EFFECT OF TOPOGRAPHIC CHANGES TO GEOMAGNETIC FIELD IN MIYAKE-JIMA VOLCANO DURING RECENT ERUPTION: RESULTS OF 3D MODELING

KOSTROV Nikolai and SASAI Yoichi
Earthquake Research Institute, The University of Tokyo, Japan

Abstract

Miyake-jima Island, about 150 km south of Tokyo in Izu-Bonin Arc, is one of the most active basalt volcanoes in Japan. During recent eruption in 2000 the large sink-hole was formed in the summit caldera. This sink-hole enlarged and deepened on and on, while eruptions took place. Measurements showed changes in geomagnetic total force during the same time. We modeled effect of topographic changes to geomagnetic field on 2 August. Calculations showed that observed changes in geomagnetic field impossible to explain only by changes in topography.

1. Introduction

Miyake-jima volcano belongs to the Izu-Bonin Arc along the eastern margin of the Philippine Sea Plate. It is one of the most active basaltic stratovolcanoes in Japan. Measurements of geomagnetic total force intensity along with others electric and magnetic field observations have long been conducted in Miyake-jima volcano (Sasai et al., 1997, 2001). During recent eruption large sink-hole was formed in the summit caldera. We calculated effect of topographic changes to geomagnetic field in Miyake-jima volcano utilizing vector integral equations approach firstly introduced by Sharma (1966). We solved following integral equation:

$$\vec{H} = \vec{H}_0 - \frac{1}{4\pi} grad_A \int_V \left[\kappa\vec{H} + \vec{I}_r\right] \cdot \frac{\vec{r}}{r^3} dV, \qquad (1)$$

$$grad_A = \vec{i} \cdot \frac{\partial}{\partial x} + \vec{j} \cdot \frac{\partial}{\partial y} + \vec{k} \cdot \frac{\partial}{\partial z}, \quad r^2 = (x-\xi)^2 + (y-\eta)^2 + (z-\zeta)^2, \quad dV = d\xi \cdot d\eta \cdot d\zeta$$

where κ is magnetic susceptibility; V is the volume of the volcano;

$\vec{H}_0 = \vec{i} \cdot H_{ox} + \vec{j} \cdot H_{oy} + \vec{k} \cdot H_{oz}$ is magnetizing field;

$\vec{I}_r = \vec{i} \cdot I_{rx} + \vec{j} \cdot I_{ry} + \vec{k} \cdot I_{rz}$ is remanent magnetization;

We used rectangular coordinate system with axis OX directed eastwards; axis OY directed northwards and axis OZ directed upwards. The origin of coordinate system was at the triangulation point (height 462.4 m) in the Southwest part of Miyake-jima volcano.

We considered the volcano to be composed of small prismatic rectangular cells with the assumption of uniform magnetization within each cell. Then we reduced the integral equation to a set of linear algebraic equations, which was solved by iteration. To prepare volcano models we developed a software program complex for 3D model construction, which works in Unix environment.

2. Model description

Our models based on Miyake-jima digital topographic maps. Maps were provided by GSI (GSI, 2000). Firstly we modeled volcano before eruption. Next we modeled it after sink-hole was formed on 2 August. We assumed that magnetization was homogeneous and used following values (Ueda et al., 1983): magnetic susceptibility 0.0126 SI, remanent magnetization 8.5 A/m , inclination 46.3°, declination –5.6°, magnetizing field 35.81 A/m. Volcano model before eruption is presented on Fig.1

