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Multiple caldera collapses inferred from the shallow electrical resistivity signature of the Las Cañadas caldera, Tenerife, Canary Islands

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Abstract

The Las Cañadas caldera of Tenerife (LCC) is a well exposed caldera depression filled with pyroclastic deposits and lava flows from the active Teide–Pico Viejo complex (TPVC). The caldera's origin is controversial as both the formation by huge lateral flank collapse(s) and multiple vertical collapses have been proposed. Although vertical collapses may have facilitated lateral slope failures and thus jointly contribute to the exposed morphology, their joint contribution has not been clearly demonstrated. Using results from 185 audiomagnetotelluric (AMT) soundings carried out between 2004 and 2006 inside the LCC, our study provides consistent geophysical constraints in favour of multiple vertical caldera collapse. One-dimensional modelling reveals a conductive layer at shallow depth (30–1000 m), presumably resulting from hydrothermal alteration and weathering, underlying the infilling resistive top layer. We present the resistivity distribution of both layers (resistivity images), the topography of the conductive layer across the LCC, as well as a cross-section in order to highlight the caldera's evolution, including the distribution of earlier volcanic edifices. The AMT phase anisotropy reveals the structural and radial characteristics of the LCC.

Keywords: audiomagnetotellurics; caldera; hydrothermal alteration; conductive layer; Tenerife

1. Introduction

The Las Cañadas caldera (LCC) (Fig. 1) is one of the best exposed calderas in the world (size: 16 × 9 km) and part of the central volcanic complex (CVC) on Tenerife. However, its origin is controversial and the debate is centred around whether the depression resulted from lateral or vertical collapses. Numerous studies argue that the present caldera wall scarp was produced by one or several lateral flank collapses directed towards the north (Bravo, 1962; Navarro and Coello, 1989; Ancochea et al., 1990; Carracedo, 1994; Watts and Masson, 1995; Ancochea et al., 1998; Watts and Masson, 1998; Ancochea et al., 1999; Cantagrel et al., 1999; Arnaud et al., 2001; Watts and Masson, 2001; Masson et al., 2002). Another line of arguments relates to the LCC's formation as a result from repeated vertical collapses produced by roof collapse during major caldera-forming volcanic eruptions (Fúster et al., 1968; Araña, 1971; Marti et al., 1994a; Marti et al., 1996; Marti et al., 1997; Bryan et al., 1998; Marti, 1998; Marti and Gudmundsson, 2000).

Although a growing number of combined geological and structural information point towards a vertical collapse origin (Marti et al., 1994a; Marti and Gudmundsson, 2000), there is no detailed sub-surface geophysical data of the entire caldera that unambiguously support this hypothesis. Only two MT studies have so far been performed to investigate the electrical properties of the caldera fill (Ortiz et al., 1986; Pous et al., 2002). At shallow depth, a resistive layer (unaltered or "fresh" lava) overlies a conductive layer (hydrothermalised lava), both of which also crop out at the surface (Fig. 2).

In order to shed light on the caldera's origin, a dense high-resolution audiomagnetotelluric (AMT) survey has been carried

