Geochronological, structural and morphological constraints in the genesis and evolution of the Canary Islands

*J.C. Carracedo[1,2], S. Day[2], H. Guillou[3], E. Rodríguez Badiola[4], J.A. Canas[5] and F. J. Pérez Torrado[6]

[1]*Estación Volcanológica de Canarias, CSIC, La Laguna, Tenerife, Canary Islands, Spain*
[2]*Cheltenham & Gloucester College of Higher Education, Cheltenham, U.K. and Greig Fester Center for Hazard Research, University College London, UK.*
[3]*Centre des Faibles Radioactivités, CEA-CNRS, Gif sur Yvette, France*
[4]*Museo Nacional de Ciencias Naturales, CSIC, Madrid, Spain*
[5]*ETSICC, Universidad Politécnica de Cataluña, Spain*
[6]*Facultad de Ciencias del Mar, ULPGC, Las Palmas, Gran Canaria, Canary Islands*

1. Introduction

The Canarian Archipelago is a group of volcanic islands on a slow-moving oceanic plate, close to a continental margin. The cause of the archipelago is controversial: a hotspot or mantle plume, a zone of lithospheric deformation, a region of compressional block-faulting or a rupture propagating westwards from the active Atlas Mountains fold belt have been proposed by different authors. However, comparison of the Canarian Archipelago with the prototypical hotspot-related island group, the Hawaiian Archipelago, reveals that the differences between the two are not as great as had previously been supposed on the basis of older data.

Concrete evidence for the relative roles of regional tectonics and mantle plumes in the genesis of the islands may come from large-scale seismological and structural studies of the deep structure of the surrounding oceanic crust and lithosphere and from constraints provided by geochemical and isotopic features of the magmas involved. Notwithstanding, it is interesting to analyse, as we do here, the existing geological information from the islands themselves, especially the timing of eruptive activity in the islands and their morphological and structural features. This may help to establish some clear constraints that may narrow down the range of acceptable models for the genesis and development of the Canary Islands.

2. Age of the Canarian volcanism

The extensive K/Ar dating carried out in the Canary Islands, with about 400 K/Ar ages published from lava flows, gives a remarkable control of the subaerial volcanic history of this archipelago. The age of the earliest exposed volcanic rocks in each island as well as the periods of volcanic activity and alternating gaps are clearly defined (Fig. 1A).

However, detailed geochronological work using accurate dating techniques and cross-checking against palaeomagnetic reversals has proved that some previous ages of these islands have substantial errors, sometimes of several million years. Such errors are especially significant in the islands of La Palma and El Hierro, where most of the subaerial lavas are of Quaternary age (Guillou et al., 1996; this volume). Recent studies have shown that ages from stratigraphic sequences, consistent with the general volcanic stratigraphy and the corresponding polarities of the standard geomagnetic polarity time-scale, are the most reliable (Carracedo et al., this volume; Guillou et al., this volume).

Two groups of islands can nevertheless be defined using the published ages: 1) Lanzarote, Fuerteventura, Gran Canaria and La Gomera, with subaerial volcanism 12 ma or older and well-defined hiatuses in the volcanic activity, and 2) Tenerife, La Palma and El Hierro, with exposed volcanics 7.5 ma or younger and essentially uninterrupted volcanic histories.

The presence of a hiatus in volcanic activity occurs only in the older islands (Middle-Lower Miocene) of Lanzarote, Fuerteventura, *Gran Canaria and La Gomera (Fig. 1A). In contrast, the volcanic activity has* continued uninterrupted in the younger islands (Upper Miocene-Quaternary) of Tenerife, La Palma and El Hierro.

Similar interruptions are observed in the prototypical hotspot islands of the Hawaiian Archipelago, where they constitute a key stratigraphic feature separating the shield-stage volcanism from the post-erosional or rejuvenated-stage volcanism (Walker, 1990). We may conclude that, as in the Hawaiian Islands, the periods of volcanic quiescence allow the separation of the Canary Islands into different categories (Fig. 1B): a) the islands of Lanzarote, Fuerteventura and Gran Canaria, at present with post-erosional, rejuvenated-stage volcanism; b) the island of La Gomera, presently in the gap stage, and c) the islands of Tenerife, El Hierro and La Palma, in the pre-gap shield stage. This time-related division may be preferable to the generally used "eastern" and "western" subdivision of the Archipelago, since it recognises the anomalous location of the older island of La Gomera in the middle of the western Canaries group.

