Journal of Volcanology and Geothermal Research 257 (2013) 90–98

Contents lists available at SciVerse ScienceDirect

Journal of Volcanology and Geothermal Research

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

Coeval giant landslides in the Canary Islands: Implications for global, regional and local triggers of giant flank collapses on oceanic volcanoes

Thomas Boulesteix [a,b,*], Anthony Hildenbrand [a,b], Vicente Soler [c], Xavier Quidelleur [a,b], Pierre-Yves Gillot [a,b]

[a] *Univ Paris-Sud, Laboratoire IDES, UMR8148, Orsay, F-91405, France*
[b] *CNRS, Orsay, F-91405, France*
[c] *Instituto de Productos Naturales y Agrobiologia, Estacion Volcanologica de las Canarias (CSIC), 38080 La Laguna, Tenerife, Spain*

A R T I C L E I N F O

Article history:
Received 9 November 2012
Accepted 11 March 2013
Available online 21 March 2013

Keywords:
Giant sector collapse
Triggering factor
K–Ar
Tenerife
Canary Islands

A B S T R A C T

Giant landslides are an important part of the evolution of most intra-plate volcanic islands. They often proceed in catastrophic events, likely to generate voluminous debris avalanches and eventually trigger destructive tsunamis. Although knowledge of the timing of their recurrence is a key factor regarding the hazard assessment in coastal environments, only a few of them have been well dated.

In this contribution, we focus on the La Orotava event on Tenerife, which we date with the unspiked K–Ar technique, between 534 and 523 ka. Such narrow temporal interval is compatible, within uncertainties, with the age of the Cumbre Nueva collapse on the neighboring island of La Palma. We thus examine here the possible common triggering mechanisms at the global, regional and local scales.

Both events occurred shortly after the climax of the oxygen isotopic stage 14, during the rapid transition towards the interglacial stage 13, reinforcing the hypothesis of a control from global paleoclimatic changes on the destabilization of oceanic islands. Intense volcanic pulses at the regional scale also lead to the synchronous overgrowth of several volcanic islands in the archipelago, but coeval destabilization on Tenerife and La Palma appears significantly controlled by the intrinsic morphology of the edifices, with contrasted instability thresholds for shield volcanoes and volcanic ridges respectively. Finally, we propose that the two events may be genetically linked. Dynamic transfer of voluminous debris avalanches during a giant landslide episode can induce isostatic readjustments, generate significant ground acceleration and finally produce a large tsunami, three processes which can concur to trigger large scale flank collapse on a neighboring mature unstable volcanic island.

1. Introduction

Giant flank collapses on intra-plate volcanic islands are a major threat for the worldwide littoral populations. Individual episodes of destabilization can generate voluminous and fast running debris avalanches, which can trigger large tsunamis when entering into the sea (McGuire, 1996; Keating and McGuire, 2000; McMurtry et al., 2004). From onland and offshore studies, large flank collapse events have been recognized worldwide (e.g.: Mitchell, 2003) and numerous enabling/triggering mechanisms have been proposed (see review by McGuire, 1996; and references therein). The effects of paleoclimatic changes, in particular, have recently been proposed as a possible instability factor on the basis of a limited number of precisely dated events distributed worldwide (Quidelleur et al., 2008). However, the interplay between such potential global factors and more regional/global ones is critical for better hazard planning and risk assessment, but remains poorly known in most cases.

The Canary Islands archipelago (Fig. 1) is a target of particular interest to address such issues because the islands have experienced repeated flank destabilizations, with more than twenty individual events recognized (e.g.: Krastel et al., 2001; Masson et al., 2002). In most instances, the pre- and post-landslide volcanic successions are partially exposed at the surface of the islands and partly accessible through a unique network of numerous sub-horizontal groundwater recovery galleries. Some of these galleries reach, and sometimes even cross, the sliding surfaces and thus constitute a valuable way to constrain the first order geometry of individual flank collapses, and to constrain the timing and eruptive consequences of lateral destabilization episodes (Boulesteix et al., 2012). We took advantage of one of them to study a major flank collapse, which opened the conspicuous La Orotava valley (Fig. 2), on the northern flank of Tenerife's northeastern volcanic ridge. From previous studies, the timing of this event was estimated between 0.69 ± 0.1 Ma (2σ; Ibarrola et al., 1993) and 566 ± 13 ka (2σ; Carracedo et al., 2011).

* Corresponding author at: Univ Paris-Sud, Laboratoire IDES, UMR8148, Orsay, F-91405, France. Tel.: +33 1 69 15 67 42.
E-mail address: boulesteix.thomas@gmail.com (T. Boulesteix).

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http://dx.doi.org/10.1016/j.jvolgeores.2013.03.008

