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The late Quaternary Diego Hernandez Formation, Tenerife: Volcanology of a complex cycle of voluminous explosive phonolitic eruptions

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Abstract

The Diego Hernandez Formation (DHF; 600–ca. 180 ka) represents the products of the most recent complete cycle of phonolitic explosive volcanism on Tenerife (Canary Islands, Spain). We provide a revised and detailed stratigraphy, new $^{40}Ar/^{39}Ar$ and (U–Th)/He age determinations for major eruptive units, a summary of new chemical data and an overview of the key characteristics of the cycle, including volume estimates, dispersal patterns, eruption styles, phreatomagmatic influences and caldera collapse episodes. The complex stratigraphy of the DHF is divided into 20 named members, each representing a major eruption, as well as numerous unnamed members of limited present-day exposure. The major eruptions are represented by the Fortaleza (370 ka), Roque (347 ka, 3 km^3), Aldea (319 ka, 3 km^3), Fasnia (309 ka, 13 km^3), Poris (268 ka, 3.5 km^3), Arafo (4 km^3), Caleta (223 ka, 3.5 km^3) and Abrigo (between 196 and 171 ka, 20 km^3) Members. The Aldea, Fasnia and Poris Members consist of highly complex successions of plinian fall, surge and flow deposits and several of the eruptions produced widespread and internally complex ignimbrite sheets. Phreatomagmatism occurred most frequently in the opening phase of the eruptions but also recurred repeatedly throughout many of the sequences. Inferred sources of water include a shallow caldera lake and groundwater, and intermittent phreatomagmatic activity was an important influence on eruption style. Another important factor was conduit and vent instability, which frequently loaded the eruption column with dense lithic debris and occasionally triggered column collapse and ignimbrite formation. Most of the major DHF eruptions were triggered by injection of mafic magma into existing phonolitic magma bodies. Two phonolitic magma types were available for eruption during the lifetime of the DHF, but each was dominant at different times. The results presented here support a caldera collapse rather than a landslide model for the origin of the Las Cañadas Caldera, although the evolution of the caldera is evidently more complex and incremental than first thought.

Keywords: Tenerife; plinian; phonolite; ignimbrite; caldera; phreatomagmatism

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1. Introduction

Explosive eruptions involving felsic magma volumes of the order of 1 km^3 or more typically produce plinian fallout and pyroclastic density currents (PDCs: flows and surges) with great destructive potential. Tenerife has a complex Quaternary history of explosive phonolitic eruptions, with an aggregate volume of the order of 100 km^3 dense rock equivalent (DRE). Some of these eruptions covered 90% of the island with PDC deposits and were accompanied by caldera formation and lateral collapse episodes. The island has a large residential population (655,000), a well-developed rural and civic infrastructure, and has seen an explosive growth in tourism and associated industries over the past few decades. Consequently, a precise understanding of the Quaternary geologic record on Tenerife is a high priority, and a large body of geochronological, volcanological, petrological and geochemical data on the phonolitic pyroclastic rocks has been collected in recent years (Martí et al., 1990, 1994; Ablay et al., 1995, 1998; Bryan et al., 1998, 2002; Huertas et al., 2002; Edgar et al., 2002; Brown et al., 2003; Brown and Branney, 2004a,b; Pittari et al., 2005, 2006; see also the volumes edited by Martí and Mitjavila, 1995, and Martí and Wolff, 2000). Conflicting interpretations remain in two critical areas: the origin of the central Las Cañadas depression (caldera versus lateral collapse scar; see Ancochea et al., 1990; Carracedo, 1994; Martí et al., 1994; Watts and Masson, 1995; Martí et al., 1997; Bryan et al., 1998; Ancochea et al., 1998, 1999; Cantagrel et al., 1999), and details of the very complex stratigraphy of the pyroclastic deposits (Bryan et al., 1998, 2002; Edgar et al., 2002; Brown et al., 2003; Brown and Branney, 2004a,b). The present paper is a summary of the event stratigraphy, geochronology and geochemistry of the Diego Hernández Formation (DHF), which represents the last complete major cycle of explosive phonolitic activity on Tenerife. It incorporates revisions to the stratigraphic schemes and interpretations presented by Bryan et al. (1998) and Brown et al. (2003), new $^{40}Ar/^{39}Ar$ and (U–Th)/He age determinations, and a synthesis of chemical data for some 350 samples. We show that the DHF cycle began with minor phonolitic eruptions, with parallels to Holocene activity from Las Cañadas (Ablay et al., 1995). If indeed a similar phonolitic cycle is now beginning, as proposed by Martí et al. (1994), then our study has long-term predictive value.

2. Geologic background

Tenerife (Fig. 1) is the largest of the Canary Islands. The basal subaerial portion, the Old Basaltic Series, consists mostly of lavas of at least three mafic alkaline shield volcanoes constructed between 12 and 3.9 Ma (Fúster et al., 1968; Ancochea et al., 1990; Martí et al., 1995, Thirlwall et al., 2000; Guillou et al., 2004), and now exposed as eroded massifs in the extremities of the island. These are overlain by the Las Cañadas edifice (Araña, 1971), a large composite stratovolcano consisting of a dominantly mafic to intermediate Lower Group (3.5–2.2 Ma), and an Upper Group (1.6–0.18 Ma) that includes the products of three basaltic-to-phonolitic volcanic cycles, represented by the Ucanca, Guajara, and Diego Hernandez formations. In the Las Cañadas caldera wall, the three formations are separated by major erosional disconformities, interpreted as the results of caldera collapse and associated lateral collapse episodes that terminated each cycle (Martí et al., 1994, 1997). Stratigraphically equivalent major disconformities outside the caldera are due to extended periods of non-deposition, when phonolitic eruptions of wide dispersal did not occur following cycle-ending collapse episodes. Basaltic eruptive activity, contemporaneous with growth of the Las Cañadas edifice, was plentiful in both the summit areas and flanks of Tenerife, and has continued into the historic period. The two main zones of basaltic eruptions are the northwestern Santiago Rift Zone and the northeastern Dorsal Rift Zone (Fig. 1). Within the summit caldera of Las Cañadas are situated the twin stratocones of Teide (3718 m) and Pico Viejo (3103 m), along with numerous satellite vents, all formed since the last caldera collapse at ca. 0.18 Ma (Ridley, 1970, 1971; Mitjavila and Villa, 1993; Ablay et al., 1998). The most recent eruptions of phonolitic magma occurred from this complex at ≤ 2 ka (Ablay et al., 1995; Ablay and Martí, 2000). Similarities between the Teide–Pico Viejo record and the basal portions of earlier cycles (Martí et al., 1994, Ablay et al., 1995, and below) suggest the Holocene phonolitic activity represents the start of a fourth Quaternary explosive cycle with the potential to produce future catastrophic caldera-forming events.

3. Overview of DHF stratigraphy

The Diego Hernandez Formation (DHF) represents the youngest of the three complete magmatic cycles in the Upper Group. Following Martí et al. (1994), the DHF includes all volcanic units erupted from the Las Cañadas caldera (LCC) that lie stratigraphically above the Granadilla Member of the underlying Guajara Formation (Bryan et al., 1998, 2000), up to and including the Abrigo Member (Fig. 2). The Granadilla eruption was the terminal caldera-forming event of