# Filtered Bouguer Gravity and Gravity Boundary Maps of Puerto Rico

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## INTRODUCTON

The filtered complete Bouguer gravity map of Puerto Rico is derived from the complete Bouguer gravity map by removing the long-wavelength components from the gridded gravity data by means of the computer program MFILT (unpublished program by Jeffery Phillips, U.S. Geological Survey). In this map we have preserved data displaying wavelengths less than 13 km; this particular wavelength was chosen because it is comparable to, or larger than, the width of major rock units such as the Utuado batholith. The map thus portrays well the gravity expression of the smaller geologic features of Puerto Rico.

Users of the filtered map should be aware that such a short wavelength will locally create ‘artifact’ anomalies adjacent to broad, steep gravity gradients. For example, the broad, steep gravity gradient east of San Juan on the Bouguer gravity anomaly map is displayed on the filtered gravity map as having a local residual gravity high and low on the south and north sides, respectively, of the gradient. The east half of the high and all of the low are probably not "real" and are merely artifacts of the filtering process. We believe that such features are relatively unimportant throughout most of the map area and are present mainly near certain gradients within the north and south coast sedimentary basins and in the vicinity of the San Lorenzo batholith, all three gravity features having been discussed separately on the Bouguer anomaly map. In any event, these three gravity features are relatively long in wavelength, so they are substantially removed, as intended, from the filtered map, in order to emphasize the smaller gravity features.

## INTERPRETATION

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; then the Paleocene and Eocene rocks; and lastly the

Cretaceous rocks, 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, granodiorites 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 (1964a) who also obtained an average density of 2.55 g/cm3 for samples of serpentinite taken every 3-5 m along a 305 rn core from a drill hole near Mayaguez. 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.

Because of the detail on the filtered gravity map and because of the small contour interval (1 mGal), the map reliability is locally highly dependent upon the number of gravity stations defining the contours. The user should keep in mind the local distribution of gravity stations when evaluating the map. In addition, local gravity features defined by only one gravity station should be viewed with doubt because of the possibility of error.

The filtered gravity map displays a variety of highs and lows, generally linear, and trending in various directions. These gravity features are caused by belts of rocks having higher or lower densities than the adjacent rocks. In order to locate the boundaries of these anomaly sources we used an automatic technique (Cordell and Grauch, 1985; Blakely and Simpson, 1986) that calculates the maximum horizontal gradient on the anomaly margins and plots a sinuous series of dots that represent the density boundaries. This method depends upon the theoretical observation that anomaly gradients tend to be steepest over the edges of gravity sources. The filtered gravity map represents a computer plot of these dots for the filtered gravity field of Puerto Rico. In areas where this program failed to identify boundaries along the margins of anomalies, we connected them along the steepest gradient by visual inspection of the filtered gravity map. In a few areas where gravity stations are locally absent or too sparse, the automatic program results may be disregarded, and instead a line is drawn following the inferred location of the anomaly gradient.

A series of 25 gravity anomalies are numbered on the gravity boundary map and are discussed below by number, and generally from east to west, though locally from north to south.

1. This discontinuous gravity low appears to be associated with Cretaceous plutonic rocks that are exposed near the lowest parts of the low. The plutonic rocks may be more continuous in the subsurface.

2. A gravity low having an amplitude of 2-3 mGal is associated with a Cretaceous or Tertiary pluton that appears to be located at or near the headwaters of streams containing gold placers.

3. A gravity high over country rocks on the east side of the San Lorenzo batholith appears to be associated with basalt and chert of El Rayo Formation and is better displayed on the Bouguer anomaly map. Contact metamorphism by the batholith may have locally increased the density of these rocks.

4. The main contact of the San Lorenzo batholith with country rock is displayed as a curvilinear gradient that surrounds the main gravity low caused by granodiorite and quartz diorite. The amplitude of this broad gravity low is, of course, substantially reduced by the wavelength filter, even though the marginal gradients are correspondingly emphasized. The various plutonic rocks on the south and southwest flanks of the batholith cause local gravity highs and are therefore higher in density, being probably somewhat more mafic.

Of considerable interest is the observation that the local gravity highs and lows within the San Lorenzo batholith correlate inversely with anomalies shown on the aeroradioactivity map (MacKallor, 1965). The lower density rocks are probably more nearly granodiorite in composition, whereas the higher density rocks are more likely closer in composition to diorite and quartz diorite. The density variations thus imply lesser amounts of hornblende and pyroxene in the granodiorite, whereas the aeroradioactivity data imply that larger amounts of potassic minerals (feldspar in particular) are present in the interpreted granodiorite as compared with the dioritic rocks. MacKallor (1965) stated that the southwestern put of the batholith is low in radioactivity, so he correctly predicted that more diorite and gabbro may be present here; again, higher gravity values are found in this area.

