Journal of African Earth Sciences 113 (2016) 88–94

Contents lists available at ScienceDirect

Journal of African Earth Sciences

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

Geochronological constraints on the evolution of El Hierro (Canary Islands)

Laura Becerril [a,*], Teresa Ubide [b], Masafumi Sudo [c], Joan Martí [a], Inés Galindo [d], Carlos Galé [e], Jose María Morales [d], Jorge Yepes [f], Marceliano Lago [e]

[a] Institute of Earth Sciences Jaume Almera, ICTJA-CSIC, Lluis Sole i Sabaris s/n, 08028 Barcelona, Spain
[b] School of Natural Sciences, Department of Geology, Trinity College Dublin, Dublin 2, Ireland
[c] Universität Potsdam, Institut für Erd- und Umweltwissenschaften, Karl-Liebknecht-Str. 24, 14476 Golm, Germany
[d] Spanish Geological Survey (IGME), Unit of Canary Islands, Alonso Alvarado, 43, 2°A, 35003 Las Palmas de Gran Canaria, Spain
[e] Department of Earth Sciences, Faculty of Sciences, Universidad de Zaragoza, Pedro Cerbuna 12, 50009 Zaragoza, Spain
[f] Department of Civil Engineering, EIIC-ULPGC, University of Las Palmas de Gran Canaria, 35017 Las Palmas, Spain

ARTICLE INFO

Article history:
Received 21 January 2015
Received in revised form
19 June 2015
Accepted 20 October 2015
Available online 23 October 2015

Keywords:
$^{40}Ar/^{39}Ar$
^{14}C
Eruptive recurrence
El Hierro
Canary Islands

ABSTRACT

New age data have been obtained to time constrain the recent Quaternary volcanism of El Hierro (Canary Islands) and to estimate its recurrence rate. We have carried out $^{40}Ar/^{39}Ar$ geochronology on samples spanning the entire volcanostratigraphic sequence of the island and ^{14}C geochronology on the most recent eruption on the northeast rift of the island: 2280 ± 30 yr BP. We combine the new absolute data with a revision of published ages onshore, some of which were identified through geomorphological criteria (relative data). We present a revised and updated chronology of volcanism for the last 33 ka that we use to estimate the maximum eruptive recurrence of the island. The number of events per year determined is 9.7×10^{-4} for the emerged part of the island, which means that, as a minimum, one eruption has occurred approximately every 1000 years. This highlights the need of more geochronological data to better constrain the eruptive recurrence of El Hierro.

1. Introduction

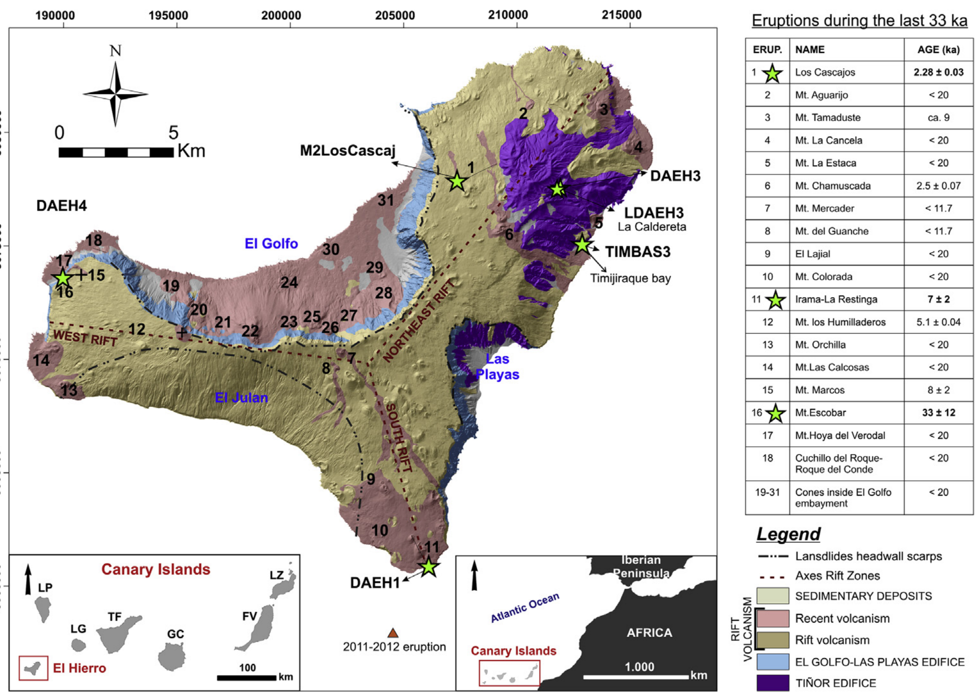
A comprehensive geochronology of recent volcanic areas allows to better constrain the temporal evolution of volcanism and its potential for future reactivation, thus providing the clues to estimate recurrence rates and hence to assess the volcanic hazard (Connor and Conway, 2000; Bebbington, 2012). This kind of studies are even of major importance in volcanic areas characterised by low frequency activity and with a short historical period, as the case of the Canary Islands and particularly, on islands with recent volcanic activity as El Hierro.

