Sediment thickness, basement structure and tectonics from inversion and modeling over northeastern South America.

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Summary

This paper presents the techniques and results of a depth to basement inversion and modeling effort over the Guyana, Suriname, and French Guiana area of northeastern South America. A new development in the application of spectral inversion of both gravity and magnetic data has allowed us to extend the inversion over the entire study. Integrating the results of the spectral inversions with Euler deconvolution and 2-D modeling results in an accurate and informative description of the tectonics and structure of the area. Results show that significant packages of sediments of exploration interest have been deposited over most of the offshore area. This indicates that the USGS (2000) estimate of over fifteen BBOE for the area is highly possible.

Introduction

The Guyana Basin extends from eastern Venezuela south to the Demerara Plateau. This area has been largely under explored for a variety of reasons. A few significant papers have been published on the area including Torres, et al. (2003), Workman (2004), Gouyet, et al. (2004), and the USGS (2000) assessment. These papers have emphasized the prospectivity of the area, but have not addressed in any detail the complex tectonic processes that formed the geological structures of the entire area shown in Figure 1. We have begun an analysis of the results of these processes using a variety of data and depth to basement analyses. An example of the data used, which illustrates the complexity of the structure and tectonics of the area is shown in Figure 1. The southeastern onshore area is poorly represented by the EGM96 gravity model which has a 55 kilometer, half wavelength resolution.

We also used magnetic data from the South America Magnetic Mapping Project (SAMMP, Fairhead et al., 1997) which were merged with a Repsol marine survey, a Staatsoilie near shore airborne survey, and other ship-track data offshore. The well and the older seismic data is through Staatsoilie. The recent survey by Repsol provided new seismic data off the northwester part of the Demerara Rise. A seismic line from Watts and Peirce (2004) was also very useful.

We have used the gravity, magnetic, seismic, well and geological data to constrain the possible tectonic scenarios. A primary first step is the integration of this wide variety of data into a GIS environment. The next is the development of a description of the basement structure using geophysical techniques, which is consistent with all of the data. The basement structure then allows us to assess the applicability of various plate reconstructs of the area which are largely unconstrained due to the subduction of much of the geological evidence. The final step is re-integration and interpretation of all data, including proprietary data and interpretations, to give the best geological and tectonic construction for the area.

As part of the determination of the basement structure, some new techniques have been developed and applied. These include the use of a Tau-P approach to spectral inversion of gravity and magnetic data, and the integration of spectral, Euler deconvolution, and modeling techniques to produce a better constrained result. Some of this is presented in the following description.

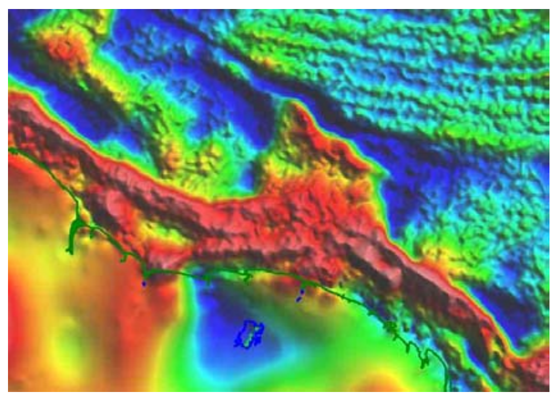

Figure 1: Shows free air gravity over the study area. The Demerara Plateau is readily evident in the center with the Guyana Basin to the northwest. Satellite data are merged with a Repsol marine survey and other ship-track data offshore, and EGM96 and SAGP (South America Gravity Project, Fairhead et al., 1997) data onshore.

Theory and Method

The spectral method for magnetic and gravity data inversion has been described by several authors. A description of part of the method used here was given by Odegard, et al. (2004). This method has been extended using a variation of the Tau-P method to make the process semi-automatic. The Tau-P method has been described and used by several authors (c.f. Estill and Odegard, 1979).

The process of mapping the depth to basement, as shown in Figure 2, involves calculating the average radial power spectrum over a rectangular window on a magnetic or gravity grid. We have found that a 40x40 kilometer window is useful for basement depths encountered in hydrocarbon exploration. Smaller windows can be used for surveys with better and higher resolution data. After the average radial power spectrum is calculated, it is displayed in a semi-log figure of amplitude versus spatial wave number. A straight line is then fit to the power spectrum, usually in the higher amplitude, lower wave number area of the figure. For gravity and magnetic data the negative of slope of this line is equal to twice the depth to the center of mass of the bodies producing the gravity or magnetic field.

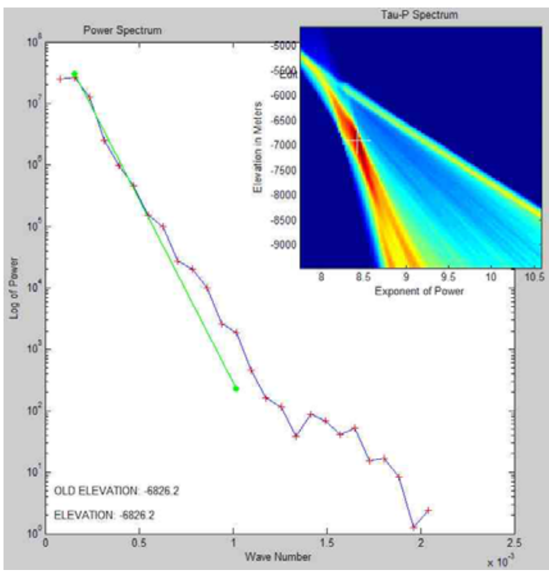

Figure 2: Displays the power spectrum from a 40 by 40 kilometer window of gravity over the Demerara Plateau. The image in the upper right corner is the Tau (exponent of power) versus P (depth) specturm of the power spectrum.

