

**ANOMALOUS CRUST IN THE EASTERN VENEZUELA BASIN AND THE
BOUGUER GRAVITY ANOMALY FIELD OF NORTHERN VENEZUELA
AND THE CARIBBEAN BORDERLAND**

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ABSTRACT

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A new Bouguer gravity anomaly map is presented for the southern Caribbean borderland and northern South America. Major features are: the Lake Maracaibo-Venezuela Andes minimum (-160 mgal); gravity maxima in the Venezuelan offshore area and on the Netherland Antilles; a steep gradient (-4.7 mgal/km) south across the Western Caribbean Mountains; the termination on Margarita ultra-mafic rocks of the minimum trend of the Lesser Antilles; and the broad gravity minimum (-200 mgal) to the east and anomalous maxima (+10 mgal) to the west associated with the Eastern Venezuela Basin.

Gravity models have been calculated for two sections over this basin. The broad gravity minimum in the east can be explained by up to 15 km of sediment and crustal downwarping to a depth of 47 km. The maxima suggest an anomalous crust, possibly caused by a higher-density basement, a crustal upwarp, or both.

The trend of the gravity maxima parallels those of the Eastern Venezuela Basin minimum and the Antillean trends as they enter Venezuela. In addition they are parallel to the ENE structural trends of the Precambrian south of the Orinoco River. Thus, the anomalous sub-sediment rocks could be related to Mesozoic tectonics, or Precambrian basement features.

INTRODUCTION

THE BOUGUER GRAVITY ANOMALY MAP

The southern Caribbean and northern South American area (lat. 8-12.5° N, long. 60-73°w) has been of interest over many years for reasons of the region's economic importance, the presence of a variety of tectonic styles, and the struggle to fit the tectonics into a scheme germane to plate tectonic evolution of the region. The gravity field of the area is of interest in itself, since it can place limits on tectonic and structural interpretations. The purpose of this paper is to present the new gravity map (Fig. 1), to discuss the major anomalies, and to focus on some anomalous features and problems in the Eastern Venezuela Basin.

The new map (Fig. 1) is a compilation of work from many sources, published (with citation) and unpublished (acknowledged by source). The map at a scale of 1:1,000,000 with a generalized geologic map overprint but without comment has been released (BONINI ET AL., 1977a).

Sources of onshore data: Princeton University; Ministerio de Energia y Minas; Cartografia Nacional de Venezuela; FOLLINSBEE, 1972 (from oil company data); HOSPERS & VAN WIJNEN, 1959; BONINI ET AL., 1977b; CASE & MACDONALD, 1973; RODRIGUEZ & GRATEROL, 1975.

Sources of offshore data: J. Matthews, U. S. Naval Oceanographic Office; G. Westbrook, Durham University; PETER, 1972; U.S. GEOL. SURVEY, 1972; SILVER ET AL., 1975; Corporacion Venezolana del Petróleo.

Sources of offshore-island data: Princeton University, Ministerio de Energia y Minas and Cartografia Nacional de