5. Where the San Lorenzo batholith intersects the southeast shoreline, there is a strong local gravity low over the granodiorite of the plutonic complex of Punta Guayanes (Kpsg), the rocks of this complex evidently being significantly lower in density than those of the main part of the batholith. This feature also correlates with an aeroradioactivity high (MacKallor, 1965), indicating a rock containing a larger percentage of potassic minerals.

6. A linear gravity low trends approximately N90E in the center of the island. The deepest part of the low lies at its east end over the Caguas pluton, a granodiorite. Other plutons crop out along the west half of the low but appear to be somewhat younger. Nevertheless, it seems that the best explanation for this feature is that it is caused by a pluton about 30 km long and 6 km wide and for the most part concealed below the surface.

7. This small gravity low is associated with an irregularly shaped Cretaceous or Tertiary pluton that is located in the area of the headwaters of the Rio Bayamon, a stream containing placer gold deposits.

8. This gravity low strikes northwest from an exposed graben containing lower Tertiary sedimentary rocks. Also associated with this low are Cretaceous or Tertiary plutonic rocks that appear more likely to be the primary source of the gravity low because they correspond better to the location and width of the low. Low 8 thus may connect with low 7 and have a similar source.

9. This gravity high strikes approximately N80W from exposed Cretaceous volcanic rocks out into the area covered by younger Tertiary sedimentary rocks of the north coast basin and is interpreted to indicate the general tectonic trends of the pre-middle Tertiary rocks. The crest of the anomaly correlates with outcrops of the Cerro Garde Lava, a

massive basalt unit, relatively high in density, that is interpreted to be the source of the anomaly.

10. Anomaly 10 is a gravity low striking N80W from the older rocks of the island out into the north coast sedimentary basin. The causes of the anomaly appear to be multiple: 10A is associated with Eocene sedimentary rocks; 10B is associated with a very narrow graben of Eocene sedimentary rocks and some associated Cretaceous or Tertiary plutonic rocks that are the probable source because the anomaly is at least 3km wide; 10C lies somewhat west of the main anomaly trend and is correlated with a major Cretaceous pluton, granodiorite of the Morovis stock.

11. Gravity high 11A trends approximately N90W and is located on the crest of a large Bouguer gravity high of Puerto Rico. Maximum gravity values occur over the Magueyes Formation (tuffaceous sandstone and basaltic flows) and the Perchas Formation (mostly submarine basaltic lavas). The adjacent circular gravity high, 11B, is associated with volcaniclastic rocks and is not explained, but is defined by only two gravity stations that should be remeasured in case of error. Comparison with the magnetic map indicates that the Perchas Formation produces the strongest magnetic anomalies in Puerto Rico, but that the area of anomaly 11B is not especially magnetic.

12. A linear gravity low strikes N80W and is predominantly associated with the area of the Cretaceous Pozas Formation (a subaerially deposited volcaniclastic rock unit containing local ash flow tuffs), the unit presumably having sufficient porosity to explain the low density. The northwest end of this low is associated with the lower Tertiary Yunes Formation, a vitric tuff containing volcanic sandstone and siltstone. The lower Tertiary rock units in general are lower in density than the Cretaceous layered rocks and are also associated with gravity lows in anomalies 8 and 10.

13. Linear gravity high 13A is associated with rock units that are composed predominantly of volcaniclastic rocks interbedded with some lava flows: the Tetuan Formation, the Manicaboa Formation, and the Vista Allegre Formation. A few kilometers to the east is the anomaly 13B, which may have a different source because it is associated with Torrecilla Breccia, a unit of volcanic breccia and interlayered lava flows.

14. A small local gravity low correlates with exposures of Malo Breccia, a mafic tuff containing interbedded breccia, flows, sandstone, and siltstone. Perhaps the tuft has considerable porosity that would explain the lower density.

15. A major gravity low is associated with the granodiorite and quartz diorite of the Utuado batholith. The low extends N65W into the area of the north coast sedimentary basin and indicates that the batholith extends for at least 15km unconformably beneath the middle Tertiary cover rocks.

16. A linear gravity high extends approximately N60W along the southwest margin of the Utuado batholith. The high is associated with volcanic breccias and flows of the Anon and Maricao Formations, the rocks near the batholith having been contact-metamorphosed to the hornblende-hornfels facies (Cox, 1985). A belt of gold-bearing porphyry-copper deposits follows this feature (metallic mineral deposits). The deposits display characteristic magnetic highs that may be associated with more local magnetic lows due to alteration.

