Continental-Oceanic Boundary Indicators in the Santos Basin, Brazil

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Summary

Heat flow variations within both continental and oceanic crust play an important role influencing hydrocarbon maturation rates. Therefore, mapping of the continental-oceanic boundary (COB) is very important in offshore oil and gas exploration. In some areas of the world such as at active margins, the COB is very distinct, while in other areas, such as the passive margin Santos Basin in offshore Brazil (Figure 1), the position of the COB is less certain and more open to interpretation. Thick sediments, evaporites and volcanic rocks present within the stratigraphic sequence tend to obscure both seismic and gravity signals making it more difficult to distinguish crustal types along this margin. This study analyzes the most up-to-date satellite altimeter-derived gravity dataset and seismic data available. This integration has helped to distinguish, and better constrain, areas of rifted and extended continental crust from areas of true oceanic crust.

Introduction

Based on crustal type and tectonic framework, most passive margins can be divided into three distinct zones: continental crust, rifted or extended/attenuated continental crust, and oceanic crust. Typical continental crust thickness at the passive margin ranges from 20 to 40 km and formed by igneous or metamorphic rocks.

During crustal attenuation (rifting), continental crust thins forming extensional features such as normal extensional faults, horst-and-grabens, and half-graben structures. Sediment supply to these active extensional grabens is sourced, not only from the erosion of proximal rift shoulder uplifts, but also from more distal hinterland areas. This hinterland-derived sedimentation typically enters the rift system via strike-slip or wrench systems that connect the graben systems together. This active sedimentation produces sediment (bed) thickening towards the centre of the rift.

As crustal attenuation proceeds, eventually oceanic crust starts to form. This crust is significantly thinner (typically 6-8km) and is formed usually by a gabbroic complex overlain by basalts. These rocks, as well as shallow upper mantle peridotites, have higher densities than typical continental crustal rocks and can be quite distinct. Basaltic lava flows comprising the top layer of the oceanic crust often form very distinctive seismic patterns known as Seaward Dipping Reflectors (SDRs). Examples of these distinct reflectors are well-known from Offshore Norway (Vöring Basin) and offshore Brazil. Oceanic fracture zones are also one of the most prominent features of the oceanic crust and can be used as a distinguishing criterion. Unlike sediment deposited in active continental rifts, sediments deposited on oceanic crust usually have constant thickness (no active uplift/tectonism) and tend to onlap pre-existing basement topography.

Density/velocity contrast, crustal thickness differences and basement/sediment relationships are all geologic criteria that can help distinguish crustal types. Integration of gravity and seismic data aids this determination.

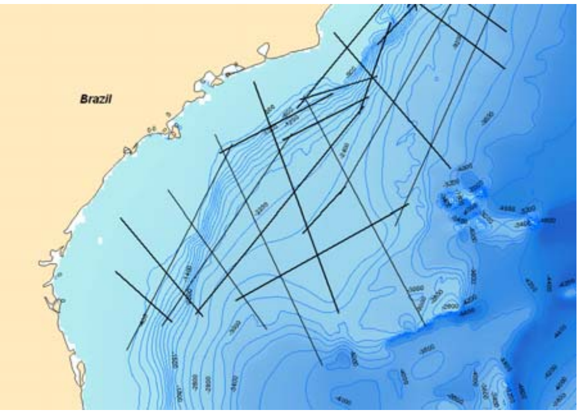

Figure 1: Bathymetry and seismic data coverage of the Santos Basin offshore Brazil.

Methodology

Satellite altimetry-derived gravity (SADG) data are commonly used in offshore exploration to map regional tectonic features such as extension of the fracture zones, identification of major rifts, and delineation of the COB. Reprocessing of the SADG is constantly conducted by various groups to improve the data resolution. SADG data used in this study were extracted from the global Sandwell and Smith dataset, version 15.1 released in 2006.

Gravity data can be used to differentiate both continental and oceanic crust based on the geological criteria listed above. After applying a Bouguer correction to the initial SADG (Figure 2), a set of gravity enhancements (Figures 3 and 4) were derived to help emphasize fracture zones, areas of rifted continental margin, and its transition to oceanic crust. The enhanced gravity fabric, fracture zone extension, and prominent shore parallel gravity gradients are used to interpret COB location.

The thickness of the crust has been estimated by 3-D structural inversion of the Bouguer gravity for the Mohorovičić (Moho) boundary. Seaward crustal thinning generally indicates rifted continental crust. The constantly thinned crust is considered to be oceanic.

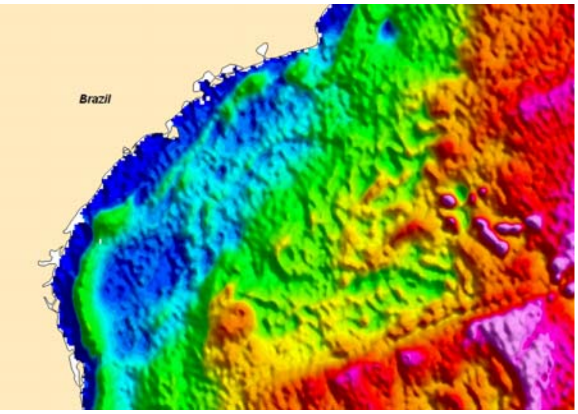

Figure 2: Bouguer gravity anomaly.

