Frontier Basins Onshore Brazil*

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Search and Discovery Article #10237 (2010)
Posted April 30, 2010

*Adapted from oral presentation at AAPG International Conference and Exhibition, Rio de Janeiro, Brazil, November 15-18, 2009

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Abstract

The latest deep-water sub-salt discoveries offshore Brazil have captured the attention of the petroleum industry. However, the development and production in the deep water remains a challenging and expensive enterprise. At the same time, large interior areas with petroleum potential are still under-explored. Among them are the Solimões, Amazonas, and Paraná basins, which alone comprise nearly 2,700,000 square kilometers of sedimentary basins. The well coverage in these areas varies between 4,000 to 10,000 square kilometers per well. This work reviews the geological settings of a few of these frontier basins onshore Brazil and their hydrocarbon potential.

Seismic exploration in some of these large basins has been hampered by their size, remoteness, and geological complexity. Meantime, the advances in the airborne prospecting technology, with the inclusion of gravity and gravity gradiometry, provide new and timely exploration tools.

Interpretation of airborne gravity and magnetic datasets is an effective way in understanding geology of such areas. These data are relatively inexpensive to collect, but they significantly contribute in delineating the basins and identifying the most adequate prospective areas. This study presents available geological cross-sections from the basins, which are analyzed by gravity and magnetic modeling. The modeling results clearly demonstrate applicability of these geophysical data for mapping basement geometry, intra-sedimentary igneous features, and sedimentary structures, which are key elements in building exploration framework for these frontier areas.

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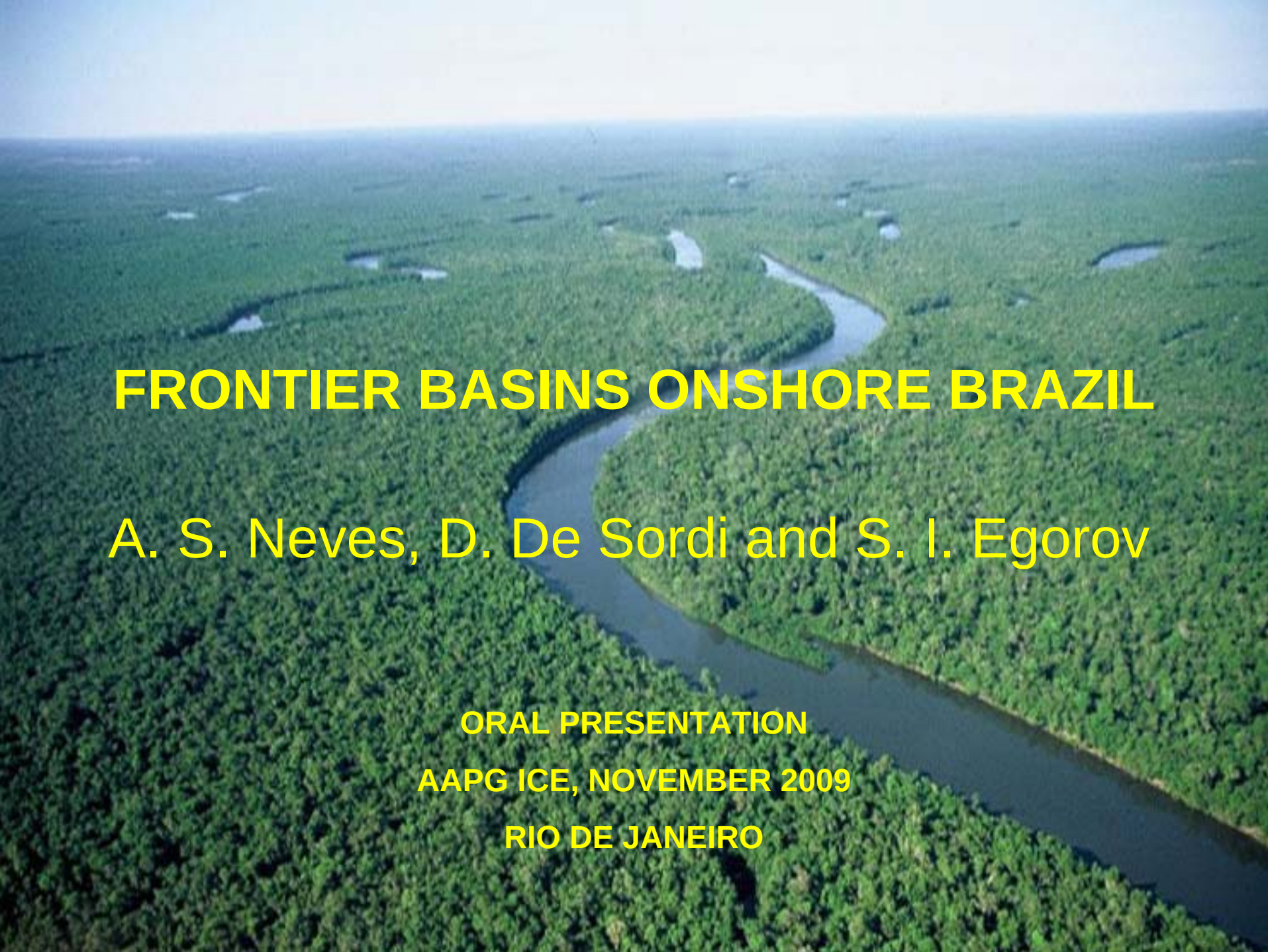

FRONTIER BASINS ONSHORE BRAZIL

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ORAL PRESENTATION

AAPG ICE, NOVEMBER 2009

RIO DE JANEIRO

Frontier Basins Onshore Brazil

After the eighties, the successes in the offshore exploration diverted exploration investments from the onshore basins.

