I N T E G R A T E D G E O P H Y S I C S C O R P O R A T I O N

FOOTNOTES
ON INTERPRETATION

IGC FOOTNOTE SERIES MARCH 2002

Regional Gravity Interpretation: Western Gulf of Mexico

Finding Basins With Regional Gravity Data

This Western Gulf of Mexico example compares free-air, Bouguer, and isostatic residual maps---all developed from the same basic data---with published regional geology of the Texas-Louisiana offshore. Only one map, the isostatic residual, readily shows the location and relative depth of offshore basins-those criteria which are important for regional play assessment.

Introduction

Regional gravity maps are often used to interpret regional trends and structures of the subsurface geology. To someone not reasonably familiar with gravity data, it may seem immaterial whether such maps represent free-air, Bouguer, or isostatic residual gravity data. In any offshore area, each data type has important advantages and disadvantages in terms of cost, convenience, and suitability. But in the final analysis, the most important consideration should be use of the gravity data which provide the soundest geologic interpretation.

Why Not Free-air Gravity?

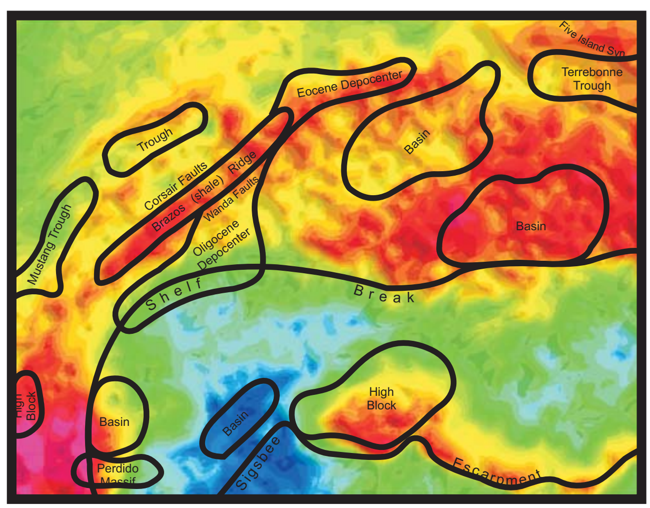
Free-air gravity, especially covering marine areas, has been preferred for years by the academic community. Why? Perhaps because it can be considered relatively "pure" data, untainted by the interpretation factors required to correct for bathymetry and /or crustal geometry. More recently, with the advent of low-cost satellite-derived free-air gravity data, the use of such data for hydrocarbon exploration purposes has been heavily promoted by commercial interests. Is this a viable shortcut to meaningful interpretation?

Satellite-derived free-air data has several important **advantages** as a database: 1) it is readily available at very modest cost, and 2) it covers virtually all marine areas with a reasonably dense and consistent regional grid. The economics can seem compelling.

Its inherent **disadvantages** include: 1) low quality data along coastlines and at high latitudes, and 2) relatively poor resolution of low amplitude (<5 mGal) and/or short wavelength anomalies (<20 km). Unfortunately, the coastal areas and smaller gravity anomalies are most often those of keen exploration interest. Some improvement in resolution through added-cost processing has been claimed but not yet widely accepted.

The "purity" of free-air data may also be its greatest weakness from an interpretation standpoint. For example, in a typical marine area there are three primary sources of gravity anomalies: density contrasts and structure at 1) the water/sediment interface, 2) within the subsurface sediments and crust, and 3) the crust/mantle interface. Therefore, unless both the water/sediment (bathymetry) and crust/mantle (Moho) surfaces are relatively smooth, at least one of them will produce large gravity anomalies which will effectively mask or distort the subsurface anomalies of exploration interest.

The sea bottom of the Western Gulf of Mexico deepens southward and can be divided into shelf, slope, and abyssal segments separated by the Shelf Break (shelf/slope gradient) and the Sigsbee Escarpment (slope/abyssal gradient). The Moho surface plunges north and northwest from beneath the Sigsbee Abyssal Plain in the central Gulf of Mexico, then beneath the shelf area, and finally below the North American craton onshore. Both the bathymetry and crustal geometry produce large-amplitude regional anomalies that overprint the free-air gravity. Local anomalies which could otherwise be used to qualitatively interpret location and relative depth of sediment basins are thereby distorted and masked. **A simplistic qualitative interpretation, interpreting high-amplitude gravity maxima as major subsurface highs and high-amplitude minima as deep basins, fares badly here.**



Satellite-derived Free-air Gravity

Note that based on anomaly amplitudes, the deepest basins appear to lie immediately east of the Perdido Massif, whereas both the truly deeper Terrebonne and Mustang troughs and the Eocene and Oligocene depocenters appear to be relatively shallow. By convention, the large maximum curving from the southwest to the east would be interpreted as a major subsurface high trend. But in reality the anomaly is an effect of the shallower water depth on the shelf. The gravity signatures of two large subbasins southwest of Terrebonne Trough are very subtle at best, masked by regional anomalies due to both bathymetry and Moho.

