Summary

This document reports research results obtained from a comprehensive research study entitled "Development of a volcanic activity evaluation method," which was conducted from April 2001 until March 2006 (five years). This document divides the results into two chapters, "Development of a volcanic activity evaluation method with dynamic numerical simulation" and "Application of the method to data obtained from actual volcanic activities."

Chapter 1 reports a "volcanic activity evaluation method with dynamic numerical simulation" developed in the research.

When analyzing crustal deformation for volcanic activity, we conventionally adopt the volcanic pressure source models that have a spherical shape (the Mogi model) or a thin layer shape (the Dike model), assuming that the concerned area has a half-infinite elastic body. We should, however, understand the limitations in the accuracy of these models when adapting them to volcanoes with complicated edifices and/or with any complicated shapes of pressure sources. In order to reduce these limitations, we established another volcanic pressure source model called the Finite-Element (FE) model or the Dynamic Numerical model, which is a volcanic pressure source model that incorporates actual topography, underground structure, and other related elements with the use of the Finite-Element Method (FEM). Thus, we developed a method that should simulate and analyze crustal deformations and stress changes with the newly established model in this comprehensive research. We took the following steps. (1-1) First, we reproduced the Mogi model with the new model and compared the solution (or crustal deformation) obtained from the new model with the one analytically obtained from the Mogi model. (1-2) Next, through the comparison, we evaluated the general design of the model using the FEM for crustal deformation calculation, and we evaluated the effects of "modeling area size" and "boundary conditions" on solution accuracy. (2) As a result, we found the area size to be incorporated into the model and boundary conditions that should make the solution accuracy sufficient for our purpose. (3) In addition, we conducted numerical calculations of crustal deformations caused by various shapes of the pressure sources with the FEM in order to understand the dependency of the deformations on the topographic features of the volcanic edifice and on other related elements. (4) With the results, we found conditions necessary for properly applying the conventionally used models.

Furthermore, we developed a modified Mogi model with altitude compensation by modifying the original formulas of the Mogi model with the inclusion of the effect of altitudes of the observation locations. By comparing solutions obtained from the modified Mogi model and the ones obtained from the new FE Model, we confirmed the usability of the modified Mogi model and determined the conditions for using it properly.

In addition, we evaluated the topographic effects on the piezomagnetic field using the FEM.

Based on the above results, we developed software for analyzing crustal activity in volcanoes, called the Magnetic and Geodetic Computer Analysis Program for Volcano (MaGCAP-V). This software can comprehensively handle data obtained from GPS, tiltmeter, magnetometer, and other such equipment; it is thus able to estimate the source locations of observed deformations. The MaGCAP-V adopts the modified Mogi model for analyzing crust deformation and is able to handle various shapes of pressure sources. Furthermore, we incorporated an FE calculation database that has actual topographies and volcano edifices so that the software can (1) display them on a screen, (2) select the best pressure source model, and (3) estimate deformation sources through interpolation.

Chapter 2 reports the results obtained from applying the above volcanic activity evaluation method

with dynamic numerical simulation to actual volcanoes.

We selected Kirishima volcano (Kirishimayama) as the volcano to which we would apply the method. We conducted continuous observations with GPS, tiltmeter, and magnetometer during this study. Since no eruption occurred during the research period there, we did not detect clear phenomena in the data of the GPS and the magnetometer. However, we did find a slight rise of volcanic activity in the data of the tiltmeter.

At Ohachi crater, a new fumarole emerged along with volcanic tremors in December 2003. A small-scale sand boil also occurred there. Furthermore, volcanic tremors of slightly large amplitude were observed at Shinmoedake; the activity of the volcano became higher than the usual state throughout the month there.

When those tremors occurred due to the slight rise of volcanic activity, the tiltmeters we installed for our research detected some tilting. Around Ohachi crater, one of the tiltmeters detected tilting toward the crater; we inferred that phenomenon indicated a pressure decrease at a shallow depth beneath the crater, and that it was caused by both the rising activity of heated water and the movement of substances. In addition, the result obtained from FEM analysis revealed that tilting depended strongly on underground structures beneath the volcano; thus, it was necessary to understand the structures in order to evaluate observed phenomena correctly.

During the research period, a rise of volcanic activity was detected on Asama volcano (Asamayama); therefore, we conducted observations using the GPS and the electronic distance meter (EDM). With the GPS, we detected a crustal-deformation-like expansion of the volcano's body at the end of July 2004, before the eruption in September 2004. Analysis of the GPS data indicated pressure sources located at both shallow and deep depths beneath the crater, and magma-associated expansion of the volcano's body before the eruption. In addition, the EDM detected expansion of the vicinity of the crater when new lava emerged at the bottom of the crater after the ascent of the magma through a conduit as one of the eruption activities. FEM analysis of this phenomenon revealed that the expansion was not caused by a load of magma accumulated at the bottom of the crater, but by an increase of pressure at shallow depth beneath the crater. Through these analyses, we also developed a method for correcting EDM data by using the meteorological numerical grid data of the Japan Meteorological Agency (JMA) .

Using GPS on Izu-Oshima volcano, we detected a crustal deformation, which we inferred was a preparation processes for the next eruption. We proposed a model to explain the phenomenon with two pressure sources: one that had a spherical shape and was located at deep depth, and one that had a dike shape with a NNW-SSE strike.

Using the volcanic activity evaluation method mentioned above, we found that the underground structure influenced the estimation of the source of crustal deformation in Miyakejima volcano. In addition, by introducing a nearly accurate underground structure, we demonstrated that the source location of a contraction (NB: We estimated that the contraction should be caused by the escape of gas.) was deeper than we had initially thought.

On Tarumae volcano (Tarumaesan), where expansion of the mountain body and thermal demagnetization were observed from 1999 until 2000, we analyzed data obtained from the volcano using MaGCAP-V. We succeeded in explaining two phenomena comprehensively: the increase of pressure underneath the lava dome and the thermal demagnetization.