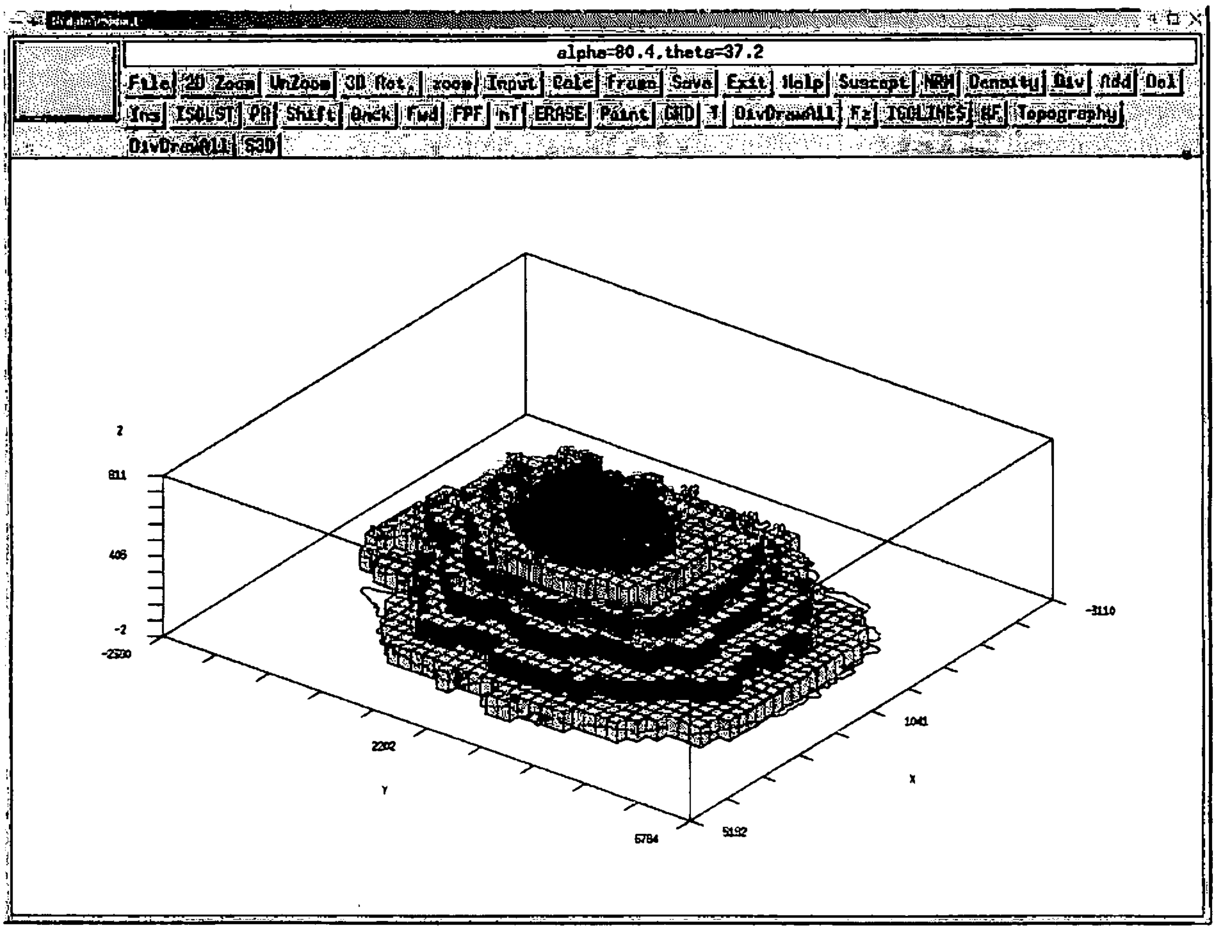


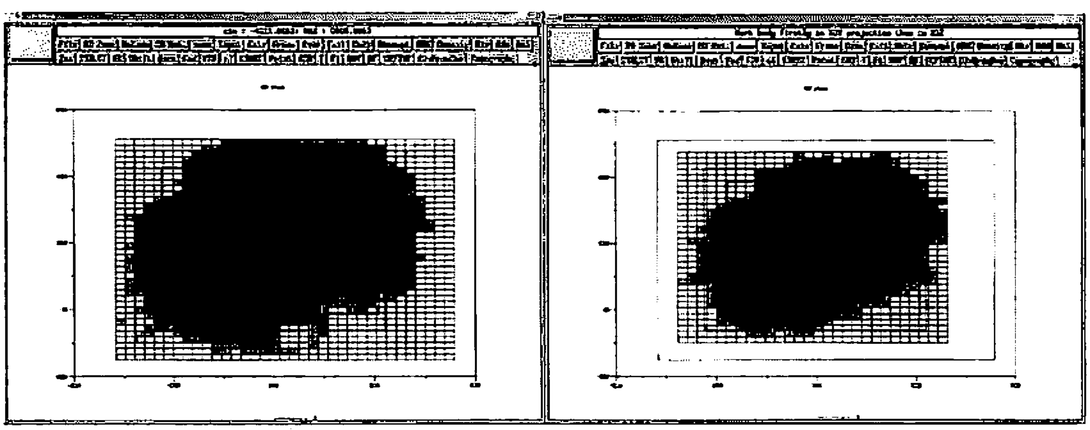
Fig.1. Graphic window of program complex for 3D model construction. The model of Miyake-jima volcano before eruption and topographic isolines are shown. Numbers at axes are distances in meters from triangulation point (height 462.4 m) in the Southwest part of Miyake-jima volcano. Axis OX directed eastwards, axis OY directed northwards, axis OZ directed upwards. At the top of the window there are buttons of our program complex.

