ARTICLE IN PRESS

VOLGEO-05905; No of Pages 9

Journal of Volcanology and Geothermal Research xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

Subsidence and current strain patterns on Tenerife Island (Canary Archipelago, Spain) derived from continuous GNSS time series (2008–2015)

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ARTICLE INFO

Article history:
Received 21 January 2016
Received in revised form 18 June 2016
Accepted 1 August 2016
Available online xxxx

Keywords:
Canary Islands
GPS time series
Volcanic deformation

ABSTRACT

In this paper we present the current crustal deformation model of Tenerife Island derived from daily CGPS time series processing (2008–2015). Our results include the position time series, a global velocity estimation and the current crustal deformation on the island in terms of strain tensors. We detect a measurable subsidence of 1.5–2 mm/yr. in the proximities of the Cañadas-Teide-Pico Viejo (CTPV) complex. These values are higher in the central part of the complex and could be explained by a lateral spreading of the elastic lithosphere combined with the effect of the drastic descent of the water table in the island experienced during recent decades. The results show that the Anaga massif is stable in both its horizontal and vertical components. The strain tensor analysis shows a 70 nstrain/yr. E-W compression in the central complex, perpendicular to the 2004 sismo-volcanic area, and 50 nstrain/yr. SW-NE extension towards the Northeast ridge. The residual velocity and strain patterns coincide with a decline in volcanic activity since the 2004 unrest.

1. Introduction

Tenerife Island (Canary Islands, Spain) has been the subject of detailed geological and geophysical research because of its volcanological evolution and geodynamic setting. After a century-long period of quiescence the central volcanic complex of the island (Teide - Pico Viejo stratovolcanoes) reactivated in the spring of 2004 with an increase of seismicity with over 3000 recorded events, five of them felt by the population. This activity was generally explained by magma addition into its northwestern area (Tárraga et al., 2006; Gottsmann et al., 2006, 2008; Almendros et al., 2007; Martí et al., 2009). Due to its great interest, several studies have been developed after this reactivation, focusing on aero-magnetic surveying in order to study the structure and growth of the island (Blanco-Montenegro et al., 2011, García et al., 2007), gravity models to analyze the structure beneath the central volcanic complex (Gottsmann et al., 2008), seismological studies using scattering seismic attenuation and imaging magma storage (Ibañez et al., 2008; García-Yeguas et al., 2012; Lodge et al., 2012; De Barros et al., 2012; Prudencio et al., 2013, 2015), resistivity measurements (Coppo et al., 2008; Piña-Varas et al., 2014), InSAR and vertical deformation (Fernández et al., 2009; Tizzani et al., 2010), tiltmeter measurements (Eff-Darwich et al., 2008) and episodic DGPS deformation analysis (Berrocoso et al., 2010).

In particular, spatial geodetic techniques have been a reliable and valuable tool for determining velocity gradients and deformation patterns on the surface. Currently GPS data and continuous position time series analysis have been thoroughly used in ground deformation and monitoring of active volcanoes as a complement to traditional monitoring systems (Myer et al., 2008; Perlt et al., 2008; Shirzaei et al., 2013; Marques et al., 2013). Geodetic tools have enabled a better understanding of these active areas and facilitated precise measurements of crustal displacement and derived strains.

In this contribution we present a rigorous crustal deformation model of Tenerife Island derived from CGPS position time series using Precise Point Positioning (PPP). We also include a velocity field analysis and a strain rate array with the data available. The results were integrated with geological information and previous studies to improve the current geodynamical analysis of the Island. A detailed assessment using newly continuous GNSS stations is of great importance in improving our knowledge of the shallow sub-surface of Tenerife and the current situation after the 2004 reactivation event.

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http://dx.doi.org/10.1016/j.jvolgeores.2016.08.006
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2. Geological settings

Tenerife Island, situated close to the NW coast of Africa in the Atlantic Ocean, is the major volcanic island of the Canary Islands archipelago (Spain) (Fig. 1). Due to its volcanic evolution, the geomorphology of Tenerife is quite heterogeneous. The presence of varied volcanic processes throughout its history have given quite a few examples of basaltic lava flows, strato-volcanoes, monogenetic cones, pyroclastic deposits and calderas (Las Cañadas). The most significant structure is the Las Cañadas-Teide-Pico Viejo (CTPV) complex which is located in the centre of the island. This formation rises nearly 4000 m above sea level and comprises a collapse caldera and a stratovolcano complex (Teide - Pico Viejo) (Ablay and Martí, 2000). Its core is thought to be ultramafic cumulitic (Ablay and Kearey, 2000; Gottsmann et al., 2008), and it is responsible for gravity, magnetic and seismic velocity anomalies (Watts et al., 1997; Ablay and Kearey, 2000; Araña et al., 2000). Surrounding this central complex we observe two main ridges NW-SE and NE-SW (Martí et al., 1994) and a subsidiary monogenetic basaltic field at the southern sector of the island (Geyer and Martí, 2010).