3. Contrasting structural features in the eastern and western Canaries?

Recently obtained onshore and offshore geological information in the younger islands of Tenerife, La Palma and El Hierro [Holcomb and Searle, 1991; Carracedo, 1994; Carracedo et al., this volume; Watts and Masson, 1995; Guillou et al., 1996; Guillou et al., this volume; Day et al., this volume) has revealed volcanological, structural and geomorphological features (triple-armed active rifts and giant landslides) typical of hotspot islands. These features are less evident in the older Canaries.

The apparent contrasting structural features observable in the younger and older Canaries may reflect only different stages of development of the islands. We consider the multiple rifts and giant landslides to be characteristic of the shield-stage of development, both in the Canaries and other intraplate oceanic islands of hotspot-related origin. These structures may be present in the older, post-erosional stage islands (Ancochea et al., 1996; Stillman, this volume). However, modifications during the erosional gaps, that in the Canary Islands are considerably longer than in most of the other archipelagos of similar origin, make their recognition difficult. At similar phases of evolution the islands appear to have similar structural features.

4. Has a hotspot generated the Canary Islands?

The association of the Canarian archipelago with an asthenospheric plume has been proposed repeatedly. In our model, the first volcanic manifestations of this hotspot would have been localised at the continental-oceanic boundary (COB) west of Fuerteventura. Sediment thickness at continental margins exceeding *10* Km *should be a major factor in modifying the strength of the lithosphere, since lower* overburden and conductivity of the sediments may be associated with significant weakening of the lithosphere. Volcanism may have propagated to the NE along the continental boundary, forming the Fuerteventura-Lanzarote ridge. The assumption that the Canarian archipelago progresses from Lanzarote to Fuerteventura and oceanwards seems inconsistent with the presently accepted geochronological and geological information, and probably reflects an unfounded link between the Canaries and the Atlas tectonism (Anguita and Hernán, 1975). The island of Fuerteventura is a lineation of volcanic complexes with similar oldest subaerial ages of about 20 ma (Ancochea et al, 1996), Lanzarote being simply a younger prolongation of Fuerteventura to the NE (parallel to the continental edge). Both islands are in fact separated by a narrow strait less than 100 m deep and form a single edifice. The initial spread of volcanism in the

Canaries would be, therefore, opposite in direction to the fracture propagating from the Atlas region postulated by Anguita and Hernán (1975).

Zones of high seismic attenuation (Canas et al., 1995) at the western end of the archipelago indicate the presence of an asthenospheric anomaly, and may be direct evidence of the presence of the plume.

5. Alternation of volcanic activity between El Hierro and La Palma?

The detailed and precise dating of volcanic activity on these two islands, which have been the most active in the Canarian archipelago in the last 1 Ma, suggests that periods of intense volcanism on one island coincides with periods of relative inactivity on the other (Fig. 2). This alternation suggests that both islands may have a common magma source in the asthenosphere. A period of intense activity on one island culminates in a giant lateral collapse which is followed by a switch in the location of the most intense volcanism to the other island. We speculate that the switch may be caused by the unloading effect of the collapse, which would place the rebounding lithosphere beneath into horizontal compression and suppress upward migration of magma.

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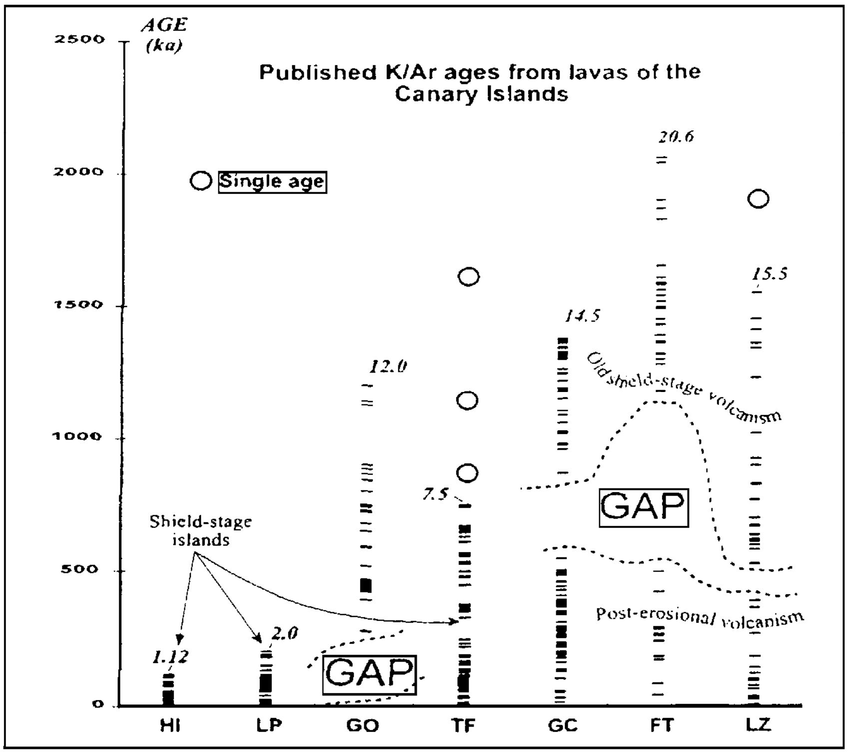

