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NUMERICAL ANALYSIS OF TECTONIC DEFORMATION BY MAGMA  
INTRUSION AND PREDICTION OF VOLCANIC ERUPTION

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**Abstract**-Numerical analysis by discrete models was used to reveal the shape and depth of underground magma body from pattern of ground movement of the Izu-Oshima volcano, Japan. Measurement of areal pattern of ground movement of volcanic surface is useful for tracing of underground movement of magma body and for prediction of volcanic eruption.

INTRODUCTION

Discrete models are suitable for numerical simulation of tectonic deformation of the Earth's crust which is essentially discontinuous with faults, joints and various boundaries of rocks. The Japanese Islands locate near of boundaries between major plates: Eurasia plate, Philippine Sea plate, Pacific plate and North American plate. Active interaction between plates induces frequent earthquakes and volcanic activities, in Japan. On the November 15th, 1986, the first volcanic eruption since 1974 started in the summit crater of the Izu-Oshima volcano, Japan. Earthquake swarms, volcanic tremors, etc. signaled the earlier subsurface magmatic activity, but the subsidence of central surface of the volcano prevented the short-term prediction of the eruption as people believed that upraise of subsurface magma body induces upheaval of ground, only.

In many cases, the inflation of central surface of volcano proved of the most reliable precursor of volcanic eruption. However, Koide and Bhattacharji(1975) pointed out that rock mass could be depressed in the central area by the increase of magma pressure above the magma body which has long-vertical depth with narrow horizontal section.

NUMERICAL ANALYSIS BY DISCRETE MODELS

In this paper, the authors applied the rigid-body-spring method (RBSM) by Kawai(1980) for a realistic simulation model of tectonic effect of subsurface magma intrusion where differential movements along fractures have vital role for deformation of the crust. In the two dimensional calculation, an elliptical hole is assumed in a rectangular plate(Fig.1). The wall of hole is applied with magma pressure. At the start of calculation, magma pressure is equal to the lithostatic pressure at the top of magma reservoir. Then, magma pressure increased step by step with the rate of 0.5 Mpa. The aspect ratio( $b/a$ ) of magma body were taken as 1, 5 and 10. The results of calculation show that fractures start at the top of magma body of

higher aspect ratios (that is dike-like magma body) and extend upwards forming fracture zone of funnel shape (Fig.2). The calculated vertical displacement of earth's surface indicates that a simple dome uplift is formed over a circular magma body, but that a central trough-like depression with flank uplifts is formed over magma bodies of higher aspect ratios(Fig.3)

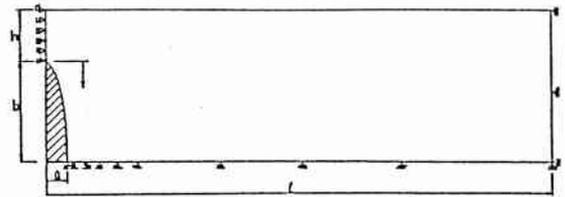


Fig.1 Model for calculation of magma intrusion.

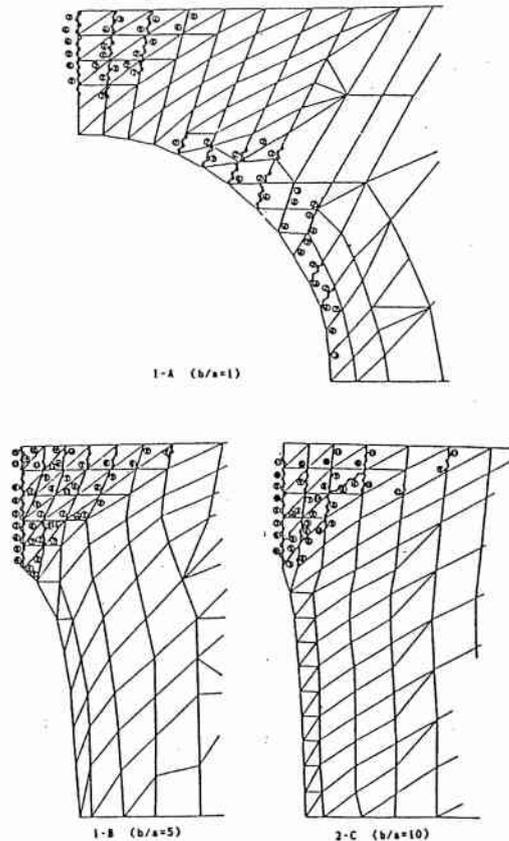


Fig.2 Extension of fractures( $h=100m, b=200m$ ) around the magma intrusion. Waved lines indicate tensile fractures and thick lines denote shear fractures. The numbers in circle indicate steps when fractures are formed.

