by the proton-precession magnetometer in co-operation with the Earthquake Research Institute of University of Tokyo. Additional several observation points were employed in that magnetic observation. Since that observation, the geomagnetic total force has been measured periodically every year, and the observed results have been presented to the Report of coordinating committee for prediction of Volcanic Eruptions [Kakioka Mag. Obs. and Earthquake Research Institute of Univ. of Tokyo, 1977; Kakioka Mag. Obs., 1985] and others [Harada et al., 1985]. In the present paper, the magnetic field variation from the observation for the period from 1976 to 1985 will be compared with the volcanic activity around 1983. As a result, it will be clarified that the long-term

variation of the geomagnetic total force observed around the volcanic active regions is well correlated with the thermal metamorphose of the underground material (the magnetization or demagnetization of the material).

2. Distribution of the observation points and outline of the observation

Fig. 1 shows locations of the observation points, which are mainly distributed around the volcanic active regions such as Yugama and Mizugama crater lakes. Those observation points were selected to be sufficiently free from the topographic changes associated with volcanic activities or other natural phenomena. Relatively small geomagnetic spatial gradient at each point introduces no significant errors in the secular variation of the total force obtained from the repeated observation every year. This is because the underground material at Kusatsu-Shirane Volcano consists of andesite whose magnetization is smaller than that of basalt. Bearing in mind that a horizontal magnetic field gradient tends to be as large as a vertical one, only vertical gradients at the observation points are listed in Table 1. The vertical gradient is derived as a difference between value of the height 1.4m and that of 1.9m. As shown in the table, all observation points have values less than 20nT. Five points show the value of 5~10nT, and particularly nine points show value less than 5nT.

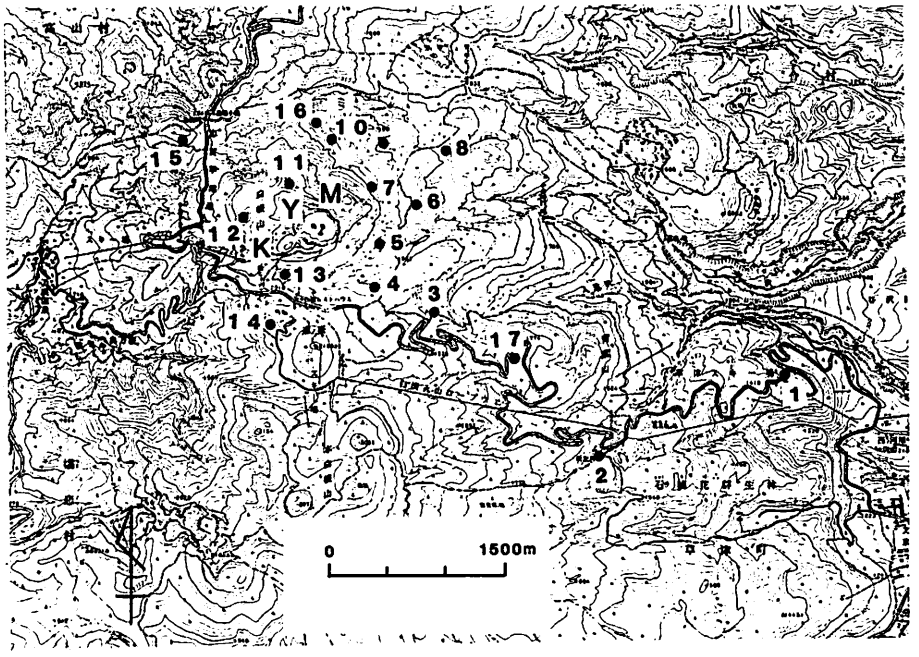


Fig. 1. The distribution of observation points of the geomagnetic total force.
K: Karegama crater lake, Y: Yugama crater lake, M: Mizugama crater lake

Table 1. Differences of the geomagnetic total force between 1.9m height and 1.4m height at each observation point