Fig. 1A

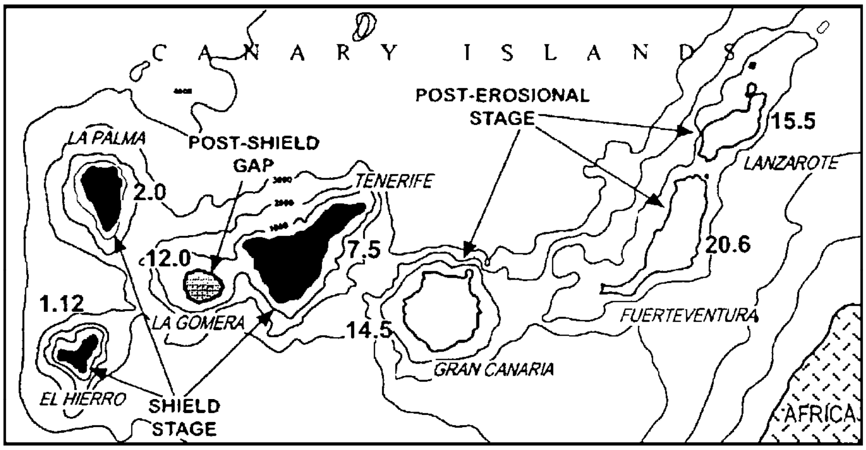

Fig. 1B

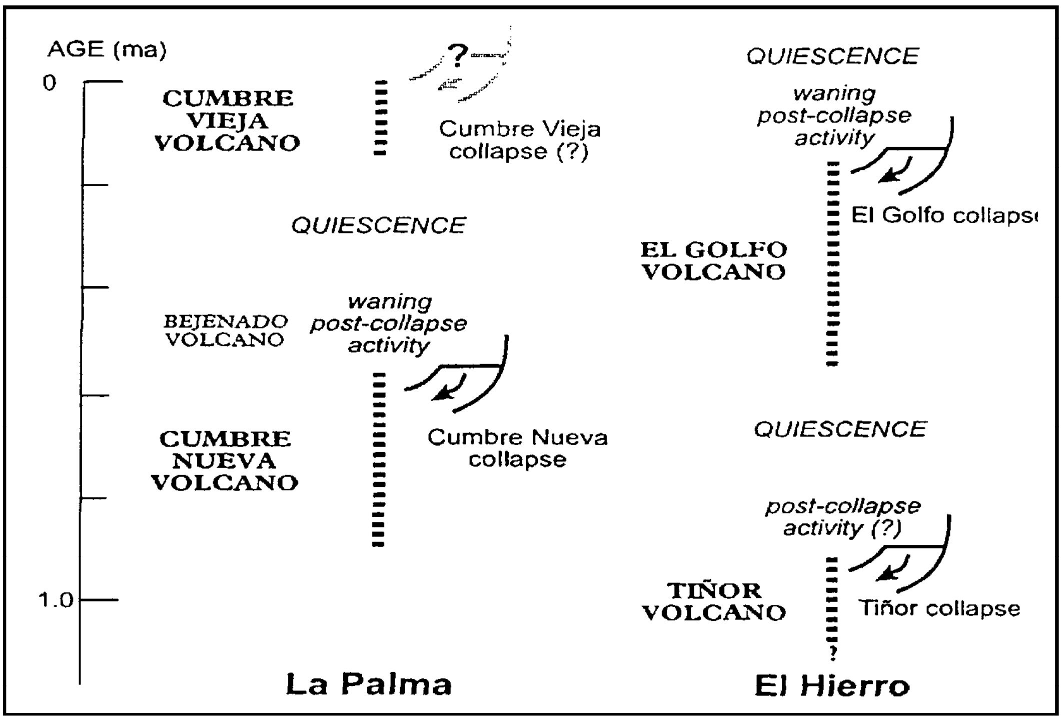

Fig. 2