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Geomagnetic changes associated with the dike intrusion during the 2000 Miyakejima eruptive activity, Japan

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Abstract

A marked magnetic field change exceeding 200 nT was detected by a three-component magnetometer at the beginning of the 2000 Miyakejima eruptive activity. The change in the magnetic field is correlated with an earthquake activity and crustal deformation, which indicate a dike intrusion very close to the observation site. A dike model based on the crustal deformation data shows that the primary cause of the magnetic change was the piezomagnetic effect associated with the dike emplacement, and that the other potential factors, including thermal and electrokinetic effects, were unlikely to be its principal cause. We obtained a new dike model by combining both the crustal deformation and the magnetic field change, which is sensitive to the strong stress changes near the edges of dike. The new dike model shows lateral and upward propagation of the dike during its intrusion, and suggests that shallow cracks induced by the dike intrusion near the ground surface contributed to the changes seen in the magnetic field.

Keywords: Miyakejima volcano; piezomagnetic effect; crustal deformation; tiltmeter; GPS; dike

1. Introduction

Observations of geomagnetic fields are essential for monitoring volcanic activities, since they provide different kinds of information on magma emplacements from geodetic and seismic observations (e.g., [1–3]). Several causes of magnetic changes during volcanic activity have been proposed: demagnetization or remagnetization due to temperature changes [1], piezomagnetism due to stress changes in the crust [4] and electrokinetic effects [5]. Of these, dike intrusions are presumed to cause geomagnetic field changes due to the piezomagnetic effect as observed during the 2002 Etna eruptive activity [6]. During the 2000 Miyakejima eruptive activity in Japan [7,8], geomagnetic field changes exceeding 200 nT were detected by three-component magnetometers at one of the observation stations on Miyakejima Island during the dike intrusion stage.

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Continuous observation data on crustal deformation and geomagnetic field changes were recorded during the 2000 Miyakejima activity. The dike intrusion process has been successfully modeled on the basis of this crustal deformation data, including ground tilt changes and kinematic GPS analysis [9]. The observation of geomagnetic field changes thus provides an excellent opportunity to study the relationship between large magnetic changes and volcanic activity. The purpose of this study is to investigate possible causes of the observed large geomagnetic changes at Miyakejima and to improve the dike intrusion model proposed by Ueda et al. [9] in consideration of both the geomagnetic changes and crustal deformation data.

2. The 2000 Miyakejima eruptive activity and the dike model

Miyakejima is an active basaltic stratovolcano lying 170 km to the south of Tokyo, Japan (Fig. 1). The most recent eruptive activity began on June 26, 2000, with an earthquake swarm and anomalous crustal deformation on the island [7,8]. Former studies of earthquake activities [7] and crustal deformation [8] showed that dikes intruded under the island at the beginning of the activity, followed by underground magma migration from Miyakejima toward the northwest until August 2000 [10,11], simultaneously with the caldera formation process [12].

By assuming rectangular dikes, Ueda et al. [9] modeled the source of the crustal deformation observed by the tiltmeters and kinematic GPS analysis from 18:30 LT on June 26 to 06:00 LT on June 27 (Japan Standard Time, UT + 9:00) [13]. The source model consists of three intrusive dikes designated DK1, DK2 and DK3, and one contractive dike, DK4, which were located in the southwestern part of Miyakejima and off the western coast of the island, as shown in Fig. 1a. The active periods of these dikes were 18:30 LT–21:50 LT (DK1), 20:50 LT–01:00 LT (DK2), 00:10 LT–06:00 LT (DK3), and

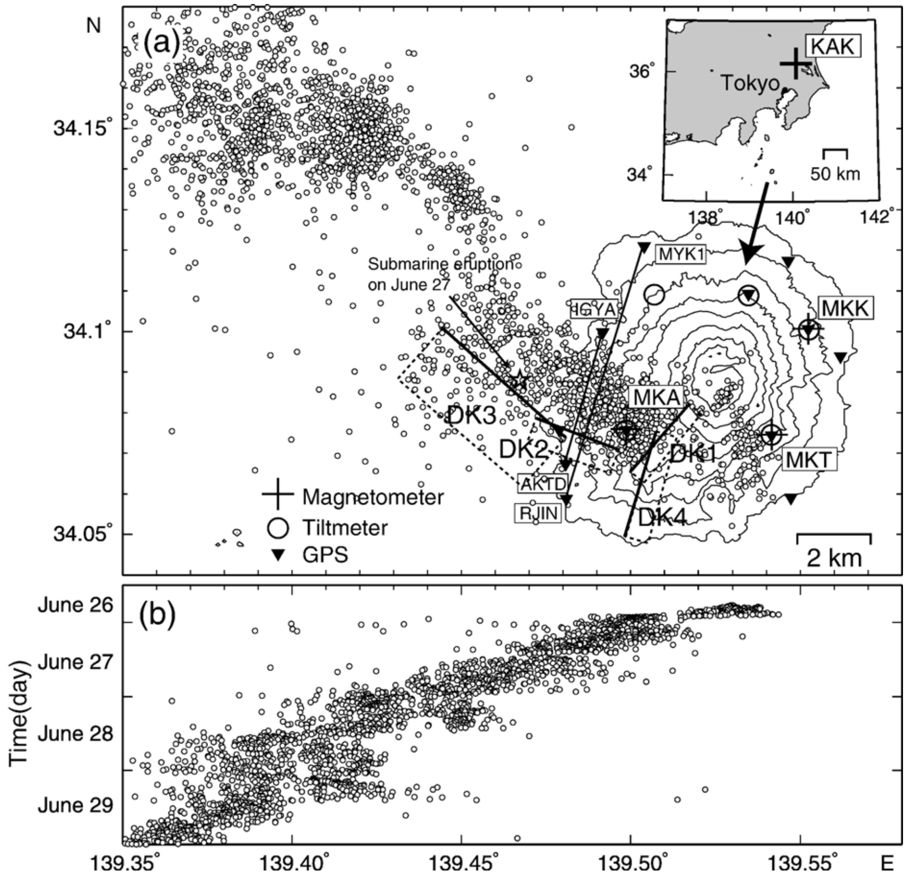

Fig. 1. (a) Map showing epicenter distribution from June 26 to 29, 2000, and observation stations. Rectangles and thick lines show horizontal projections of the dike model obtained by Ueda et al. [9] and its upper boundary, respectively. The model consists of four dikes that successively intruded or contracted from 18:30 LT on June 26 to 06:00 LT on June 27, 2000. The thin lines depict baselines between GPS stations. (b) Spatio-temporal distribution of the earthquakes as determined by NIED [8].