Observation Point	Difference (1.9 m)—(1.4 m)	Observation Point	Difference (1.9 m)—(1.4 m)
1	0.8 nT	10	−2.5 nT
2	−8.9	11	−19.0
3	−12.0	12	−2.6
4	1.1	13	6.9
5	−5.7	14	8.8
6	−4.8	15	−1.8
7	−4.0	16	−5.7
8	19.2	17	−0.4
9	−2.2		

The magnetic measurement has been carried out by setting the sensor of the portable proton-precession magnetometer at the height of 1.4m above the ground. The magnetometer has been set setting carefully to keep the constant position at each observation repeated every year. The total force at each point is a mean values of 10 or 15 one minute values, each of which is an average of 5 values measured every 5 seconds from 50 sec to 10 sec. In order to pick up any abnormal change associated with the volcanic activity, Yatsugatake magnetic observatory is used as a standard observation point. Yatsugatake observatory belongs to the Earthquake Research Institute of University of Tokyo and is located about 60 km south of Kusatsu-Shirane Volcano. In addition to the standard observation, the reference observation is made at a certain point in the volcanic region for the purpose of reduction of the regional difference of the external magnetic field variation, for example, solar quiet daily variation. The reference total force is measured every minute during each repeat observation. The correction value is calculated by comparing the standard and reference data at midnight (00-03LT). The reference points were located about 1.5km south of Yugama at the observation of 1976~1982, north of Sanjo-ropeway station in 1984 and around the observation point No. 5 in 1985, respectively.

Non-magnetic pile was buried at each observation point as a marking. Among them, the piles at the observation points, Nos. 7, 11, 13, were destroyed by ejected blocks associated with the small explosion on November 13, 1983. However, they were repaired in 1984. No ejection of blocks and ash was observed except the period of small explosion from October 1982 to May 1984.

3. Result of the observation

Fig. 2 shows secular variation of the geomagnetic total force at the observation points relative to that of the standard observation at Yatsugatake magnetic observatory. Occurrence frequency of the volcanic earthquakes on every month is also summarized in the figure. The secular variation in Fig. 2 shows decreases in the total

force at every observation points. That tendency is consistent with the secular variation in the Central Japan, in which the annual change rate increases with locating the point southward. In other word, the amount of the annual change of the total force at Yatsugatake, which is located about 60km south of the observation points at Kusatsu-Shirane, is larger than that of every observation points from No. 1 to No. 17.

Fig. 3 exhibits the secular variation at the observation points (No. 2~No. 17) relative to that at No. 1, which is located far from the volcanic active regions. The results shown in Fig. 3 are summarized as follows,

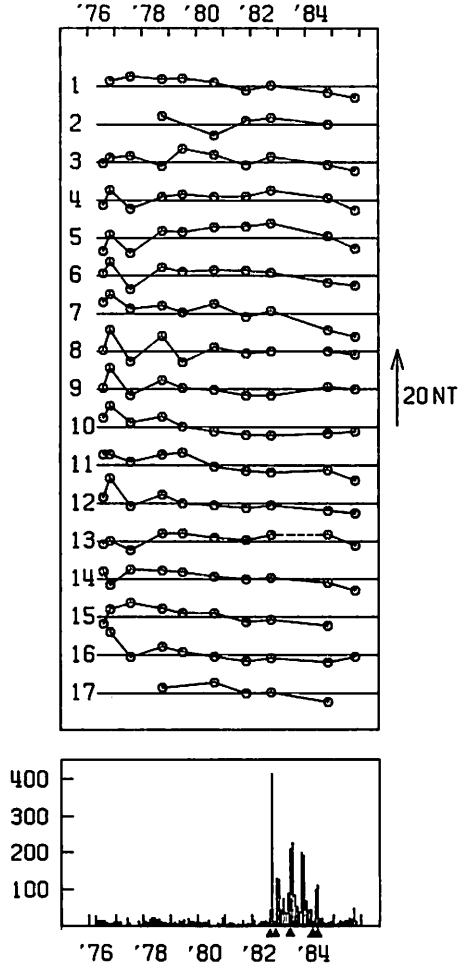


Fig. 2. Variation of the geomagnetic total force relative to that of Yatsugatake Magnetic Observatory and monthly number of volcanic earthquakes. Triangles below the horizontal axis denote the eruptions.