The model consists of several layers of rectangular cells. Dimensions of a cell are shown in Table 1 layer by layer.

Layers from the bottom to summit	Cell dimensions, meters
1. 0–100 meters	200x200x100
2. 100–200	200x200x100
3. 200–300	200x200x100
4. 300–400	200x200x100
5. 400–500	200x200x100
6. 500–600	100x100x100
7. 600–650	50x50x50
8. 650–700	50x50x50
9. 700–720	50x50x20
10. 720–740	50x50x20
11. 740–760	50x50x20
12. 760–780	50x50x20
13. 780–800	50x50x20
14. 800–820	50x50x20

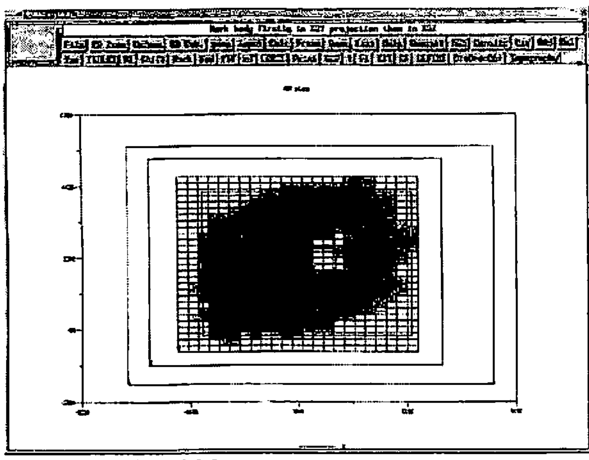
Table 1. Structure of volcano model before eruption.

Figure 2, Fig.3, and Fig.4 represent geometry of the sink-hole model. Layers of the model are the same as in previous one. Darkened cells denote magnetized rocks.

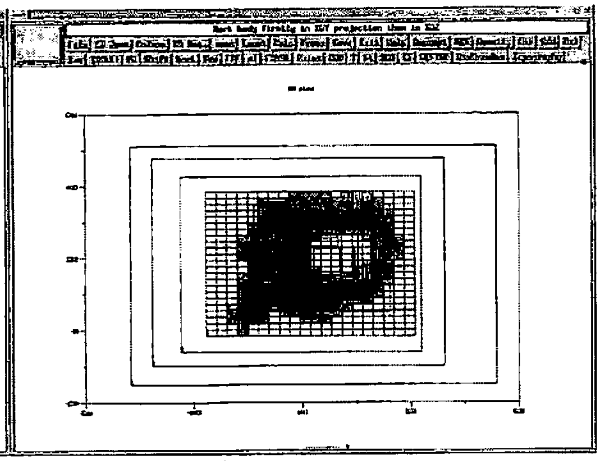


Layer 1, 0–100 m Layer 2, 100–200 m

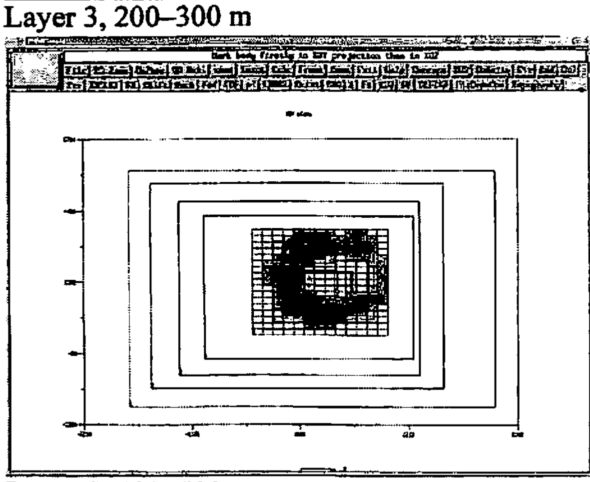
Fig.2. Structure of layers 1 and 2 of the sink-hole model.