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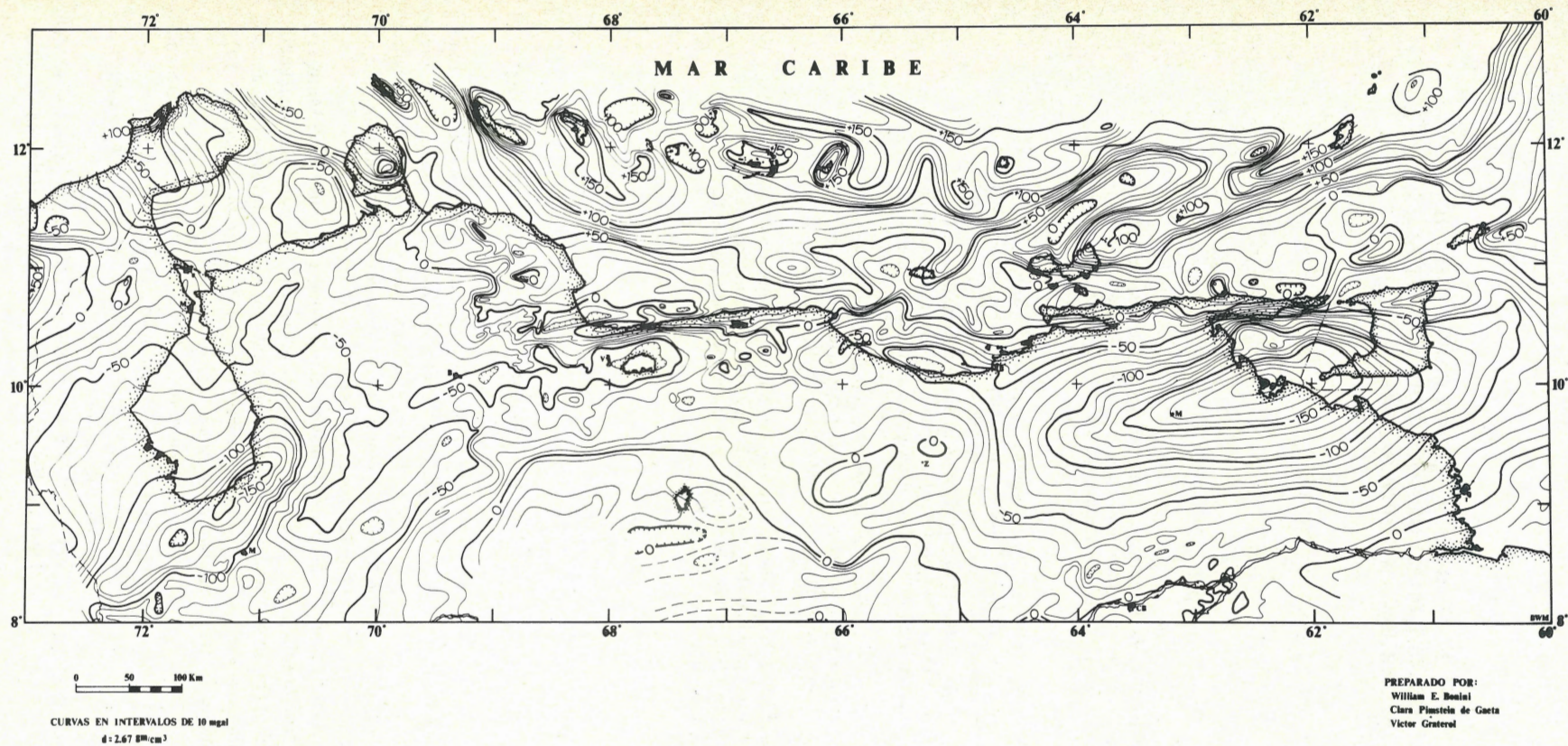


Fig. 1
Bouguer gravity anomaly map of northern Venezuela and Caribbean borderland (after Bonini et al., 1977a). A density of 2.67 g/cm³ has been used in the mass correction for land stations and also to reduce sea station free air anomalies to water-corrected Bouguer anomalies.

Venezuela for Los Monjes, Islas de Aves, Los Roques, Orchila, Blanquilla, Margarita, Tortuga, Coche and Cubagua; Netherlands Antilles, LAGAAY 1959.

The project began in 1971 as a cooperative programme between the Dirección de Geología, Ministerio de Energía y Minas and Princeton University. Its goal was to compile existing data and to make new observations to fill in areas of little or poor coverage. The map includes many new data and can be used to update a portion of the Caribbean gravity map of BOWIN (1976).

MAIN FEATURES OF THE GRAVITY FIELD

The main features of the gravity field of the southern Caribbean borderland and northern Venezuela have been pointed out by many workers in the area, particularly those referenced in this paper. The new map permits refinement of some previous observations and new ones to be made.