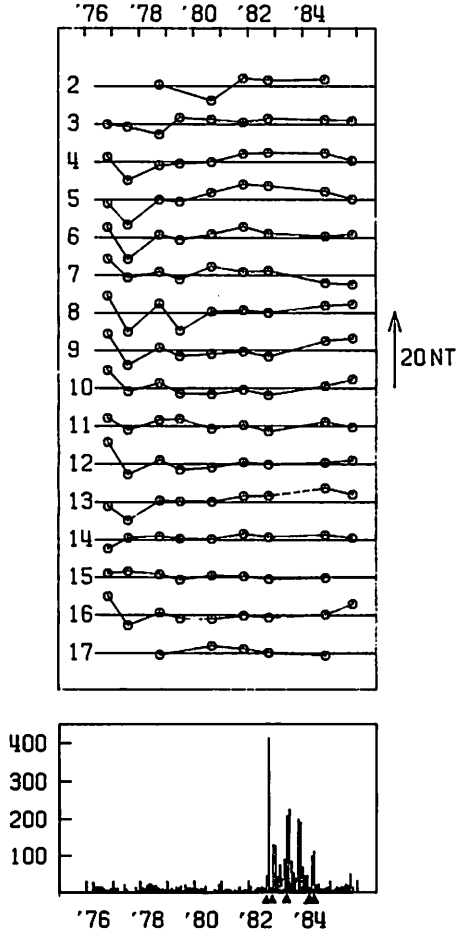


Fig. 3. Variation of the geomagnetic total force relative to that of observation point No. 1 and monthly number of volcanic earthquakes. Triangles below the horizontal axis denote the eruptions.

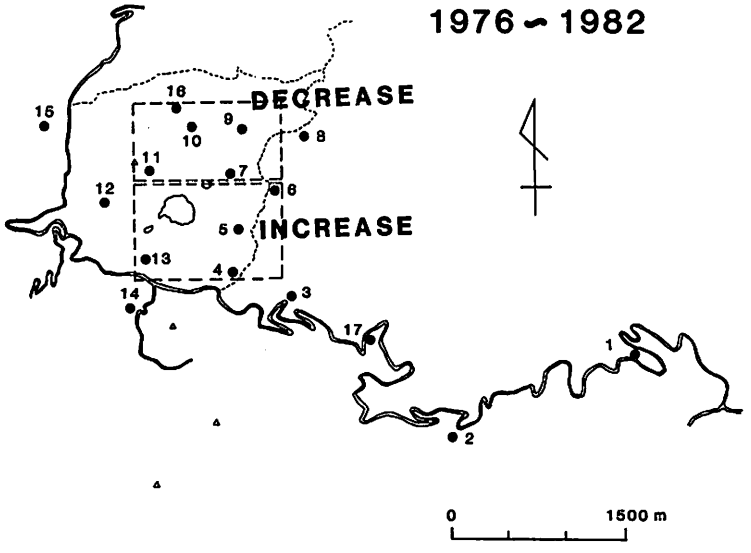
(1) Relative variation of the total force in the period from 1976 to 1981: the total force tends to decrease at Nos. 7, 9, 10, 11 and 16, which are located in the northward of the volcanic active region, while it tends to increase at Nos. 4, 5, 6 and 13, which are located in the southward. It should be noted that larger changes shown at some stations in 1977 might be related with measurement in the magnetic storm.

(2) Relative variation of the total force in 1982: small steam explosions occurred on October 26, 1982 around the volcanic active regions, Yugama and Karegama. Five days after the explosions, magnetic observation was carried out. It should be noted that the tendency of the secular variation changed from increasing to decreasing at Nos. 5 and 6, which were located near the volcanic active regions. No clear change could be found at other points.