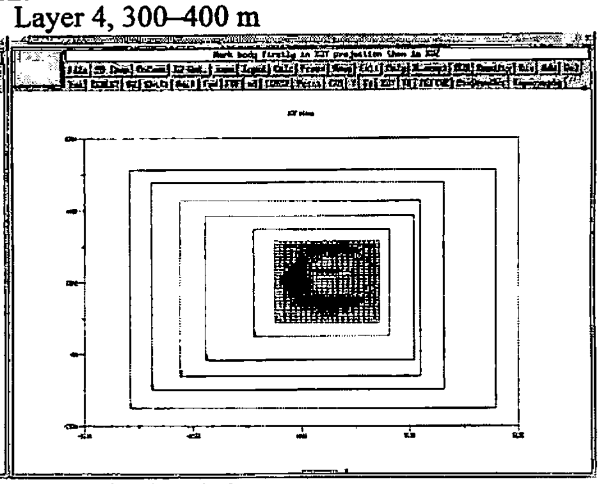
Layer 3, 200–300 m



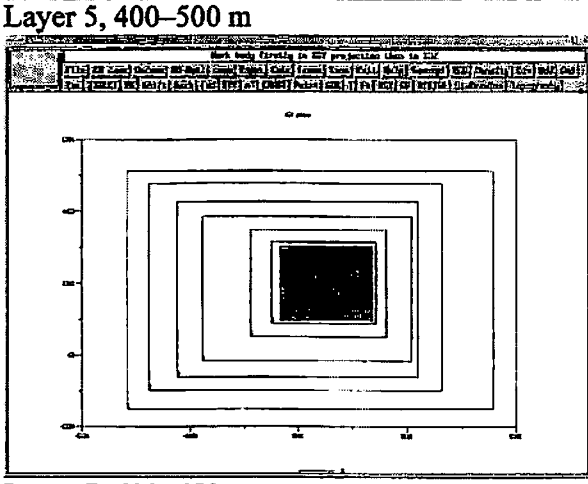
Layer 4, 300–400 m



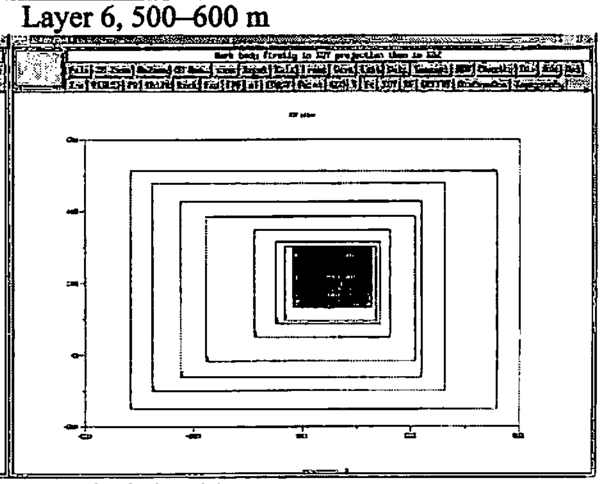
Layer 5, 400–500 m



Layer 6, 500–600 m

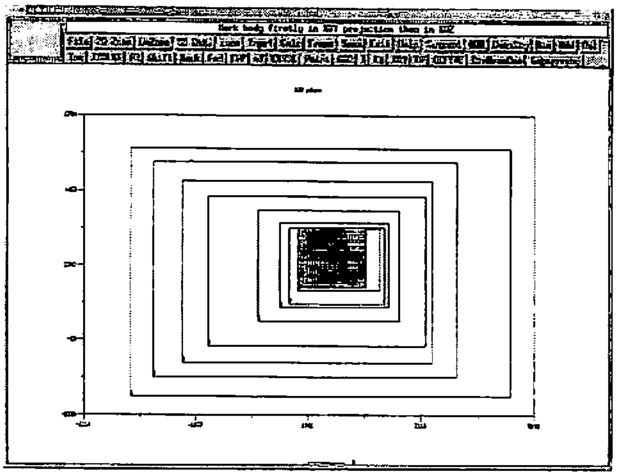


Layer 7, 600–650 m



Layer 8, 650–700 m

Fig.3. Structure of layers 3 – 8 of the sink-hole model. Dark cells represent magnetized rocks.



Layer 9, 700–720 m

Fig.4. Structure of layers 9 of the sink-hole model. Dark cells represent magnetized rocks.

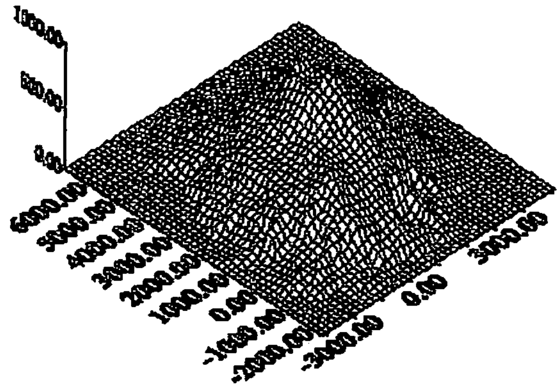


Fig.5. Model fields were calculated on this grid. The grid approximates volcano topography.

3. Results and conclusion

We calculated magnetic fields for these models. Fields were calculated on the grid, which approximates volcano topography. The grid is shown on Fig.5. Then we found a difference between magnetic total forces of the sink-hole model and volcano model before eruption. The difference is shown on Fig.6. Comparisons of observed effect with calculated one is shown in Table 2.