Bouguer anomalies (Fig. 1) of most general interest are:

- (1) The southeast Lake Maracaibo – northwest Andes minimum (as low as -160 mgal). This is related to low density basin sediments and most probably overthrusting of the Andean rocks onto these sediments, possibly as much as 20 km.
- (2) The maxima associated with the offshore islands (including that on Paraguana as well). The orientation of individual island-and-platform maxima changes from northwest for the Netherlands Antilles, to west for Los Roques, to northeast for Orchila and Margarita. Most islands are separated by minima suggesting that many may be fault-bounded with sedimentary basins between basement (island) blocks. Islas de Aves, east of Bonaire, is the exception. The eastern portion (Aves de Bartovento) is a minimum.
- (3) The steep gradients across the Venezuelan Cordillera de la Costa. The -4.7 mgal/km gradient from the Venezuelan coast south over the Cordillera ends in a minimum (-60 mgal) centered near Lago de Valencia. This suggests the presence of a deep density discontinuity, perhaps a near-vertical crust-mantle fault with a displacement of about 12 km, or low-density sediments underlying the metamorphic rocks of the Western Caribbean Mountains (BONINI ET AL., 1977b).
- (4) The Lesser Antillean maximum trend ($+150$ milligal). This trend passes through Grenada and terminates on Margarita, where ultra-mafic rocks are exposed. The gravity minimum trend (-10 mgal) to the north, which parallels the maximum trend, is an extension of the Grenada Trough.
- (5) The Eastern Venezuela Basin minimum and maxima. BOWIN (1976) has pointed out that the minimum may be the most negative free air anomaly on land at sea level. Similarly, it is probably the most negative Bouguer anomaly on land at sea level as well.

THE EASTERN VENEZUELAN BASIN

The basin contains a major Tertiary oil province and extends from south of the Western Caribbean Mountains at about Long. 68° W for over 700 km eastward into the Atlantic Ocean east of Long. 61° W. It is about 200 km in a north-south direction. Wells have rarely been drilled over 4 km in depth, and deeper wells drilled bottom in Tertiary sediments. Coverage is incomplete, but estimates from isopach and structural contour maps (YOUNG ET AL., 1956) and sections (PIERSON, 1965) suggest that a considerable thickness of Tertiary sediments exists. It is possible that it may be 8 km to the base of the Miocene and possibly 13 km to the base of the Cretaceous (basement?) north of Maturín (M on Fig. 1, see Fig. 2). North of Zaraza (Z on Fig. 1, see Fig. 3) it may be as much as 3 km to the base of the Miocene, 6 km to the base of the Oligocene (one well is 1 km into the Oligocene) and possibly 9 km to the basement.

Gravity models

Two sections have been made and gravity models calculated. The Maturin section (Fig. 2) is oriented $N 12^{\circ} W$ and is constructed from the Orinoco River through Maturín (M) and Isla La Sola, and to the Grenada Trough extension. The north-south Zaraza section to the west (Fig. 3) is drawn from the Orinoco River through Zaraza and Isla La Tortuga.

The procedure in constructing these gravity models has been to calculate the effect of the sedimentary section (i.e. to strip the sediments) and to fit the remaining gravity anomaly with a two layered crust.

Density and crustal thickness considerations

Density-depth relationships for some Tertiary Venezuelan rocks are known from DALMUS (1958), and others are estimated from age and sediment-type curves from WOOLLARD (1962). In general densities of 2.60 g/cm³ or greater are predicted from these curves for depths in excess of 2.5 to 3.0 km. Density values used in the models are shown on Figs. 2 and 3.

