Complete Bouguer Gravity Map of Puerto Rico

by

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INTRODUCTION

This complete Bouguer gravity map of Puerto Rico(Arc/Info export file, raster file) is based upon about 2,950 gravity stations, all but 6 of which were collected by the U.S. Geological Survey from 1962 to 1990. Kitchen and others (1991) described the data set and sources in detail, so only a few of the more important aspects are repeated here. An earlier gravity map of Puerto Rico was published by Shurbet and Ewing (1956). It is based on a smaller number of stations, which in general have since been reoccupied. Observed gravity values for the present survey are referenced to the International Gravity Standardization Net of 1971 as described by Morelli (1974). Theoretical gravity is based on the Geodetic Reference System of 1967 (International Union of (Geodesy and Geophysics, 1971). The reduction density is 2.67 g/cm3. Inner-zone terrain corrections were manually calculated from templates, and outer zones to a distance of 166.7 km were calculated by computer according to a digital elevation model. Absolute error for each station is mainly in the terrain corrections and for the most part is probably no more than 0.4-0.9 mGal.

Relative error between nearby stations is generally much less than the absolute error and in reasonably level terrain is less than 0.2 mGal. The smoothness of the gravity contours in areas of high station density is testimony to the relative accuracy of the data set.

To prepare the map, the complete Bouguer gravity values were interpolated into a rectangular grid having a spacing of 0.5 km and then contoured by means of a computer program.

INTEPRETATION

Interpretation of the Bouguer gravity map is here confined to the major gravity features of the island, that is, those features whose narrowest dimensions exceed about 20 km. The smaller features are in general better defined by the filtered Bouguer gravity map (wavelengths <13 km) and are discussed in the text accompanying that map.

High-density rocks produce gravity highs and large volumes of low-density rocks produce gravity lows. In general, volcaniclastic or clastic rocks, of which the island is mostly composed, increase in density with age, mainly because of decreasing porosity: alluvial deposits are the lowest in density, say 1.8-2.2 g/cm3; the Oligocene and younger Tertiary rocks are higher in density, about 2.2-2.5 g/cm3; then the Paleocene and Eocene rocks, about 2.4-2.7 g/cm3; and lastly the Cretaceous rocks, most of which probably have densities of about 2.65-2.75 g/cm3 (Bromery and Griscom, 1964a), depending upon the relative proportions of andesitic or basaltic volcanic debris. Local massive basaltic flows may have densities as high as 2.95 g/cm3. Plutonic rocks vary in density depending upon composition. Granitic rocks have densities in the range of 2.65-2.70, granodiodtes and quartz diorites in the range of 2.67-2.77, and more mafic rocks 2.77-2.90 g/cm3. The above statements about rock densities are only general estimates because relatively limited amounts of density data are available. Densities for 29 miscellaneous Cretaceous rock samples from southwestern Puerto Rico are available in Bromery and Griscom (l964a) who also obtained an average density of 2.55 g/cm3 for samples of serpentinite taken every 3-5 m along a 305-m core from a drill hole near Mayaguez. Mitchell (1957) reported wet and dry densities for 38 samples of "typical rocks"; results include average saturated bulk densities of 2.42 g/cm3 for 10 samples of younger Tertiary rocks, 2.79 g/cm3 for 11 samples of volcanic rocks, and 2.90 g/cm3 for 5 samples of metamorphic rocks (presumably metamorphosed mafic volcanic rocks). Kitchen and others (1991) reported densities of 71 rock samples that are older than middle Tertiary and that were collected from the south half of the island; their results show great scatter and emphasize the difficulty in determining average densities for such heterogeneous rock units.

Average density contrasts between the sedimentary rocks of middle Tertiary sedimentary basins on the north and south coasts and the older rocks beneath the basins can be calculated by using basement well data, that is, known thickness of the sedimentary rocks, together with reasonable extrapolations of regional gravity gradients over the older rocks out into the basins. Griscom and Rambo (1970) calculated the density contrast of the south coast basin rocks to be -0.4 and -0.425 g/cm3 on the basis of two gravity profiles that intersected deep wells to basement. Similarly, A. Griscom (unpubl. data, 1975) calculated a density contrast of 0.4 g/cm3 for the north coast basin on the basis of a north-south gravity profile intersecting Test Well No. 4CPR (Briggs, 1961). These results imply that the average saturated bulk density for these basin rocks is approximately 2.25-2.35 g/cm3, a range that is based upon the likely densities for the average Cretaceous volcaniclastic rocks. Briggs (1961) reported average dry bulk of 2.40 g/cm3 on three samples from each of two cores of Lares Limestone from depths of 3,704 and 3,726 ft (1,130 and 1,137 m) in well 4CPR on the north coast. Using the measured total porosity of 13.0 percent and the grain density of 2.75 g/cm3, this density recalculates to a saturated bulk density of about 2.52 g/cm3, a result that is not too useful considering the very restricted sample locality.

