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Carbon dioxide emissions from vegetation-kill zones around the resurgent dome of Long Valley caldera, eastern California, USA

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Abstract

A survey of diffuse CO_2 efflux, soil temperature and soil-gas chemistry over areas of localized vegetation-kill on and around the resurgent dome of Long Valley caldera California was performed to evaluate the premise that gaseous and thermal anomalies are related to renewed intrusion of magma. Some kill sites are long-lived features and others have developed in the past few years. Total anomalous CO_2 emissions from the thirteen areas average around 8.7 t per day; but the majority of the emissions come from four sites west of the Casa Diablo geothermal power plant. Geochemical analyses of the soil-gases from locations west and east of the plant revealed the presence of isobutane related to plant operations. The $\delta^{13}C$ values of diffuse CO_2 range from $-5.7‰$ to $-3.4‰$, similar to values previously reported for CO_2 from hot springs and thermal wells around Long Valley.

At many of the vegetation-kill sites soil temperatures reach boiling at depths ≤20 cm. Soil temperature/depth profiles at two of the high-emissions areas indicate that the conductive thermal gradient in the center of the areas is around 320 °C m^{-1}. We estimate total heat loss from the two areas to be about 6.1 and 2.3 MW. Given current thinking on the rate of hydrothermal fluid flow across the caldera and using the CO_2 concentration in the thermal fluids, the heat and CO_2 loss from the kill areas is easily provided by the shallow hydrothermal system, which is sourced to the west of the resurgent dome. We find no evidence that the development of new areas of vegetation kill across the resurgent dome are related to new input of magma or magmatic fluids from beneath the resurgent dome. Our findings indicate that the areas have developed as a response to changes in the shallow hydrologic system. Some of the changes are likely related to fluid production at the power plant, but at distal sites the changes are more likely related to seismicity and uplift of the dome.
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Keywords: Long Valley caldera; diffuse CO_2 efflux; soil gas; geothermal system; volcano monitoring

1. Introduction

The Long Valley caldera (LVC; shown in Fig. 1) formed 760,000 ka after the explosive eruption of 600 km^3 of pyroclastic material that now makes up the Bishop Tuff (Bailey et al., 1976; Bailey, 1989). About 600,000 ka uplift in the west-central portion of the caldera produced a resurgent dome that is dissected by numerous northwest-trending faults (Bailey et al., 1976). Eruptive activity along the Inyo craters chain within the west moat of the caldera has continued into the Holocene, demonstrating the potential hazard posed by renewed volcanism (Miller, 1989). An episode of seismic unrest beneath the resurgent dome began in