The average density for metamorphic rocks of the Western Caribbean Mountains (92 samples) is 2.705 g/cm³ (BONINI ET AL., 1977b). Thus, 2.70 g/cm³ has been assumed for the basement and upper crust, whereas 2.95 g/cm³ has been assumed for the lower crust and 3.10 g/cm³ for the mantle. Little is known directly of the crustal velocity structure of northern Venezuela, but densities assumed are in the lower range as suggested by velocity-density curves of WOOLLARD (1962). If greater densities had been used (e.g. 3.30 g/cm³ for the mantle) the crust-mantle depths calculated would be less. In each section it has been assumed that there is a uniform 32 km crust at the Orinoco River where the Bouguer anomaly equals zero, with a 15 km upper crust and 17 km lower crust. Deep seismic data is lacking offshore also, but shallower refraction information (OFFICER ET AL., 1959) was used to control the model

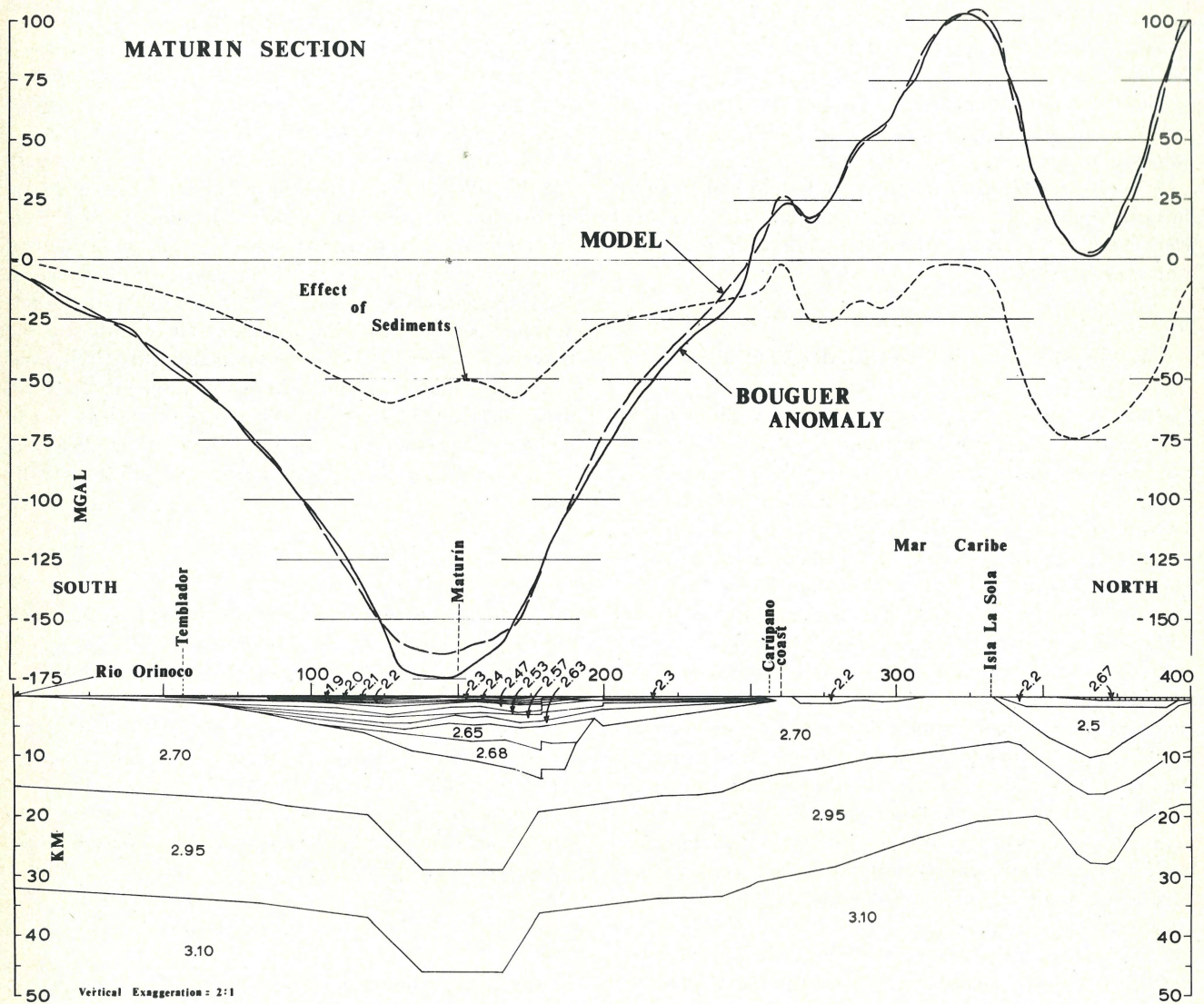


Fig. 2

Section through Maturin (M on Fig. 1) on a bearing of $N 12^{\circ} W$ from the Orinoco River to the Grenada Trough. Densities are in grams per cubic centimetre. The 2.67 g/cm^3 layer in the Grenada Trough is the water-layer correction used in the Bouguer reduction. In the model the $2.95\text{--}3.10 \text{ g/cm}^3$ interface is the Mohorovičić discontinuity. The 'effect of sediments' plot is the contribution of those layers with densities of 2.68 g/cm^3 and less.

near Isla La Tortuga.

DISCUSSION OF EASTERN VENEZUELA BASIN RESULTS

Maturin section

Up to 15 km of sediment has been postulated for this portion of the Eastern Venezuela Basin (Fig. 2), with up to 10 km of

post-Cretaceous sediment. The gravity minimum can be explained by the sediments (55 mgal) and a depression of the upper and lower crust into the mantle, with the Mohorovičić discontinuity as deep as 47 km.

North of Isla La Sola in the extension of the Grenada Trough, crustal thickening, a substantial thickness of sediment, or both are needed to explain the minimum. Access to deep-seismic reflection and refraction data will be needed to refine the marine portion of the model. However, crustal thinning north of the coast appears to be a requirement.