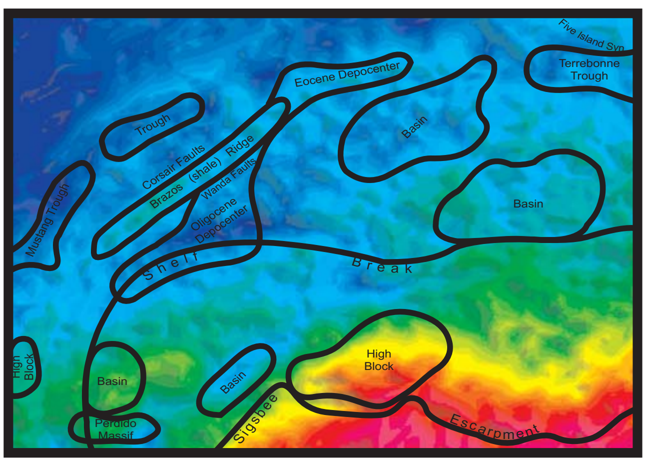
Conversely, the subsurface highs just north of the Sigsbee Escarpment show up expectedly as gravity maxima, as does the dense shale Brazos Ridge.

The difficulty in getting a consistent qualitative interpretation of the Western Gulf geology based on unconstrained free-air gravity is evident.

Why Not Bouguer Gravity?

A Bouguer gravity map is considered the industry standard for both onshore and offshore areas. Offshore, the Bouguer correction, together with 3D terrain corrections, can effectively remove gravity anomalies due to sea bottom topography. This essentially resolves one major problem with free-air data. It may be argued that a poor bathymetric database or a poor choice of density for the Bouguer reduction will introduce errors. Granted, this could be a valid concern for prospect-size interpretation, but for regional studies any such error is small relative to the bathymetry-related anomalies in free-air data.

Bouguer maps of marine areas were once necessarily restricted to areas where bathymetry could be collected concurrently with shipborne gravity or where navigation charts could provide relatively detailed water depth data. The advent of worldwide digital bathymetry databases such as ETOPO5 or ETOPO30 now make it feasible to calculate Bouguer and terrain corrections to satellite-derived free-air gravity. The resulting Bouguer map has removed bathymetry-sourced anomalies, but not Moho-sourced anomalies.

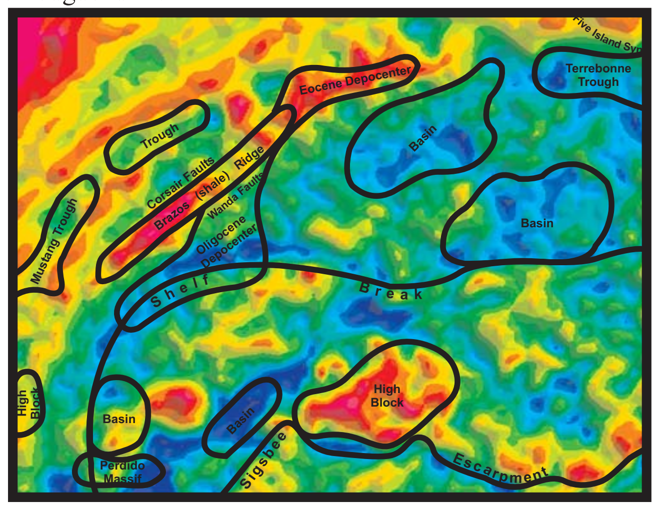


Terrain-corrected Bouguer Gravity

Bouguer and terrain corrections to the Western Gulf free-air gravity result in a map with a very strong maximum area to seaward (south) of the Sigsbee Escarpment and a strong minimum area to the north and west, on the shelf. **The remaining Moho effect has masked or distorted the anomalies of geologic interest, making a simplistic, qualitative gravity interpretation difficult if not improbable. Anomalies with a typical basin-type signature are hidden in the regional gradient.**

IGC's Isostatic Residual Gravity

An isostatic correction continues the process of removing as many of the known effects as possible from the gravity field. Calculation of an isostatic residual involves additional assumptions, among which are the choice of crust/mantle density contrast and of compensation depth. Tests have shown that the process is sufficiently robust to allow variations in those assumptions without greatly changing the final regional interpretation. IGC uses an Airy-Heiskannen model to make isostatic corrections to the Bouguer data.



IGC Isostatic Residual Gravity

Even a casual inspection of the Western Gulf of Mexico isostatic residual map reveals that it offers the best definition of known basins and structural highs. The Terrebonne Trough, the two subbasins immediately to its southwest, and the Oligocene Depocenter are all large-amplitude minima that could be convincingly identified as major deeps in any qualitative interpretation. Other residual anomalies suggest the presence of at least two more unmarked basins. Subsurface high blocks immediately north of the Sigsbee Escarpment are gravity maxima, as expected.

Yet even after application of Bouguer and isostatic corrections, the Eocene Depocenter and the basin north of Perdido Massif remain as gravity maxima. This paradox suggests the presence of anomalous local geology, such as high-density basin fill or high-density basement blocks.

References

Green, C.M. and Fairhead, J.D., 1998. Satellite-derived gravity: where we are and what's next. The Leading Edge, vol. 17, no. 1.

Simpson, R.W. et al., 1985. A new isostatic residual gravity map of the conterminus United States. Abstract, SEG 55th Ann. Mtg.

Yale, M.M. et al, 1998. What are the limitations of satellite altimetry? The leading Edge, vol. 17, no. 1

INTEGRATED GEOPHYSICS CORPORATION
Tel: 713/680-9996 Fax: 713/682-6928
Email; info@igcworld.com Web; http://www.igcworld.com

EDITORIAL STAFF: Mike Alexander