Because the process of fitting a line to data is similar to the Tau-P method for seismic data a similar process can be used. For each frequency point of the calculated spectrum a seismic type trace is constructed as a delta function of the exponent of the power. This delta function is then convolved with a cosine wavelet to simulate error in that value of the spectrurn. A Tau-P spectrum, with amplitude that is the semblance of the linear fit, is calculated over a window of Tau's and P's. The maximum of the semblance is taken as the best fit of a line to the original spectrum. This pick is shown as a "+" in the Tau-P spectrum window in Figure 2. The semblance can be weighted to emphasize shallow or deep solutions. Finally automatic depth picks are hand edited to correct erroneous solutions.

Using grid based Euler techniques such as those published by Mushayandebvu, et al. (2004), Williams, et al. (2003) or Nabighian and Hansen (2001) a variety of solutions can be found for depths to magnetic basement and to density variations. The density variations can be related to high density basement or to other features.

Using the spectral solutions as a constraint, Euler solutions can be selected which best fit the expected depth to basement. Since the spectral solutions can also be in error, an iterative technique is used which starts with the spectral solutions having the largest weighting, and ends with the Euler solutions having the largest. The results will be similar to those shown in Figure 3.

In addition to the potential fields data, seismic and well data are also used to constrain the initial inversion. Finally 2-D modeling over seismic lines and wells is used to further constrain the results.

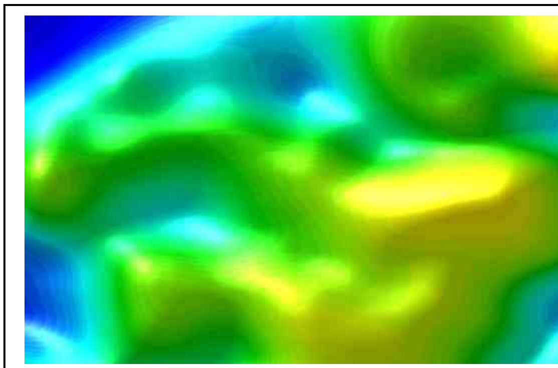

Figure 3: Depth to basement structure over the northern part of the Demerara Plateau derived using gravity data.

Conclusions

We have used gravity, magnetic, seismic and well data to determine a depth to basement structure over northeastern South America. This structure has allowed us to constrain the early tectonic development of this relatively unknown area. Results show that a significant amount of sediment has been deposited over the Guyana basin including the Demerara Plateau. In particular, the Orinoco Trough or Trench, which was formed during the rifting of the Greater Antilles/Bahamas away from South America and Africa, shows a significant thickness of sediments. The hydrocarbon potential of these sediments and this area is currently under assessment.

References

EGM96:
http://earth-info.nima.mil/GandG/wgsegm/egm96.html.

Estill, R. and M.E. Odegard (1979) Structure of the Hawaiian ridge determined using Tau inversion, Geophys. Res. Lett., v. 6, n. 2, pp. 69-72.

Fairhead J.D., J.D. Misener, C.M. Green, G. Bainbridge and S.W. Reford, 1997, Large Scale Compilation of Magnetic, Gravity, Radiometric and Electromagnetic data; The new exploration strategy for the 90's; Proceedings of Exploration 97; Fourth Decennial International Conference on Mineral Exploration edited by A G Gubins, p. 805-816.

Gouyet, S., P. Unternehr, and A. Mascle, 1994. The French Guyana margin and the Demerara Plateau: geologic history and petroleum plays. In Mascle, A. (Ed.), Hydrocarbon and Petroleum Geology of France. Spec. Publ.—Eur. Assoc. Pet. Geosci., 4:411–422.

Mushayandebvu, M.F., V. Lesur, A.B. Reid, and J.D. Fairhead, 2004, Grid Euler deconvolution with constraints for 2D structures Geophysics, Volume 69, Issue 2, pp. 489-496.

Nabighian, M. N. and R.O. Hansen, 2001, Unification of Euler and Werner deconvolution in three dimensions via the generalized Hilbert transform
Geophysics, Volume 66, Issue 6, pp. 1805-1810.

Odegard, M.E., W.R. Weber, D. Dragoi-Stavar, and W.G. Dickson, 2004, Depth to basement using spectral inversion of magnetic and gravity data: Application to Northwest Africa and Brazil

Torres, M.A., D. Ramos, and R.E. Giraudo, 2003, Geological Significance, Play Concepts and Hydrocarbon Potential of the Berbice Mega Incised Valley, Offshore Guyana, Guyana Suriname Basin, AAPG Bulletin, Vol. 87, No.13. (Supplement) AAPG International Conference Barcelona.

USGS WPA, 2000, World Petroleum Assessment 2000 – description and results; U.S. Geological Survey Digital Data Series - DDS-60,
http://energy.cr.usgs.gov/WEcont/regions/reg6/R6.pdf

Watts, A.B. and C. Peirce, 2004, Cruise report, RRS Discovery D275, Amazon Cone seismic experiment, ACE, IRIS Data Management System, Seattle.

Williams, S.E., J.D. Fairhead, J.D., and G. Flanagan, 2003, Grid-based Euler deconvolution: completing the circle with 2D constrained Euler, 73rd Annual International Meeting, Society of Exploration Geophysicists, Expanded Abstracts, pp.572-575.

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