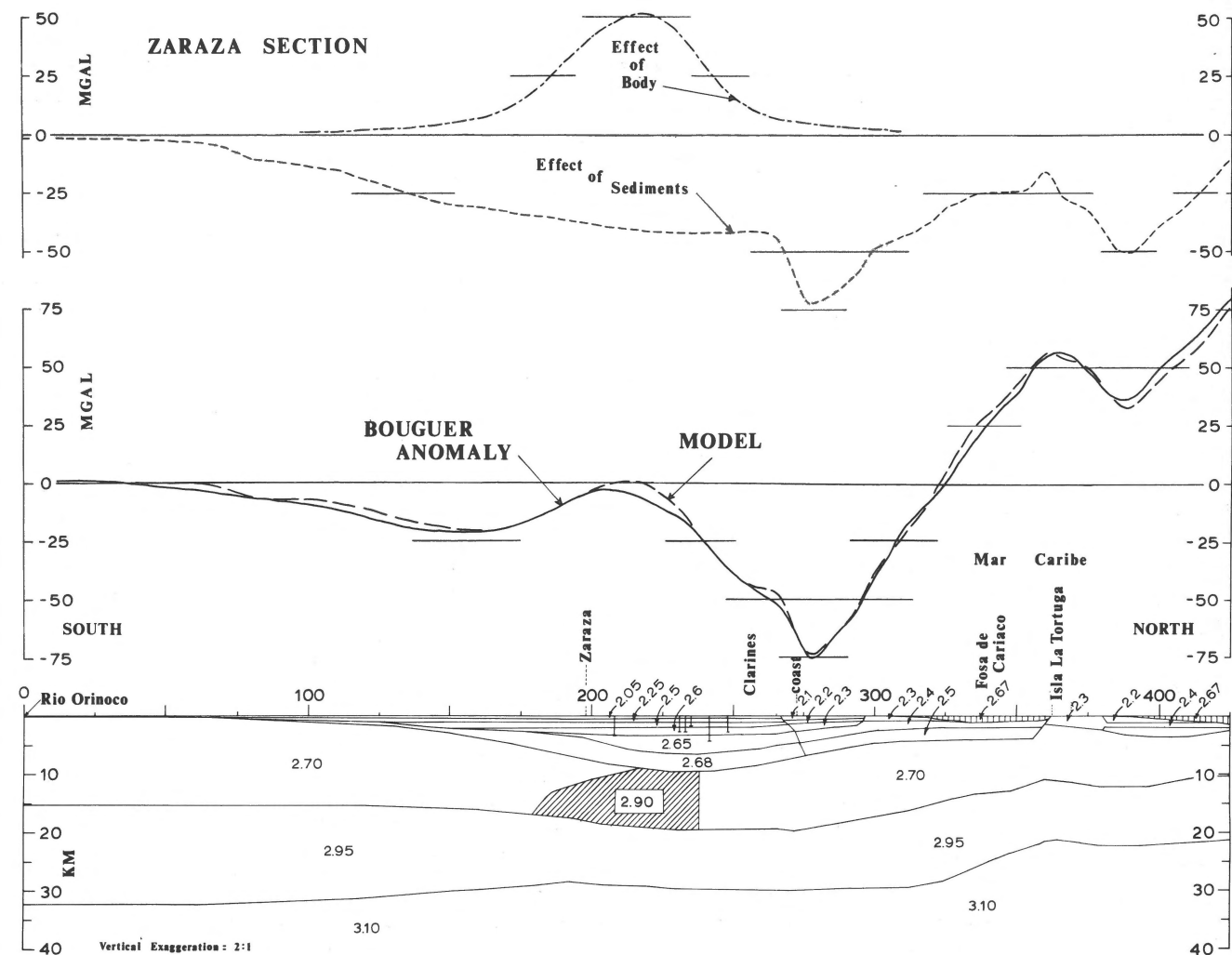


Fig. 3

Section through Zaraza (Z on Fig. 1) on a north bearing from the Orinoco River to north of Isla Tortuga. Densities are in grams per cubic centimetre. The 2.67 g/cm^3 layer with vertical hatching is the water-layer correction used in the Bouguer reduction. The 'effect of sediments' plot is the contribution of those layers with densities 2.68 g/cm^3 and less. The 2.90 g/cm^3 slant-hatched body is one possibility to explain the gravity high north of Zaraza, and the gravity effect of this body is plotted.

Zaraza section

About 8 km of sediments of post-Cretaceous age are postulated to exist in the western portion of the Eastern Venezuela Basin. Inasmuch as part of this area already shows a Bouguer anomaly maximum, the correction (or stripping) of the sediments leaves a 50 mgal high residual. This large residual can be explained by thinning the crust considerably and/or by increasing the density of the upper crust to that of the lower crust. This suggests a crust-mantle upwarp or extensive bodies of basic rock either intruded, or infolded, into the upper crust.

A simplified higher-density body is shown and cross-hatched

on Fig. 3. Whatever the explanation, it is a most anomalous feature of the gravity field and suggests that anomalous crust is present in that area.

North of the coast the Cariaco Trough has little or no gravity expression, but Isla La Tortuga shows a minor high and a thinned crust is predicted north of that island.