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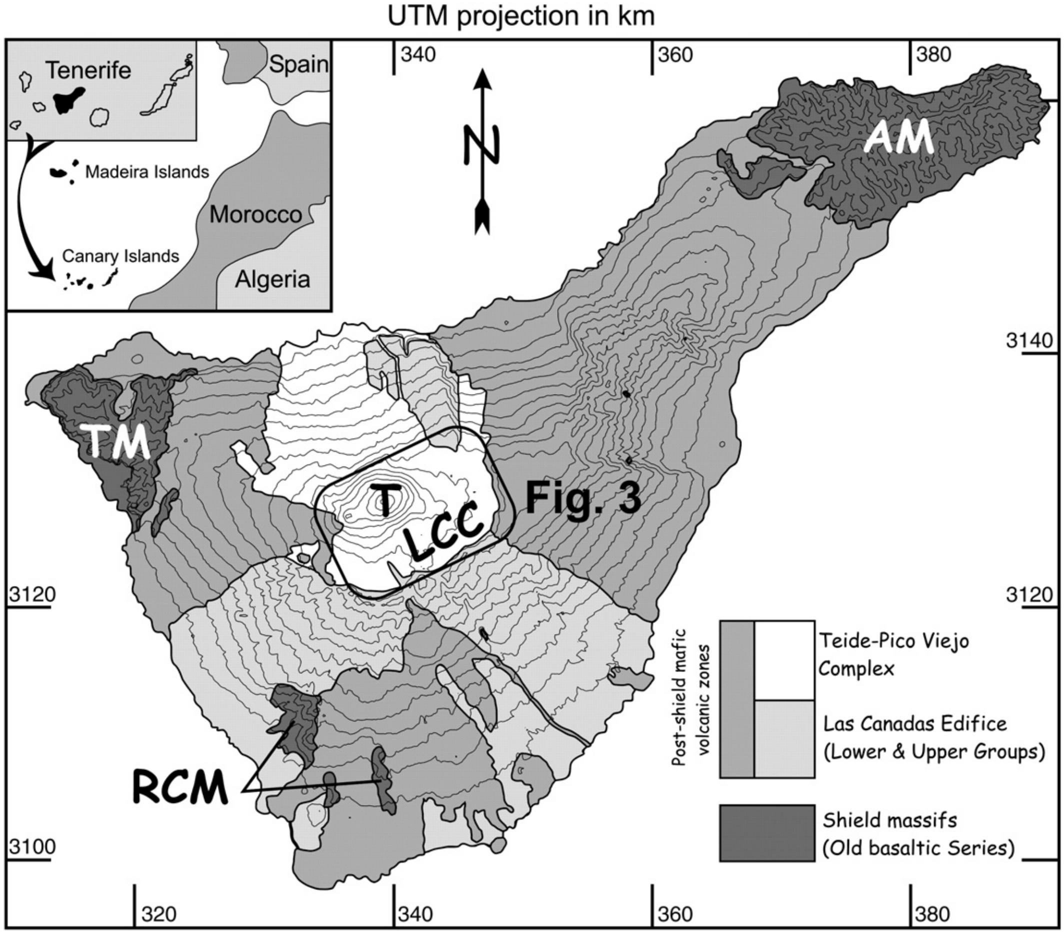

Fig. 1. Simplified geological map of Tenerife (Canary island). The three old basaltic series are: Anaga Massif (AM), Teno Massif (TM) and Roque del Conde Massif (RCM). Rotated central rectangle (Fig. 3) shows the study area, the Las Cañadas caldera (LCC) with the Teide volcano (T).

out. Here we report on results from 185 soundings performed inside the area bounded by the LCC scarp wall. We present results on the internal shallow structure of the LCC (depths between 0 and 2000 m below the surface) in an effort to extend our knowledge on the interior architecture of the CVC. We provide: (1) electrical resistivity maps and constrain the thicknesses and topography of two major lithological layers; (2) an interpretation of hydrothermal processes occurring at the LCC; and (3) a structural interpretation of our results and their implications for the formation of the LCC.

2. Audiomagnetotelluric (AMT) method and specifications

The magnetotelluric (MT) method is a passive surface geophysical technique, which uses the Earth's natural EM fields to investigate the electrical resistivity distribution at depth, from

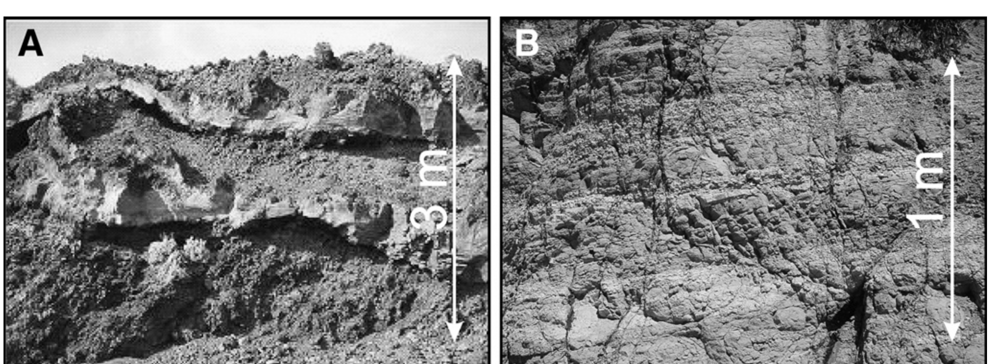

Fig. 2. A) "Fresh" lava and pyroclastic flows — resistive layer. B) Hydrothermalised clay-rich lava — conductive layer.