Station name	Effect of topographic changes to geomagnetic field	
	Calculated F, nT	Observed (Sasai et al., 2001) F, nT
KMT	-1.6	20
KMU	-6.7	-32
TRK	-23.6	-19
TAR	-6.8	2
KNS	13.2	37
IGU	40	42
TJM	9.3	21

Table 2. Comparisons of observed effect with calculated one.

As one can see from Table 2 model gives the effect less than measured effect excepting station KMU. Thus it is impossible to explain observed effect only by topographic changes. It should be taken into account thermal demagnetization as well as inhomogeneously magnetized rock structure of the volcano.

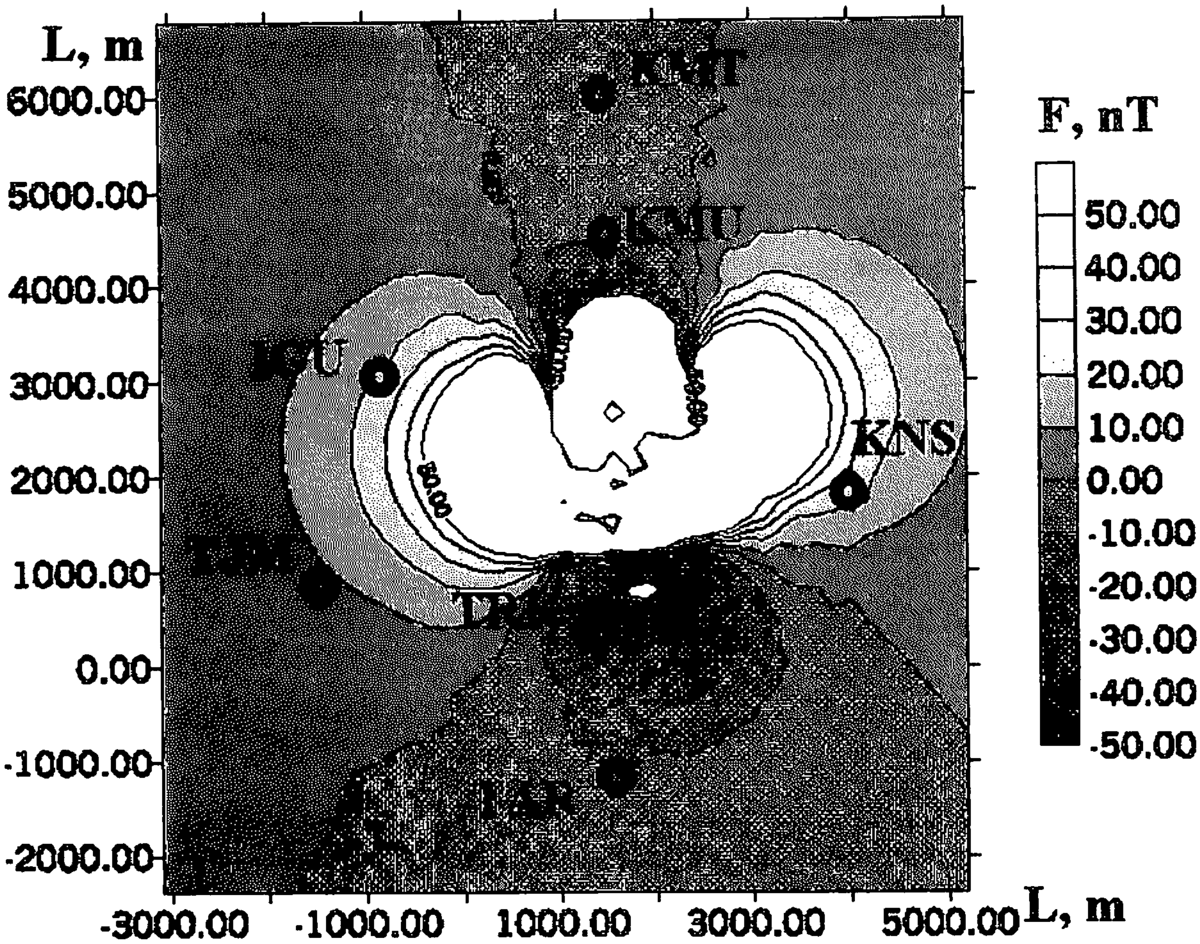


Fig.5 Effect of topographic changes to geomagnetic field in Miyake-jima volcano on 2 August 2000: result of 3D modeling. Position of some observation stations and station names are shown.

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