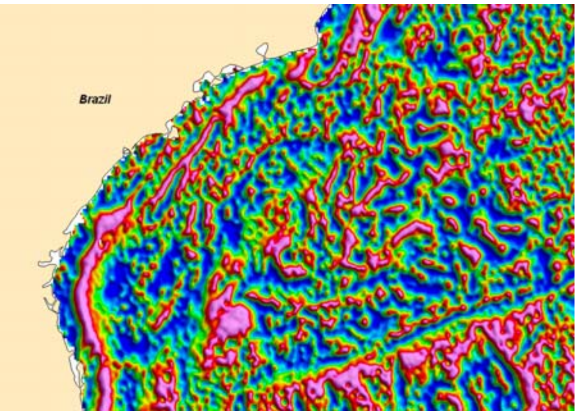

Figure 3: Enhanced Bouguer gravity anomaly.

The Bouguer gravity and its enhancement signatures in the Santos Basin are very complex and COB mapping is obscured due to the presence of thick salt and also basalts in the north. Integration with seismic data can provide additional constraint to resolve this problem in some areas. Seismic data can assist in delineating the continental-oceanic boundary based on basement/sediment relationships, the presence (or absence) of SDRs and the regional extent of the Moho across the study. In this work we investigated a series of seismic time sections illustrating characteristic patterns of these features (Figures 5 and 6).

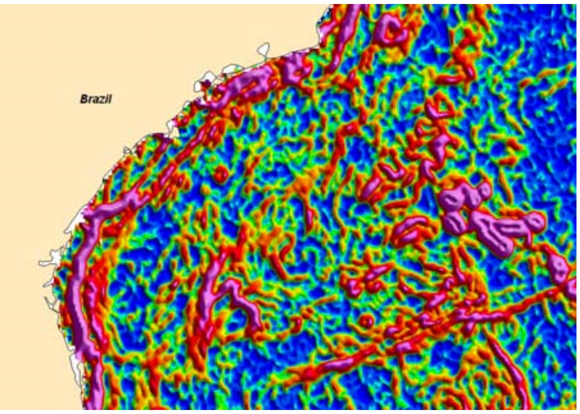

Figure 4: Horizontal gradient of Bouguer gravity anomaly.

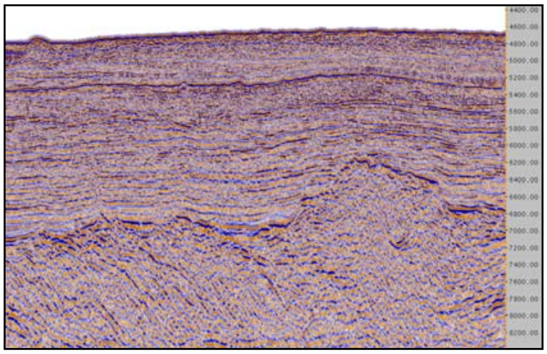

Figure 5: Seismic time section shows sediments burying pre-existing relief of the oceanic crust basement.

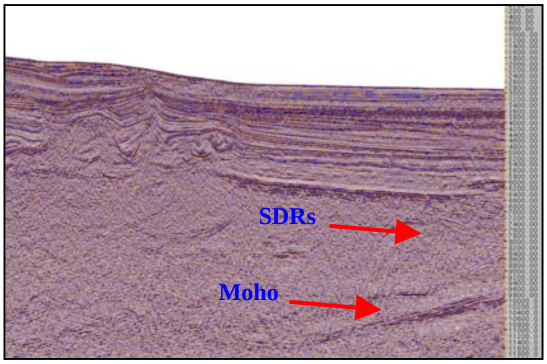

Figure 6: Seismic time section of rifted continental crust/ oceanic crust transition zone in the southern part of the Santos Basin. Oceanic crust indicators, in this case SDRs and Moho reflector depth are easily identified on the section.

Conclusions

In the Santos Basin, a set of gravity enhancements has allowed delineation of the main tectonic features. Crustal thickness was estimated from 3-D gravity inversion work. Modeling along the seismic lines has allowed better constraint on the position of the COB. Seismic features indicative of both continental and oceanic crust have been used to confirm these findings.

This analysis and interpretation suggests that allochthonous salt may extend over oceanic crust in the Santos Basin. In this case, low-density salt compensates the higher density signature of oceanic crust reducing the amplitude of the gravity anomaly thereby making the boundary less obvious than for other passive margin areas.

Although we redefined the position of the continental-oceanic boundary, ambiguities still exist. Improvement of the sub-salt imaging and/or basement well penetration are needed to increase confidence of the COB position.

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EDITED REFERENCES
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