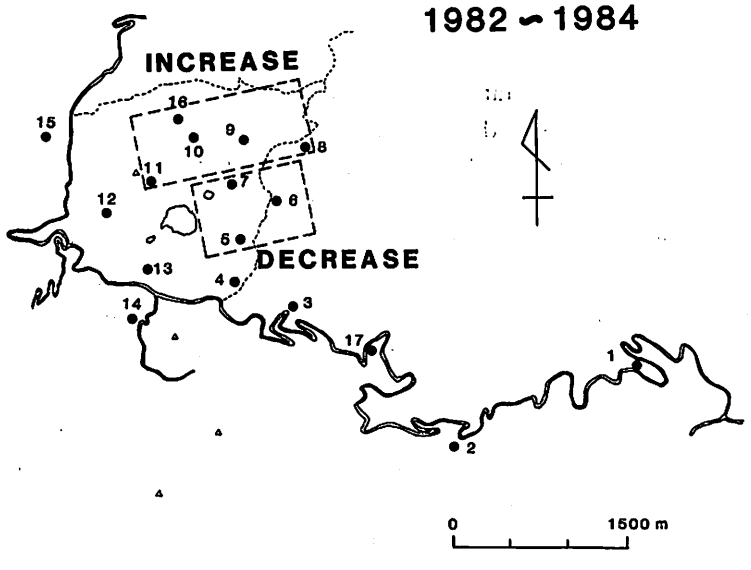
(3) Relative variation of the total force in the period from 1982 to 1984: the occurrence number of the volcanic earthquakes rapidly decreased in May 1984. The magnetic observation was carried out in October 1984. The total force tends to increase at Nos. 8, 9, 10 and 11, which are located in the northward of the volcanic active regions. While it tends to decrease at Nos. 5, 6 and 7, which are located southward or eastward of that regions. Those tendencies are opposite to those shown during the volcanic quiet period from 1976 to 1981. However, an increase in the total force at No. 13, wich is located in the southward region of the volcanic active regions, is anomalous in view of general feature of the total force variations. The observational results at this point might be associated with damage of pile by the explosion above mentioned, although that point was repaired. Thus, the tendency at No. 13 should be confirmed accumulating measurements hereafter. There was not any clear change at the points which were located far from the volcanic active regions.

(4) Relative variations of the total force in the period from 1984 to 1985: the tendency of the variation in 1984~1985 is almost similar to that in 1982~1984 at every point. Namely, the points located in the northward of the volcanic active regions show increase in the total force, while the observation points located in the southward show decreasing. It should be noted that No. 16 shows relatively rapid change.

Points of increasing and decreasing relative variation of the total force are marked by dotted square as shown in Figs. 4a, 4b and 4c. Fig. 4a shows the results for the volcanic quiet period from 1976 to 1982, while Figs. 4b and 4c show the results after volcanic active period from 1982 to 1984 and from 1984 to 1985, respectively. The results summarized in Figs.4a~4c suggest that location for increasing and decreasing regions was reversed during the volcanic active period of 1984. The demarkation line between increasing and decreasing regions was shifted from the central part of Mizugama to the north-east part. According the results from the observation in 1985, the demarkation line was further shifted to northward.