Of special note is that just north of the coast and Clarines (Figs. 1 and 3) there is a minimum closure with steepened gradients. This suggests a low-density source, probably a considerable thickness of lower density sediment in the basin beneath the shelf between the coast and the Cariaco Trough.

CONCLUSIONS

Major gravity anomaly features have been further defined as shown on the new gravity anomaly map of the southern Caribbean borderland and northern South America. The major features dealt with in detail relate to the Eastern Venezuela Basin.

Postulated structural contours on basement in the Eastern Venezuela Basin show sediment thicknesses of up to 15 km. By stripping these sediments (correcting for the negative effect of the sediments) a large negative gravity residual remains in the eastern portion (Maturín), whereas a large positive gravity residual remains in the western portion (Zaraza). The Maturín negative can be explained by crustal downwarping to depths of 47 km, whereas the Zaraza positive appears to be anomalous and requires a higher density basement, or crustal upwarp. Although the source of the high anomalies is unknown, it can be noted that the ENE trend of the Zaraza gravity maxima is parallel to that of the Eastern Venezuela Basin minimum and the Antillean trends as they enter Venezuela. In addition they are parallel to the ENE structural trends of the Precambrian south of the Orinoco River. Thus, the sub-sediment rocks in this area may be related to Mesozoic tectonics, or may be Precambrian basement.

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