17. Anomaly 17 is a low associated with a belt of volcanic breccia interbedded with flows and volcaniclastic rocks. The rock units include the Anon Formation and the interbedded Lago Garzas and Anon Formations. Although these rocks are described as similar to the rocks producing the adjacent gravity high (16), there must be some major differences to account for the lower density; lack of contact metamorphism is probably not a sufficient explanation. This gravity low trends diagonally across southwestern Puerto Rico and appears to be associated with the major fault system or suture that separates the two major gravity and tectonic domains of Puerto Rico, as described on the complete Bouguer gravity anomaly map. The gravity low branches at its northwest end and the west branch is associated with the middle Eocene Rio Culebrina Formation, which is composed of mudstone, breccia, and volcanic sandstone. A belt of mineral occurrences and deposits correlates with this major gravity boundary.

The northwest ends of anomalies 15, 16, and 17 plus two flanking gravity highs (unnumbered) all appear to be terminated by a linear boundary striking about N80E. Inspection suggests that this line may be extended until it intersects the north shoreline at about long 65$^{o}$37' W. This boundary appears to form the northwest limit for the N60$^{o}$-65$^{o}$ W grain of the central Puerto Rico gravity field and would appear to be the gravity signature of a major fault predating the middle Tertiary cover rocks and is possibly late Eocene in age. This boundary is also apparent in the magnetic data.

18. A pronounced gravity high having unknown source rocks concealed below the middle Tertiary north coast sedimentary basin has an equidimensional shape and strongly magnetic signature. The cause of the anomaly is interpreted to be a mafic pluton because of the shape, but mafic volcanic rocks are also a possibility.

19. An arcuate gravity high is associated with an area of Cretaceous pillow basalt flows and volcanic breccia of the Conception Formation and with a large area of the Lago Garzas Formation composed mainly of volcanic breccia and lava flows. The Lago Garzas is an unusual example of a Cretaceous or Tertiary unit seeming to produce a gravity high whereas generally the rocks of this age produce lows. Perhaps this unit includes an unusually high percentage of flows; or much of it is underlain at shallow depth by Concepcion Formation.

The western part of the north boundary of this gravity high has an unusual northeast strike that is not easily explained because the geologic map indicates the north contact to be a fault striking approximately N85W beneath the alluvial cover in this area. Perhaps the alluvium is thick enough near the shore to explain some of the local minimum (-5mGal) west of this boundary.

20. An irregular gravity low strikes southeast from Mayaguez across the southwest corner of the island. The low is mainly associated with serpentinite but is also associated in part with large areas of two-pyroxene olivine basalt distributed irregularly along the northeast sides of the serpentinite body. Because intrusive basalt has a high density, it is suprising to find the basalt in a gravity low. We interpret that the basalt must be thin, in general less than 0.5 km thick, and also underlain by more of the low-density serpentinite that causes the gravity low. The serpentinite is interpreted to be generally antiformal in shape with outward-dipping contacts, the north contact dipping far less steeply than the south contact.

21. This linear gravity low is also associated with serpentinite and appears to

connect at its east end with gravity feature 20, also caused by serpentinite. The two detailed gravity profiles (closely spaced stations) that cross feature 21 indicate that the source has an antiformal shape with the north flank dipping less steeply than the south flank. A computed model cross section along the westernmost gravity profile (Bromery and Griscom, 1964a, fig. 3) uses a density contrast of 0.15 g/cm3 and shows the serpentinite extending to depths of at least 2.8 km, the south contact dipping about $70^{o}$ S. and the north contact dipping about $50^{o}$N.

22. A gravity low, trending generally east-west, follows a valley floored by alluvial fill and lower Tertiary sedimentary rocks. The source of the gravity low continues east beneath the Tertiary sedimentary rocks of the south coast sedimentary basin. On the basis of the abrupt change in gravity level, the south side of the valley appears to be a fault whereas the north side may merely be the feather edge of the sedimentary deposits.

23. Two local gravity highs are connected by an east-west-trending gravity ridge having a somewhat lower amplitude. The highs are underlain by massive outcrops of high-density amphibolite, which may also underlie the connecting gravity ridge in the subsurface.

24. A linear gravity high is located on the north flank of the south coast sedimentary basin. In two places where closely spaced gravity stations are available this high is associated with Cretaceous volcaniclastic rocks south of a belt of lower density lower Tertiary rocks. The south side of this high is a fault, down to the south, marking the border of the south coast sedimentary basin.

25. A gravity high west of anomaly 24 appears to be associated with Cretaceous or Tertiary diorite intrusions.

26. Anomaly 26 is a gravity high bounded on both sides by east-striking faults that appear to define a horst in the south coast Tertiary sedimentary basin.