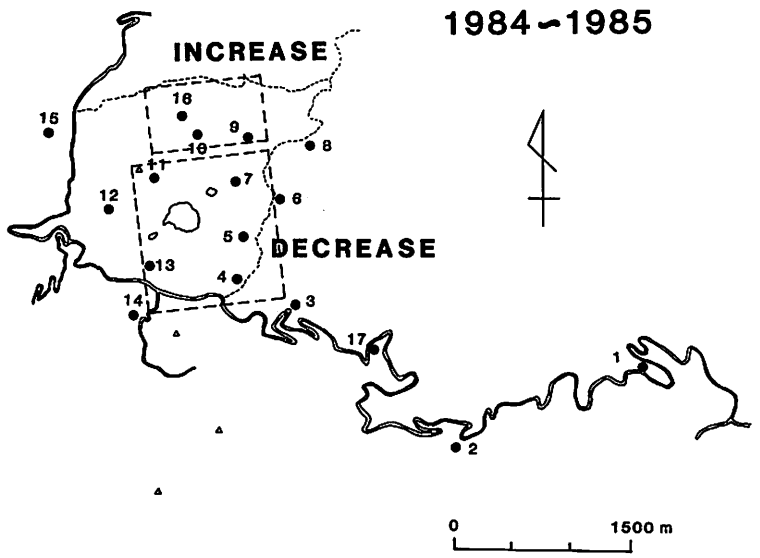


(a) 1976—1982,



(b) 1982—1984,

Fig. 4. Spatial distribution of the relative variations of the geomagnetic total force against the observation point No. 1. Curves denote roads.



(c) 1984—1985

Fig. 4. (Continued)

4. Discussion

It has been clarified that the secular variation of the geomagnetic total force was reversed at the region of the southern and northern parts of the volcanic active region during the volcanic active period of 1984. Considering the accuracy of the measurement, we can conclude that those variations summarized in Figs. 4a~4c are associated with the volcanic activity. Such the association will be interpreted as follows,

(1) The observational results during the volcanic quiet period from 1976 to 1981 are caused by increasing magnetization of the underground material in the northward of Yugama. Namely, after the explosion of Mizugama in 1976, reduction of the heated region or cooling occurred causing the magnetization of the underground material around the volcanic active region.

(2) The observational results during the period from 1982 to 1985 are interpreted by decrease in magnetization by heating of the underground material in the north-east region on Mizugama. The shift of the demarkation line between increase and decrease in the total force from the north-eastern part of Mizugama in 1984 to further northern part in 1985 indicates a possibility of shift of the volcanic active region.

(3) Any volcanism associated variation could not be seen at the observation points located far from the volcanic active region more than 1km. That fact suggests the volcanism associated magnetization occurred in a very localized region, only several hundred meter underground, for example.

(4) The observations in 1984 and 1985 were carried out 5 and 17 month after

the volcanic active period. Therefore the occurrence frequency of the volcanic earthquake as well as apparent volcanic activity had already decreased at that time. However, the results from the magnetic observation suggested that heating of the underground material had still made the magnetization beneath the volcanic active regions decrease.

(5) According the results from the measurement of fumarolic temperature in 1984 by Ossaka and Hirabayashi (1985), heating still continues in the northern part of the top of Kusatsu-Shirane Volcano. According the report of the volcanological bulletin of JMA (1984), hypocentral distribution of the volcanic earthquake are concentrated in the region of 500m~1000m depth in the north-eastern part of Mizugama. Those results are consistent with the assumptions derived from the magnetic observation. After the preliminary theoretical examination (Tsunomura, private communication), the behavior of the magnetic variation during the period from 1982 to 1984 could be interpreted by appearance of a spherical demagnetization area of 200m diameter at the underground of 500m depth (1500m above the sea-level) around the observation point No. 7.

5. Conclusion

We confirm that the systematic spatial distribution of variations of the geomagnetic total force around the volcanic active regions can be interpreted by magnetization or demagnetization of material beneath the volcanic active regions resulted from the volcanic thermal effect. If we can construct continuous observation points which locate north and southside in the active regions to carry out continuous measurement of the total force, we will find more effective volcanism associated informations, especially that from the deep area of the volcanic active region.

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草津白根火山における全磁力観測

大地　洸

概　要

1976年の草津白根火山の小規模の爆発以後，活動域とその周辺部に測点を設け，プロトン磁力計による繰り返えし測量を実施してきた。一方，火山活動は，1982年10月から1984年5月までは活動的で，火山性地震の頻発と5回の水蒸気爆発があった。

筆者は1976年～1985年の測量の結果と火山活動の推移を対比して，活動域周辺の測点の全磁力変化は活動域地下浅部の熱による消磁又は帯磁に基因する変化として説明できることを示した。