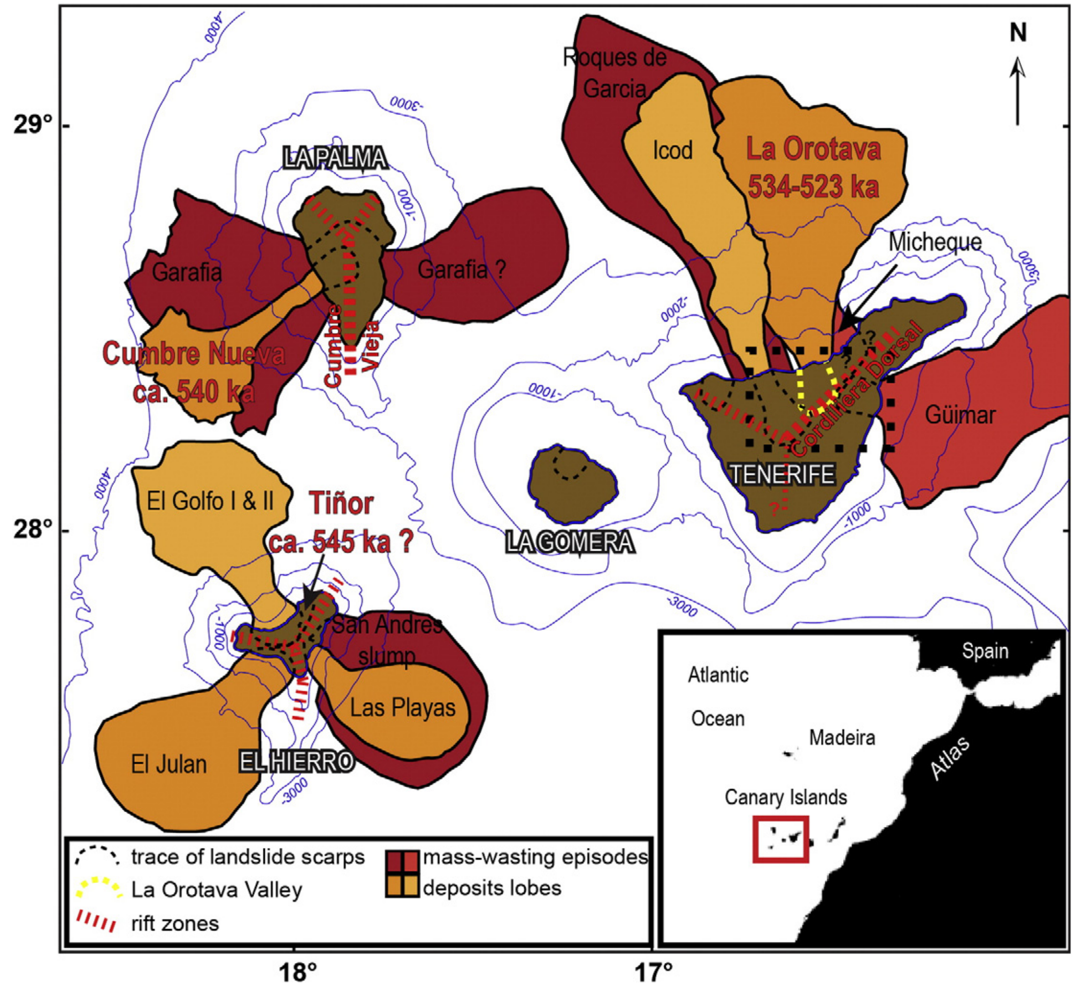

Fig. 1. Map of the major landslide episodes in the western Canary Islands modified after Masson et al. (2006). The names and ages of the landslide episodes considered in this contribution appear in red. Elements of bathymetry are given by thin blue lines. The extent of Fig. 2 is indicated by a thick black loosely dotted frame. Location of the archipelago and extent of the map (red box) in inset.

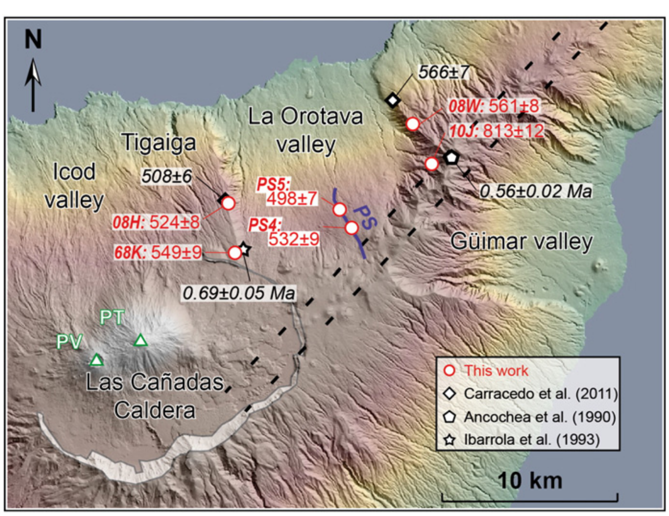

Fig. 2. Shaded relief map of the central part of Tenerife showing the position (more details in text and Table 1) and the ages (in ka, 1σ) of the dated samples. The double dashed black line represents the axis of the NE Rift Zone. The thick blue line stands for the trace of the Pino Soler gallery (PS). The green triangles represent the location of the summits of Pico Teide (PT) and Pico Viejo (PV).

Here, we precisely constrain the age of the La Orotava event at an age equivalent to the Cumbre Nueva flank collapse, on the neighboring island of La Palma (Fig. 1). The coeval occurrence of both episodes leads us to examine and discuss the respective influence of global, regional and local factors on the development of giant landslides on intra-plate volcanic islands and to consider possible mutual interactions between individual large landslides within a given archipelago.

2. Precise dating of the La Orotava event

Several methods have been used to estimate the age of large flank collapse events, e.g.: from the thickness of the sediments overlying their submarine deposits (Watts and Masson, 1995), from the correlation with the age of turbiditic events (e.g.: Hunt et al., 2011), or from oxygen isotopes measured on planktonic foraminifera entrained in the landslide products (McMurtry et al., 1999). When possible, isotopic dating of the pre- and post-landslide volcanic units is a valuable way to bracket the age of large flank collapses (Hildenbrand et al., 2006; Quidelleur et al., 2008; Samper et al., 2008; Carracedo et al., 2011; Boulesteix et al., 2012; Jicha et al., 2012).

Therefore, we targeted here in priority (1) the youngest lava flows affected by the collapse event in the lateral walls of the landslide depression, and (2) the oldest unambiguous expression of the volcanism filling the La Orotava landslide scar. For this, we explored the Pino Soler water recovery gallery (1150 m a.s.l), located at the center of the La Orotava valley (Fig. 2), and drilled through the