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Reconstructing eroded paleovolcanoes on Gran Canaria, Canary Islands, using advanced geomorphometry

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ABSTRACT

Original volcanic edifices of two successive stages of Gran Canaria are reconstructed using a geomorphometric analysis of existent or restored paleosurfaces. In the reconstruction, surface fitting was applied preferably to planèzes (i.e. triangular facets of original volcano flanks) and quasi-planar surfaces, QPS (those occurring on planèzes, or scattered, slightly eroded portions derived from original cone surfaces) with the help of red relief image map (RRIM) analysis. Out of the long-lasting, Mid-Miocene to Holocene subaerial evolution of the island, the Late Miocene Fataga volcano and the subsequent, Pliocene Roque Nublo volcanoes were the largest and highest. The eruptive center of Fataga, a composite edifice (12.2–8.8 Ma) that may have grown up excentrically with respect to the previous Tejeda caldera, is well-defined by both two planèzes (named Veneguera–Mogán and Fataga–Tirajana) and QPS remnants. Its calculated original volume, ≤1000 km^3, is close to the largest stratovolcanoes on Earth. However, its ≥3300 m elevation, obtained by exponential fit, may have been significantly lower due to the complex architecture of the summit region, e.g. a caldera responsible for ignimbrite eruptions. Roque Nublo, a 3.7–2.9 Ma stratovolcanic cone, which was superimposed upon the Fataga rocks ≥3 km west of the Fataga center, has left no considerable paleosurfaces behind due to heavy postvolcanic erosion. Yet, its remnant formations preserved in a radial pattern unambiguously define its center. Moreover, surface fitting of the outcropping rocks can be corrected taking the erosion rate for the past 3 Ma into account. Such a corrected surface fit points to a regular-shaped, ≥3000 m-high cone with a 25 km radius and ca. 940 km^3 original volume, also comparable with the dimensions of the largest terrestrial stratovolcanoes.

1. Introduction

The complex evolution of superimposed volcanic edifices at the Canary Islands is probably best exemplified on Gran Canaria, the second largest island (Fig. 1). Its eruptive activity consisted of two volcanic stages typical of the Canaries: a complex shield-building and a rejuvenated stage, respectively (Schmincke, 1976; Carracedo, 1999; Carracedo et al., 2002). These stages were separated by a long erosional gap, and due to a balance between intense volcanism and erosion, all stages are represented in the present-day topography to smaller or greater extent unlike at other Canary Islands. The complex distribution of rocks enhanced by long-term erosion has resulted in a "pancake" structure, of which the higher levels are intensely eroded but often form remnants or outliers (Carracedo and Day, 2002) which is useful for a geomorphological reconstruction.

Although the volcanic stratigraphy and chronology of Gran Canaria is well-known (Fig. 2; Schmincke, 1976; McDougall and Schmincke, 1977; Balcells et al., 1992; van den Bogaard and Schmincke, 1998; Schmincke and Sumita, 1998; Guillou et al., 2004; Menéndez et al., 2008; Rodriguez-Gonzalez et al., 2012), the original morphologies of the island are poorly constrained. Volcanism on Gran Canaria was related mostly to a set of overlapping volcanic edifices that represent four subsequent eruptive activities: (1) the oldest, 14.6–14.0 Ma shield volcano (Güigüí and Horgazales basalts) was followed by the outpouring of the 14.0–13.3 Ma trachitic–rhyolitic Mogán ignimbrites including a caldera stage (Tejeda caldera); (2) emplacement of the trachyphonolitic Montaña Horno rocks (13.3–13.0 Ma) was followed by the trachyphonolitic pyroclastic rocks and lava flows of the Fataga Group (12.4–8.8 Ma) that, at least partly, can be connected to a central (strato)volcano; (3) a rejuvenated activity produced the Roque Nublo Group (4.9–2.6 Ma), connected mostly to the Roque Nublo stratovolcano (3.7–2.9 Ma) that issued out basanitic, trachitic to phonolitic lavas and pyroclastic rocks and was affected by major sector collapses; and (4) the post-Roque Nublo activity (3.0 Ma–3 ka) that was related to

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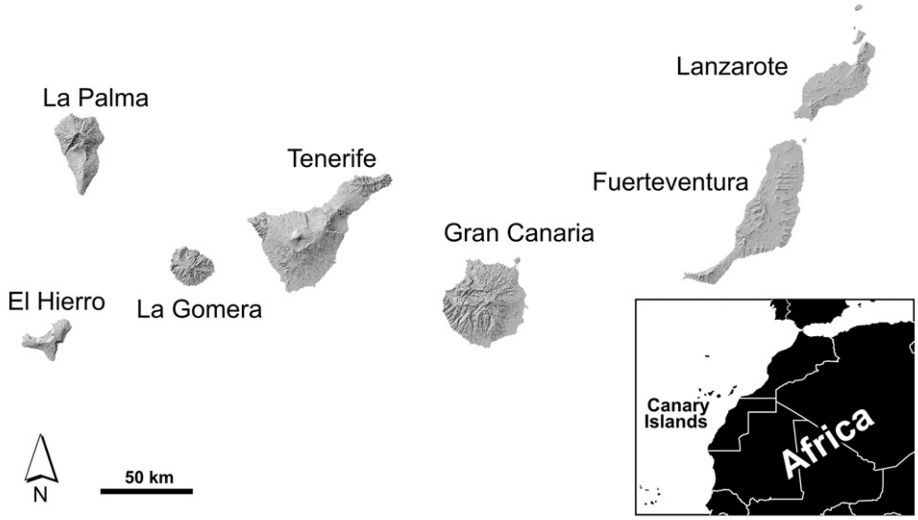

