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Diffuse CO_2 efflux from Iwojima volcano, Izu-Ogasawara arc, Japan

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Abstract

Iwojima volcano, located on the southernmost part of the Izu-Ogasawara arc, is characterized by the extrusion of trachyte or trachy andesite lavas and pyroclastic rocks of Holocene and surface thermal manifestations. Small phreatic explosions have been recorded frequently during the last 100 years with the most recent in 1999 and 2001. In order to elucidate the behavior of volcanic volatiles and to assess the potential activity of this volcano, diffuse CO_2 efflux, CO_2 content and $\delta^{13}C$–CO_2 in soil gas, and soil temperature at 30 cm depth were measured at 272 sites in March 2000, 112 sites in December 2000 and 40 sites in December 2001. We found that high CO_2 efflux values, of more than 100 g m^{-2} day^{-1}, occurred at several locations on Motoyama volcano corresponding with high soil temperatures (more than 60 °C at 30 cm depth) region and with areas where CO_2 with magmatic $\delta^{13}C$ was observed. Here, the magmatic $\delta^{13}C$ determined for fumarolic CO_2 data ranged from −2‰ to +3‰, which is clearly higher than magmatic gas values (−8‰ to −2‰) typically found in island arc settings around the world. However, this can be explained in terms of carbon-isotope fractionation between calcite and CO_2 under subsurface temperature and pressure conditions at Iwojima. A total efflux of CO_2 for Iwojima volcano is estimated to be 760 t day^{-1}, with a magmatic contribution of about 450 t day^{-1}. This value is rather high compared with other volcanoes in island arc settings. Since Iwojima has no visible plume, almost all volcanic CO_2 is released as diffuse efflux through the volcanic edifice.
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Keywords: Iwojima volcano; diffuse CO_2 efflux; soil gas; fumarolic gas; carbon isotope ratio; phreatic explosion

1. Introduction

Geochemical studies on volcanoes during the last 15 years have shown that large amounts of CO_2 are released not only from their active craters but also from their flanks as diffuse soil emanations (Baubron

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et al., 1990; Allard et al., 1991a, Farrar et al., 1995; Chiodini et al., 1998; Sorey et al., 1998; Gerlach et al., 1998; Hernández et al., 1998, 2001a,b,c, 2003; Brombach et al., 2001; Salazar et al., 2001; Wardell et al., 2001; Rogie et al., 2001; Shimoike et al., 2002). Recently, Morner and Etiope (2002) reviewed the CO_2 efflux data from volcanic and non-volcanic sites. CO_2 is the second most abundant species after H_2O in magmatic gas, and is thought to degas at an early stage of magma ascent because of its low solubility in magma. This often makes diffuse CO_2 efflux a useful indicator of magmatic intrusion. At Mammoth Mountain, California, a shallow magma intrusion occurred in 1989–1990 inducing diffuse flank emissions of magmatic CO_2 possibly as much as 1200 t day^{-1} of CO_2, which killed trees (Farrar et al., 1995; Sorey et al., 1998). Prior to the 2000 eruption of Usu volcano, the diffuse CO_2 efflux at the summit caldera increased, as a result of advective gas migration toward the surface, and then declined significantly after the eruption due to a voluminous release of CO_2 from erupting vents. In this case, the spatial distribution of the CO_2 efflux is related to the structure of the volcanic edifice, with area of high efflux corresponding to fault zone conduits and enhanced permeability of the surface cover (Hernández et al., 2001a). The correspondence between high CO_2 efflux and elevated soil temperature, as has been observed at Miyakejima (Hernández et al., 2001b), Tarumae (Hernández et al., 2001c), Cerro Negro (Salazar et al., 2001) and Nisyros (Brombach et al., 2001) volcanoes, is indicative of shallow condensation of a steam phase accompanying CO_2 upflow.

Although the above examples suggest that diffuse CO_2 efflux measurements are a useful indication of volcanic and hydrothermal phenomena, further study is required to quantitatively relate diffuse CO_2 efflux to gas pressure at the level of the magma reservoir, and to delineate better the relations between changing rates of diffuse CO_2 degassing and the onset or level of volcanic activity. One approach is to compare the plume flux from active vents with the diffuse emissions from the flanks of a volcano. Studies carried out at Vulcano (Baubron et al., 1990) and Satsuma-Iwojima (Shimoike et al., 2002) volcanoes showed that CO_2 emission from the summit craters is several times higher than that through the soil. No evidence of diffuse emission of volcanic CO_2 was observed at Popocatepetl volcano (Varley and Armienta, 2001) which showed a huge amount of plume CO_2 emission from the summit crater (Goff et al., 2001). Etna, however, releases huge but comparable amounts of CO_2 from both active craters and flanks (Allard et al., 1991a). Few surveys have been carried out at volcanoes with weak or non-existent plume emissions from summit craters. In one such case at Miyakejima volcano, a significant release of diffuse CO_2 from the summit region occurred without plume emissions before the 2000 eruption (Hernández et al., 2001b), which caused the subsequent collapse of 1.6 km in diameter and 0.5 km in depth of the summit region.

Here we present the first detailed measurements of the spatial and temporal features of diffuse CO_2 degassing at Iwojima volcano, where an intense hydrothermal system is observed without summit plume emissions. The aim of this work is to elucidate the behavior of diffuse volcanic CO_2 degassing at Iwojima volcano. We seek to understand the relationship between the magma supply system, the volcanic structure and distribution of diffuse degassing and to determine the potential of diffuse degassing as an indication of impending phreatic or eruptive activity. In addition, we compare our total CO_2 efflux data with other volcanoes with or without summit plume emissions.

2. Iwojima volcano

Iwojima (24°47′ N, 141°20′ E) is a small volcanic island 8 km long and with a total area of 22 km^2, situated 1250 km south of Tokyo (inset of Fig. 1). It is located on the southernmost part of the Izu-Ogasawara volcanic arc, which extends southward to the Mariana arc. Both arcs are formed as a result of the subduction of the Pacific plate beneath the Philippine Sea plate.

Fig. 1 shows the generalized geology of Iwojima after Oyagi and Inokuchi (1985). Iwojima Island was formed during the Holocene and consists of three main parts: (1) Motoyama stratovolcano, a central cone within a summit caldera that is hidden by the sea; (2) Suribachiyama, a pyroclastic cone with a crater of 300 m diameter and 60 m depth; and (3) Chidorigahara plain, which connects the two volcanic

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