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Gravity inversion for modelling of subsurface structures associated to the volcanic evolution of La Gomera island (Canarian Archipelago, Spain)

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It is firmly established that, of all the geodetic or geophysical techniques available, gravity modelling plays an important role in helping us to understand volcanic structures. We present here a study of the structural setting of the volcanic island of La Gomera by the analysis and interpretation of high-resolution gravity data obtained over the island. The gravity data allow us to model the main subsurface anomaly sources of the island, which are related with its volcanic evolution. Our outcome is consistent with the results of previous geophysical and volcanological studies.

La Gomera island occupies a central position in the Canarian archipelago. This archipelago is the result of construction and destruction of successive large edifices covering a time span of several million years. Intrusion of magma has caused the development of an enormous amount of dikes that constituted step by step the main framework of the hypabyssal roots of these edifices.

La Gomera has a surface about 372 km2 with a roughly circular contour and it is characterised by its central massif of 1487 meters height, dropping steeply to the sea. This island is the only one on the archipelago with no signs of Pleistocene volcanic activity. Its distinctive morphological feature is the intense degree of erosion in all formations, with deep, vertical-walled valleys that cut the island radially and in which the tabular successions of basalts can be seen. The most complex and interesting unit of La Gomera is its Basal Complex, which crops out in a restricted area located at the North and it is formed of plutonic volcanic and sedimentary rocks cut by an extremely dense dyke network. According to several authors, the characteristics of this complex seem to support the hypothesis that these rocks were formed by processes of magmatic sedimentation in a fairly turbulent medium. These conditions could correspond, for instance, to the ones in a reservoir beneath a volcano. Another possibility is that this basic and ultramafic complex could represent uplifted fragments of the deep crust or the upper mantle under the sea floor. The Basal Complex represents the submarine growth stage (the Submarine Edifice) and the hypabyssal roots of the different growth stages recorded in the island. Next, the first subaerial edifice was built up in two main stages. The first stage is represented by a large basaltic shield, of about 22 km in diameter, whose centre would be located near Vallehermoso Caldera (at the North of island) and would probably be extended some 5 km offshore the present northern coastline. Over the second growth stage an edifice of 25 km in diameter partly capped the earlier one. The second large edifice (the Young Edifice) emitted lava flows that covered up the central and southern areas of the island whilst they only filled deep ravines already excavated on the northern flank. The fact of La Gomera having an almost circular shape has traditionally been interpreted as the result of the built up of a single large volcanic edifice. However, the study of several authors about radial swarms of basic dikes shows that the island has gradually grown southwards but, because of the slow displacement of the magmatic focus, La Gomera does not display the N–S elongated shape which would be expected.

In order to obtain a better knowledge about these volcanic and tectonic processes in the island, we have achieved a gravity survey to apply inversion techniques,which provide us a model of the crustal structures. The gravity data set, from the Institute of Astronomy and Geodesy (CSIC-UCM) and the Spanish National Geographic Institute, corresponds to 192 stations distributed over the whole island, although they are strongly conditioned by the sharp topography. Also, 899 marine gravity data from US Geological Survey have been used here. The obtained Bouguer anomaly map is analysed by means of a least squares prediction calculating a mean level of uncorrelated observational noise of 1.77 mGal. This anomaly is considered to obtain information about the distribution of mass density in the crust and upper mantle. To determine the geometry of these sources of the observed gravity field, we use a 3-D gravity inversion based on genetic algorithm upon a prismatic partition of the subsoil volume, and adopting a priori values of density contrast (positive and negative). The model of crustal anomalous masses identified in the inversion process show correlation with several volcanic and tectonic structures of the island of La Gomera. The main structure of this model corresponds to a high density body situated at the North of the island that it is located at depths ranging from the deepest sections to the surface. This body can be associated to the earliest volcanism at La Gomera and its growth stage. Also, we found correlations between the gravity model and the ancient volcanic system constituted by the felsic complex of the Vallehermoso Caldera. Other structures are identified and associated to the subsequent volcanic stages and the building of subaerial edifices in the island.