Fig. 1. Geographic setting of the Canary Islands (inset) and DEM representation of their subaerial parts (source of the 10 m DEM: GRAFCAN, 2009).

fissures and small-size monogenetic centers confined mostly to the northeastern part of Gran Canaria. One of the most recent eruptions was radiocarbon dated at 3075 $\pm$ 50 years (Nogales and Schmincke, 1969). With regard to the above-mentioned shield-building and rejuvenated stage, the 1st and 2nd eruptive activities are traditionally included in the former and the 3rd and 4th in the latter.

The volume of the submarine portion of Gran Canaria, representing the shield-building stage (1), and consisting of a central shield and its apron, was estimated >24,000 km^3, whereas that of the recent subaerial island 850 km^3 by Schmincke and Sumita (1998). The latter, still considerable volume implies that, despite deep erosion, significant portions of subaerial paleovolcanoes that grew upon the shield have been preserved. However, little has been published on the original geometries and dimensions of individual volcanic edifices. In particular, no GIS-based approach to volcanic geomorphology has been applied so far, although a 10-m resolution digital elevation model (DEM) has been available in the past years (last release: GRAFCAN, 2009), and supported, for instance, drainage basin analysis and erosion rate calculations (Menéndez et al., 2008; Rodriguez-Gonzalez et al., 2012).

This paper focuses on the reconstruction of the two main volcanic edifices of the subaerial island: a late Miocene central volcano related to the Fataga rocks, and the Pliocene Roque Nublo stratovolcano. The reconstruction is based on the topographic manifestation of mappable geological units and, where possible, preserved paleosurfaces.

Our main concept is that the distribution of volcanic rocks belonging to a given volcanic edifice, if not covered by subsequent volcanism, still

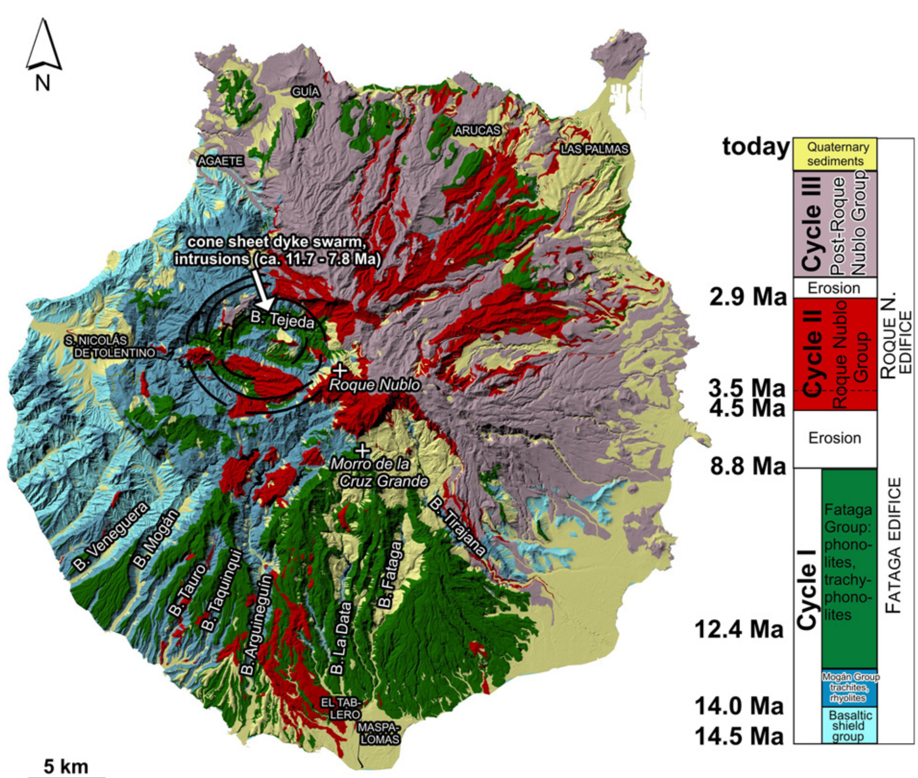

Fig. 2. Simplified geology of Gran Canaria draped on 10 m-resolution DEM image. Stratigraphic column is based on Balcells et al. (1992).