The resistivity log of the Lares Limestone indicates a relatively constant resistivity in excess of 80 ohms m2/m for most of the formation, indicating that its density may be relatively constant throughout. The density of the other middle Tertiary units is probably somewhat less than that of the Lares Limestone because of the somewhat greater amounts of dense limestone in the latter unit.

We discuss below the three major features on the Bouguer gravity map of Puerto Rico. Shurbet and Ewing (1956) and Mitchell (1957) also made general mention of these features and their causes.

1. The gravity field of Puerto Rico is characterized by a major gravity high along the eastern two-thirds of the island. This feature is best displayed in the central third of the island, where it trends approximately N75W. The high seems to correlate generally with the location and strike of the oldest rocks in this part of Puerto Rico and thus follows the crest of a broad antiform. The cause of this high is two-fold, mainly high-density rocks at shallow depths near the center of the island and secondarily, low-density rocks on the north and south sides of the island (see point 3, this discussion). The high-density rocks are probably, for the most part, not exposed and may be uplifted former oceanic or deep island-arc crust in the core of the antiform. Mitchell (1957) reached a

somewhat similar conclusion, ascribing the gravity high to an "underlying basement complex." The maximum gravity values at the crest of the high are about +175 mGal, which may be compared with average high values of about +135 mGal in the flatter gravity field of western Puerto Rico. Using an average density contrast of 0.25 g/cm3 between Cretaceous rocks and hypothesized former oceanic crust (presumed to be 2.95 g/cm3), the 40 mGal of relief implies about 4 km more of Cretaceous material in the western third of the island than at the crest of the antiform. The relatively lower and flatter gravity field in western Puerto Rico indicates that no major antiformal structure is present here and that a major tectonic boundary is probably located at the fault system striking N60W, across the island and following approximately the southwest side of the Utuado batholith.

The appearance of the central gravity high in the eastern third of the island is substantially distorted by the low gravity field of the San Lorenzo batholith (see point 2, this discussion) so that here the hypothetical "pre-batholith" form of the high is uncertain

The amplitude of the gravity high over Puerto Rico is influenced also by the isostatic effects of the thickened crust that lies beneath the island and that supports this topographic high relative to the oceanic water depths on either side. This thickened crust is lower in density than the mantle material that lies at shallower depths beneath the adjacent oceanic crust and therefore produces a gravity low over the island. Correcting for this low will increase the relative amplitude of the gravity high over the island and produce steeper gravity gradients on each flank.

2. The San Lorenzo batholith, in the southeast corner of the island, displays a subcircular gravity reentrant or valley on the flanks of the high discussed in point 1. This low has an amplitude of at least 15 mGal in the center of the batholith and at least 35 mGal at the shore. Batholiths customarily display gravity lows, in general being lower in density than the rocks they intrude. The +144-mGal contour approximately follows the west and north contacts of this quartz diorite pluton but does not contain the plutonic rocks in the extreme southwestern parts of the batholith. These southwestern-most plutonic rocks are thus interpreted to be either relatively thin or of somewhat higher density than the rocks in the main body of the pluton. The gravity low becomes even lower in the extreme eastern put of the batholith near the shore. Here the composition of the pluton changes from quartz diorite to a granodiorite that must be even lower in density. The gravity field falls still lower offshore to a single gravity station, the accuracy of which is unknown.

The northeast contact of the batholith is only weakly defined by a low-amplitude (5-mGal) gravity ridge extending along the country rocks just outside the pluton. The main gravity gradient leaves the north end of the pluton and extends northeast towards the east end of the island along the 140- and then, farther east, the 130-mGal contours. This pattern is interpreted to signify that the batholith extends east in the subsurface beneath country rocks and lies generally south of the 130-mGal contour where it crosses the east shoreline. These batholithic rocks probably connect in the subsurface to the southeast with those exposed on the Isla de Vieques.

3. Gravity lows on the north and south coasts of Puerto Rico are associated with a sequence of sedimentary rocks of Oligocene and younger age that form basins unconformably overlying older rocks. These layered rocks dip gently and thicken seaward, becoming even thicker offshore. The effect of these low-density masses upon the gravity map is to produce steep gravity gradients in the vicinity of the north and south coasts, the gradients sloping down to the north and south, respectively, out into offshore areas of low gravity. Local steepening of these gradients is interpreted to signify basin-margin faults, downdropped toward the basin; interpreted examples of such east-west-trending faults (see the Gravity Boundary Map of Puerto Rico) occur in the vicinity of San Juan and, on the south coast, along the basin margins east of Ponce for a distance of about 30 km. The south coast sedimentary basin becomes more shallow about 10 km offshore at Isla Caja de Muertos where gravity values rise slightly to 90 mGal and pre-Oligocene sedimentary rocks are exposed. Various earlier geophysical studies of this basin are described and reproduced in Griscom and Rambo (1970).