Previous geochronological studies on El Hierro have been focused on the reconstruction of its subaerial volcanic evolution, using mainly radiometric dating (K–Ar and $^{40}Ar/^{39}Ar$) and magnetostratigraphy. Abdel-Monem et al. (1972) and Fuster et al. (1993) provided the first (whole rock) K–Ar ages, ranging from 3.05 ± 3.00 to 0.19 ± 0.01 Ma and from 0.80 ± 0.06 Ma to less than 0.05 Ma, respectively. These ages were afterwards revised and discarded by later authors (Guillou et al., 1996; Carracedo et al., 2001; IGME, 2010a, b, c, d) who considered them inconsistent with new results on subaerial volcanism ranging from 1.12 ± 0.02 Ma to 2.50 ± 0.07 ka BP. Other studies have also contributed to constrain the temporal evolution of El Hierro. Széréméta et al. (1999) provided four K–Ar ages from the scarp of El Golfo landslide ranging from 0.347 ± 0.006 Ma to 0.134 ± 0.004 Ma. Recently, Longpré et al. (2011) restricted the age of the large flank collapse of El Golfo between 87 ± 8 ka and 39 ± 13 ka using $^{40}Ar/^{39}Ar$ dating.

Few radiocarbon ages have been obtained for the Holocene period of the island. Pellicer (1977) presented ^{14}C ages of 4.2 ± 0.1 ka BC and 6.74 ± 0.15 ka BC attributed to the Tanganasoga volcano (Fig. 1; Table 1 in Supp. Mat.). Pérez-Torrado et al. (2011) dated nearby deposits to Tanganasoga obtaining similar ages (3.90 ± 0.07 ka BP and 8.10 ± 0.06 ka BP). These ages have been recently discussed and rejected by Pedrazzi et al. (2014) due to stratigraphic discrepancy. Another two recent volcanoes have been dated by Pérez-Torrado et al. (2011) and Guillou et al. (1996) with the ^{14}C technique, obtaining ages of 5.10 ± 0.04 ka BP (near vents to

* Corresponding author.
E-mail address: laurabcar@gmail.com (L. Becerril).

http://dx.doi.org/10.1016/j.jafrearsci.2015.10.012
1464-343X/



Eruptions during the last 33 ka

ERUP.	NAME	AGE (ka)
1	Los Cascajos	2.28 ± 0.03
2	Mt. Aguarijo	< 20
3	Mt. Tamaduste	ca. 9
4	Mt. La Cancela	< 20
5	Mt. La Estaca	< 20
6	Mt. Chamuscada	2.5 ± 0.07
7	Mt. Mercader	< 11.7
8	Mt. del Guanche	< 11.7
9	El Lajial	< 20
10	Mt. Colorada	< 20
11	Irama-La Restinga	7 ± 2
12	Mt. los Humilladeros	5.1 ± 0.04
13	Mt. Orchilla	< 20
14	Mt.Las Calcosas	< 20
15	Mt. Marcos	8 ± 2
16	Mt.Escobar	33 ± 12
17	Mt.Hoya del Verodal	< 20
18	Cuchillo del Roque-Roque del Conde	< 20
19-31	Cones inside El Golfo embayment	< 20

Fig. 1. Simplified geological map of El Hierro Island, from IGME (2011). This geological map includes the location of newly dated samples (green stars) and recent eruptions identified by geomorphological criteria. The insets show the location of the Canary Islands in relation to the Iberian Peninsula and Africa, and the whole Canary archipelago, where LZ: Lanzarote; FV: Fuerteventura; GC: Gran Canaria; TF: Tenerife; LG: La Gomera; LP: La Palma. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Mt. Humilladeros) and 2.50 ± 0.07 ka BP (Mt. Chamuscada), respectively (Fig. 1; Table 1 in Supp. Mat.).

