Gravity Anomalies in the Galápagos Islands Area

In a recent report Case *et al.* (*1*) presented a free-air gravity anomaly map of the Galápagos Islands based on 32 gravity stations on the islands. On the basis of their data they stated that the Galápagos Islands are associated with an east-west trending "residual negative anomaly" which is superimposed on a "broader positive anomaly of unknown amplitude and extent." They concluded that "the gravity data can be most readily interpreted in terms of a low-density region related to a hot spot or plume" beneath the islands.

We believe, however, that the data of Case *et al.* in no way support this interpretation. Their observations can, in fact, be explained simply if the Galápagos Islands are in some form of isostatic equilibrium. Any form of isostatic compensation will result in an "edge effect" in the free-air anomaly at the location of a large change in relief. For a relatively narrow feature, the edge effect anomalies over the two "edges" merge, resulting in a large positive anomaly. For a wider feature, the two edge effects become separated, resulting in an area of less positive anomalies over the center of the feature.

The major difficulty with the interpretation of Case *et al.* is that they did not quantitatively consider that the observed gravity anomalies could arise, at least in part, from the topography of the islands and its compensation.

A number of studies (*2, 3*) have shown that gravity anomalies in the vicinity of volcanic islands can be in large part explained by a downwarping model in which the strong outer layer of the earth (lithosphere) is treated as a loaded elastic beam (or plate) overlying a weak fluid substratum (asthenosphere). This model has also been used in studies of the deformation of the lithosphere due to ice sheets (*4*) and sediments (*5*).

We show (Fig. 1) a north-south profile across the Galápagos platform at longitude 90°30′W and the deformation which would result if the platform represents a two-dimensional load on a lithosphere treated as an elastic beam overlying a weak fluid. The topography is taken from the bathymetry maps of Chase (*6*), and the effective flexural rigidity assumed in the computations is 1.0×10^{30} dyne-cm. This value is similar to generally accepted values obtained in other studies (*3–5*).

We also show the gravity effect of the deformation model in Fig. 1. The undeformed crustal structure, assumed in computing the gravity anomalies, is representative of the mean crustal structure of the Pacific basins deduced by Shor *et al.* (*7*). The model results in large positive anomalies over the Galápagos platform with amplitudes of about 80 mgal over the outer islands of Floreana and Marchena and about 45 mgal near the islands of San Salvador

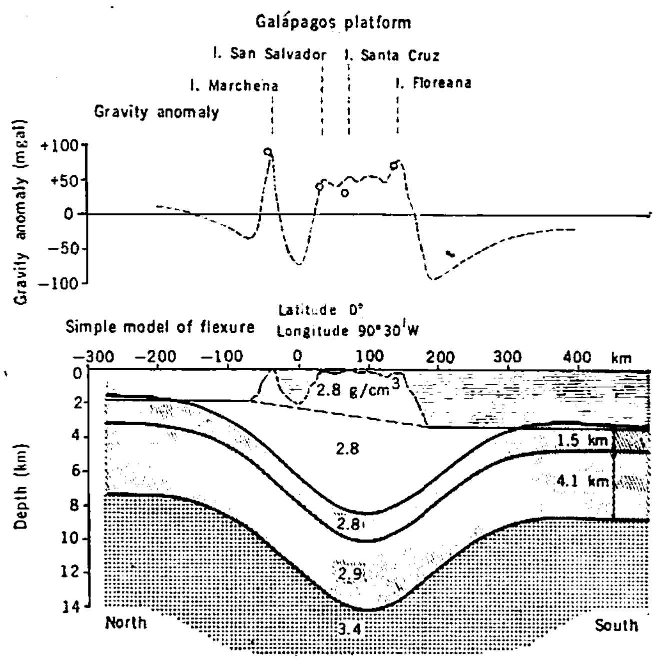

Fig. 1. Comparison of observed free-air gravity anomalies (data points) in the vicinity of the Galápagos platform with the computed gravity effect (dashed line) of a simple model of deformation due to the load of the platform. Observed gravity data are from (⊙) Case *et al.* (*1*) and (●) the R.V. *Vema* (unpublished data); bathymetric contours are from Chase (*6*). The gravity effect of the simple model predicts less positive anomalies over the center than over the edges of the platform.

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and Santa Cruz. There are also large negative anomalies associated with the edge of the platform and the trough between Marchena and San Salvador.

We have included in Fig. 1 observed free-air anomalies obtained from Case *et al.* (*1*) and from the R.V. *Vema* which are located within 5 km of the profile. The computed curve is in good agreement with the observed values. It is of particular interest that the crustal deformation model predicts a decrease of about 40 mgal between the gravity anomalies measured on the outer and inner islands. The predicted decrease occurs in the region of the residual negative anomaly of Case *et al.* The decrease in the amplitude of the positive anomalies toward the center of the platform is, in fact, characteristic of wide loads. It arises because the deformation, and therefore its negative gravity contribution, increases toward the center of the load, while the positive gravity effect of the load has a nearly constant value over that region. In contrast, relatively narrow loads, such as islands comprising the Hawaiian Ridge, are characterized by a large-amplitude positive anomaly over the center.

The argument (*1*) that "the residual negative free-air anomaly indicates an isostatic imbalance that should tend in the long run to raise the crust rather than bend it down" is invalid. The section shown in Fig. 1 is in isostatic equilibrium. The principle of isostasy states that there is a surface within the earth on which the pressure due to overlying structure is equal. Part of the pressure may be due to the mass of the section, but part may also be due to bending stresses in the lithosphere (*8*). Thus, large gravity anomalies may exist even though a region is in isostatic equilibrium.

We have made no attempt in Fig. 1 to match the computed gravity effect of the deformation model to the contours of the free-air anomaly map of Case *et al.* We consider their contours largely invalid. Short-wavelength free-air gravity anomalies in oceanic regions generally correlate most closely with changes in topography (*9*). In spite of this, the map in Case *et al.* shows a steady gentle decrease in free-air anomalies between Marchena and San Salvador, ignoring the gravity effect which would arise from a channel 1800 m deep between these islands (Fig. 1).

We are not attempting to prove that a hot spot or mantle plume does not underlie the Galápagos Islands, or that Fig. 1 necessarily represents the actual crustal structure beneath the islands. We have used a simple deformation model, which has been applied to other volcanic islands, to explain the observed data in a quantitative manner. Thus, it is not valid to interpret gravity data in terms of a hot spot or mantle plume beneath volcanic islands until the gravity effect of the topography and the manner in which it is supported is quantitatively accounted for.

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