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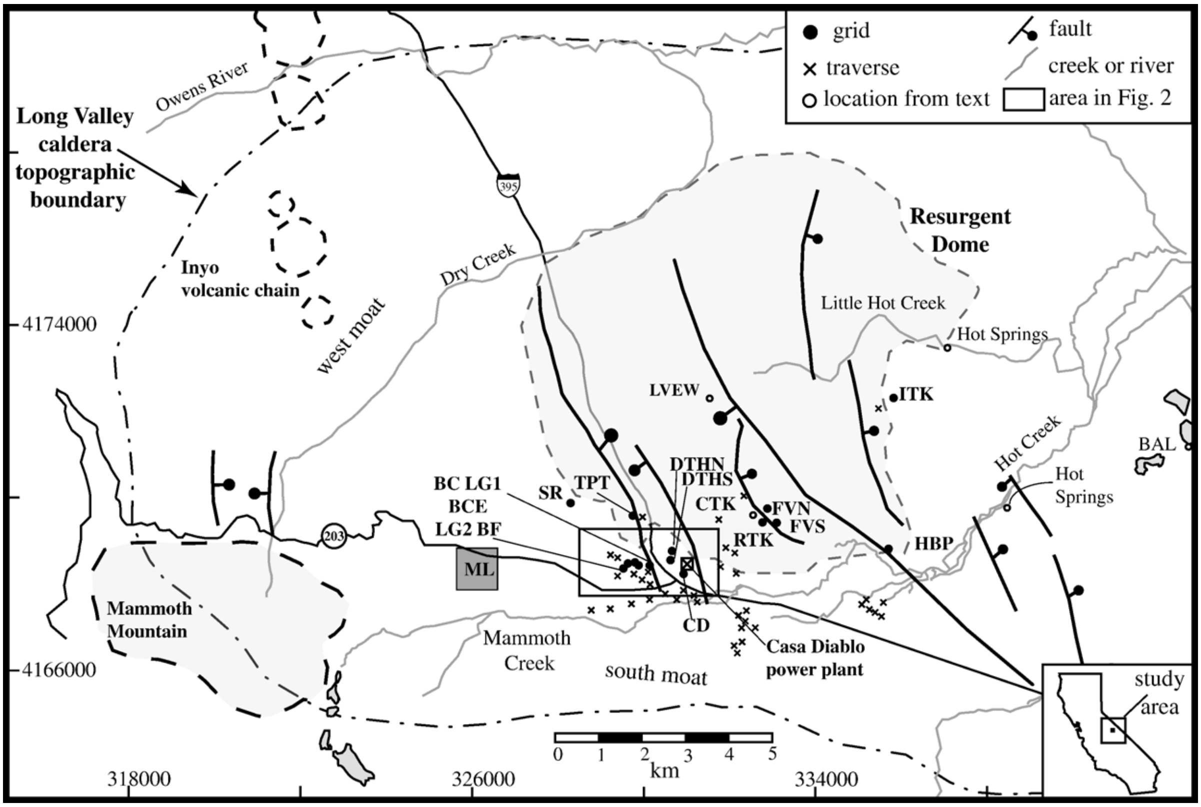

Fig. 1. Map showing grid locations and other locations mentioned in the text. ML = Mammoth Lakes town site, BAL = Big Alkali Lake hot spring. Rectangle shows the area included in Fig. 2.

1980 and is associated with approximately 80 cm of cumulative uplift on parts of the dome since that time (Hill et al., 2002). Uplift within caldera systems can signal renewed intrusion of magma that can preface an eruption (e.g. Rabaul; McKee et al., 1984), but it is known from studies elsewhere [e.g., Yellowstone caldera, U.S.A., (Waite and Smith, 2002) Campi Flegrei caldera, Italy, (Todesco et al., 2004)] that this is not always the case. Studies of hydrologic and geochemical parameters are sometimes useful in determining the source of uplift. Of particular relevance to this study, diffuse soil degassing and temperature measurements have been used to examine relations between gas emissions, uplift, and energy release at Solfatara Volcano, Italy (Chiodini et al., 2001).

The large efflux of CO_2 and associated tree kill that followed the 1989 intrusion beneath Mammoth Mountain on the west rim of LVC is well documented (Farrar et al., 1995; Gerlach et al., 2001). Less studied however, are smaller discrete areas of vegetation kill inside the caldera that have appeared over the past two decades. Gerlach et al. (1996) made a preliminary study of diffuse CO_2 emissions on and around the resurgent dome, but further interpretation of their results requires tighter constraints on background flux. We report here the results of soil temperature, soil-gas chemistry and CO_2 efflux measurements in areas of plant mortality and derive an estimate of total CO_2 flux from these areas that can be corrected for background biogenic emissions. Data from this study help refine knowledge of thermal fluid flow paths around the resurgent dome and are used to provide an estimate of the heat flow in two high-CO_2 emissions areas. The results are used to evaluate the premise that gaseous and thermal anomalies are related to magmatic intrusion beneath the resurgent dome.

2. Long Valley caldera and its hydrothermal system

A generalized model of the hydrothermal system at LVC is that a magmatic heat source is located in the west moat of the caldera or beneath Mammoth Mountain, and that fluids rise from the source reservoir and flow laterally to the southeast through fractures and contact zones between rhyolite units (Sorey et al., 1995). Within the south moat, the first surface expres-