The volcanism of the Canary Archipelago has been affected by several regional fault systems. These faults are classified into two different families according to their origin: The features related to the opening of the Atlantic (NE-SW direction) and those influenced by the tectonics of the Atlas range in the African continent (NW-SE). These regional fault systems have an influence on the entire tectonic framework of Tenerife and determine the location of the eruptions on the whole island (Ablay and Martí, 2000; Geyer and Martí, 2010). During the Holocene volcanic activity, two kinds of volcanism occurred in Tenerife (Martí et al., 2008): (1) a basaltic fissure volcanism, located mainly on the ridges and the south of the island and (2) phonolitic eruptions related to the CTPV complex. The record of historical eruptions includes the Sietefuentes, Fasnia and Arafo volcanoes (1704–1705) in the NE-SW ridge and Garachico (1706) and El Chinyero (1909) volcanoes in the NW-SE. The Chahorra eruption (1798) is located outside the ridge areas, on the western flank of the Pico Viejo stratovolcano (Romero, 1992). The active Teide-Pico Viejo twin stratovolcanoes started to grow inside the Las Cañadas caldera about 180 k ago (Martí et al., 1994) and have mainly produced lava flow and explosive eruptions of basaltic to phonoltic magmas. The products from these eruptions partially fill the caldera, and the adjacent Icod and La Orotava valleys, to the north, both originated by landslide processes related to the caldera formation (Martí et al., 1997).

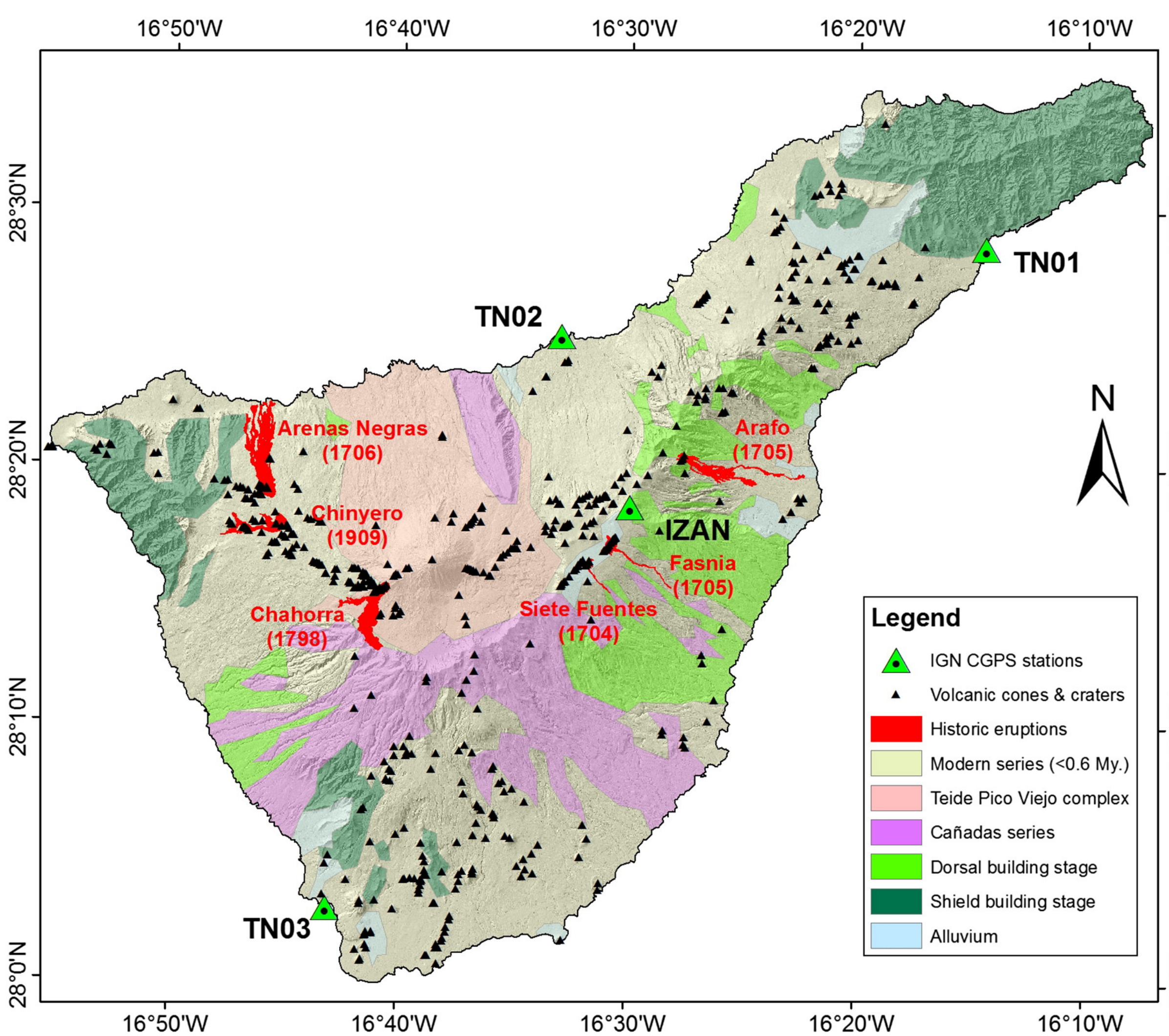

Fig. 1. Schematic geological map of Tenerife Island (Canary Archipelago) (based on Carracedo et al., 2007). The historical lava flows (in red), recent volcanic cones and craters (black dots) and the CGPS stations used in this study (green triangles) are indicated. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Please cite this article as: Sánchez-Alzola, A., et al., Subsidence and current strain patterns on Tenerife Island (Canary Archipelago, Spain) derived from continuous GNSS time series (20..., J. Volcanol. Geotherm. Res. (2016), http://dx.doi.org/10.1016/j.jvolgeores.2016.08.006