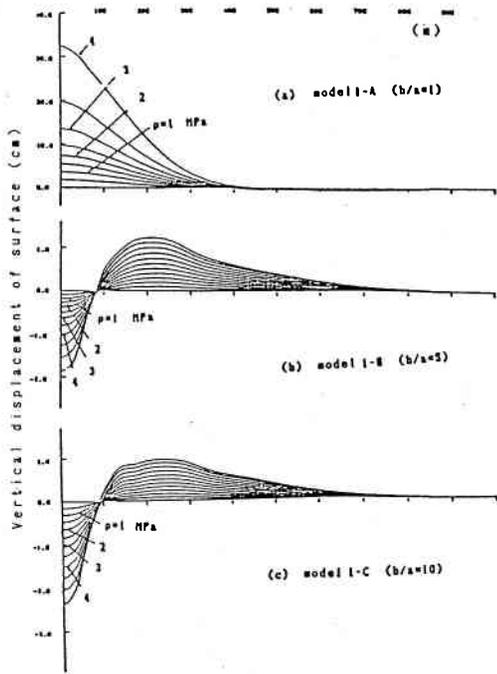


Fig.3 Vertical displacement of surface over subsurface magma intrusion ( $h=100\text{m}, b=200\text{m}$ ).

### TROUGH-LIKE SUBSIDENCE AS INDICATOR OF DIKE-LIKE MAGMA INTRUSION

In the Izu-Oshima volcano, trough-like subsidence during the time span which includes the eruption event, is clearly shown from the comparison of leveling data. The result of calculation indicates that the width of trough-like depression is nearly twice of the depth of top of magma intrusion (Fig.4). As the width of trough in the Izu-Oshima is about 4 Km in the narrowest part, the top of magma intrusion is expected at the depth of about 2 Km in the south-eastern part of Izu-Oshima volcano (Fig.5). The maximum subsidence of about 30 cm is expected by the magma pressure of about 6 MPa (Fig.6).

The results of three-dimensional calculation, also, clearly indicate that the trough-like subsidence in the Izu-Oshima volcano is a kind of "keystone graben" where the trough depression is formed by splitting of rock mass by the intrusion of dike-like magma wedge (Fig.4,5). Therefore, the subsidence of summit of Izu-Oshima volcano indicated the surface intrusion of magma and increase of magma pressure, that is, the subsidence is also the precursory phenomena of volcanic eruption in some cases.

### CONCLUSION

Numerical analysis by discrete models is used successfully to simulate the formation of Keystone graben by subsurface intrusion of dike-like magma body beneath the Izu-Oshima volcano, Japan. Measurement of areal pattern of ground movement of volcanic surface is effective for the prediction of volcanic eruption, only with adequate numerical model for magma intrusion.

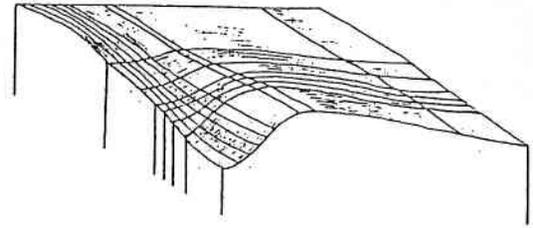


Fig.4 Sketch of vertical displacement of volcanic surface due to a subsurface dike-like intrusion calculated from the three dimensional RBSM model.

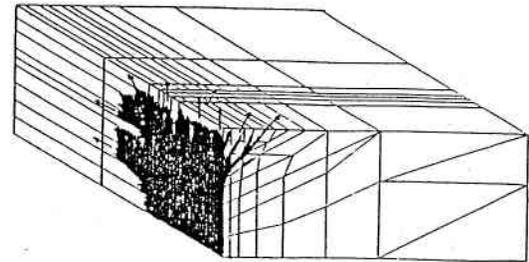


Fig.5 Extension of fractures around a dike-like magma intrusion estimated from the three dimensional RBSM model.

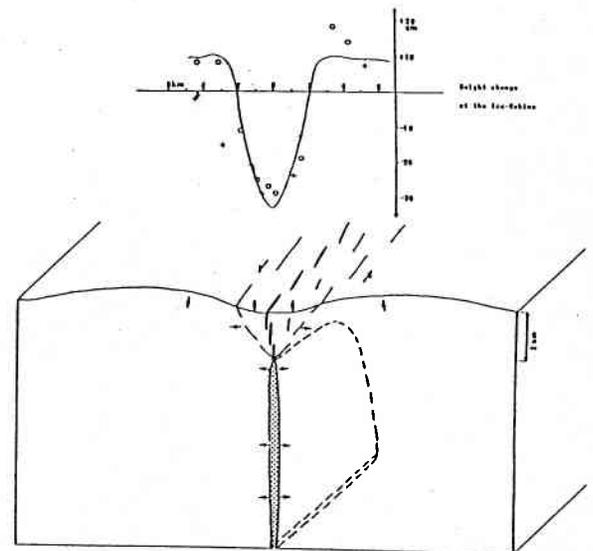


Fig.6 Model of graben subsidence over a large dike-like magma intrusion in the Izu-Oshima volcano. The upper diagram shows the vertical displacement measured in the Izu-Oshima volcano with the theoretical curve where the magma pressure is 6MPa.

### REFERENCES

- Kawai, T. (1980): Some consideration on the finite element method, *Int. J. Numerical Methods in Engineering*, 16, 81-119.
- Koide, H. and S. Bhattacharji (1975): Mechanistic interpretation of rift valley formation, *Science*, 189, 791-793.
- Tada, T and M. Hashimoto (1987): The 1986 eruption of Izu-Oshima and crustal deformations, *The Earth Monthly*, 9, 396-403.