In order to improve our understanding of El Hierro geological evolution, to characterise some of the most recent eruptions on the island and to estimate the eruptive recurrence, we have carried out a geochronological study throughout the volcanostratigraphic sequence of El Hierro. A thorough revision and compilation of all previous geochronological information on the island was completed with new $^{40}Ar/^{39}Ar$ and ^{14}C ages and new relative ages determined using geomorphological criteria. We provide an updated geochronological catalogue for El Hierro, and discuss its implications for the last eruptive period on the island.

2. Geological and geochronological framework

El Hierro is the south westernmost and youngest of the Canary Islands (Fig. 1) with 1.12 Ma age (Guillou et al., 1996) and represents the emerged part of a volcanic edifice which rises 5500 m from the sea floor. The submarine eruptive activity on the southern rift could have started 133 Ma ago (Van den Bogaard, 2013). Its subaerial part emerges 1501 m above sea level and it has an area of about 269 km^2 (Fig. 1).

Three main volcanic cycles, known as the Tiñor Edifice (1.12–0.88 Ma), the El Golfo-Las Playas Edifice (0.545–0.176 Ma), and the Rift Volcanism (0.158 Ma–Present) (Guillou et al., 1996; Carracedo et al., 2001), have contributed to the growth of the island (Fig. 1). Periods of quiescence, deformation, erosion and sector collapse separated these cycles (Fig. 1). The last growing stage of El Hierro was controlled by a structural configuration of three-armed rift zones (0.158 Ma ago; Guillou et al., 1996; Carracedo et al., 2001). This last cycle was characterised by a relatively homogeneous volcanism, mainly forming scoria cones and mafic lava flows from fissure fed eruptions, which occurred simultaneously along the three rifts of the island on- and offshore. During the past 600 years (historical period), no eruptions have been recorded on El Hierro, except the 2011–2012 submarine eruption (López et al., 2012).

The morphology of El Hierro is mainly conditioned by three giant amphitheatres (El Golfo, Las Playas and El Julan) that represent the headwall scarps of giant landslides (Fig. 1). In total, at least six giant landslides have occurred during the construction of the subaerial part of El Hierro. The four principal ones are: Las Playas I and II (~545–0.176 Ma and 0.176–0.145 Ma respectively), El Julan (>0.158 Ma) and El Golfo (~87–39 ka) (Masson, 1996; Masson et al., 2002; Gee et al., 2001; Longpré et al., 2011). Another two landslides have been proposed during the first stages of the subaerial construction of the island, probably between 1.12 and 1.04 Ma, affecting the northern side of the Tiñor Edifice (Carracedo et al., 2001; IGME, 2010a, b, c, d) at around 0.8 and 0.5 Ma (IGME, 2010a).

3. Stratigraphical location and petrographic description of the samples

A total of six samples were collected throughout the volcanostratigraphic sequence of El Hierro (Fig. 1; Table 1; Table 1 in Supp. Mat.): two mafic lava flows and three dykes were analysed by the $^{40}Ar/^{39}Ar$ method and one charcoal sample was analysed by the ^{14}C technique. None of the samples had been dated before. Lava flows and feeder dykes had been previously studied from a volcano-structural point of view (Becerril et al., 2013b, 2015). The charcoal sample was collected on a fieldtrip specifically designed to search charcoal related to the most recent eruptions on the island.

Three of the five rock samples (TIMBAS3, DAEH3 and LDAEH3) belong to the Tiñor Edifice. Sample TIMBAS3 represents a lava flow covering a limited pillow lava outcrop in the Timijiraque bay (Figs. 1 and 2a). DAEH3 and LDAEH3 belong to a feeder dyke and its associated lava flow, respectively, situated close to La Caldereta