At the time, offshore exploration occurred in relatively shallow waters. It did not involve the high technology and corresponding high costs associated with present deep water exploration.

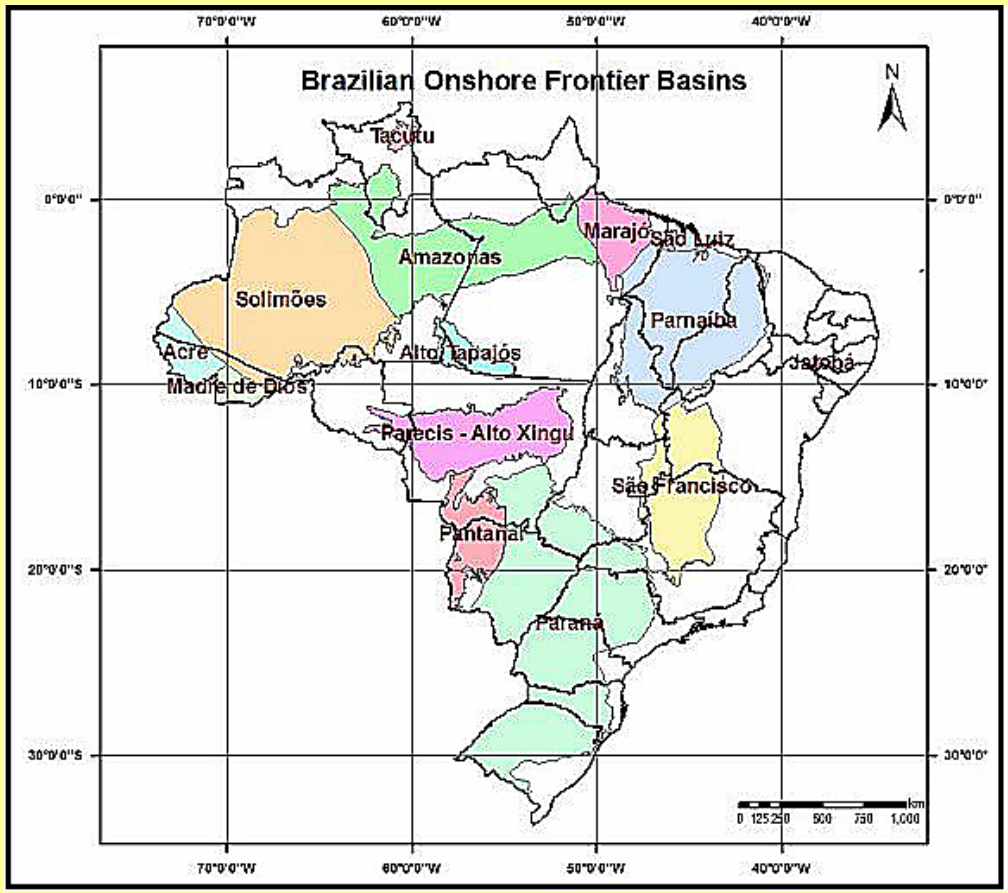
On the other hand, many of the onshore basins were located in areas of difficult access and with poor logistical support.

Thirty years make a great difference. The country's infra-structure has developed. The access and support of onshore basin areas has become easier. Geological knowledge of these basins has improved.

It is worthwhile to look at the onshore basins at the light of the present situation and of the capabilities of modern exploration methods.

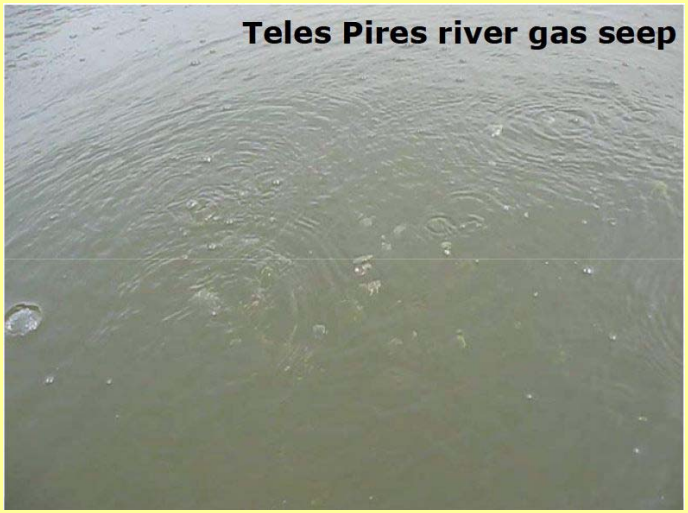
Area of Onshore Basins

- **The study by Bacoccoli and Landau (2003) identified 18 onshore basins in Brazil.**
- **Excluding 4 smaller basins unlikely to possess relevant hydrocarbon accumulation, the remaining 14 basins cover an area of about four million square kilometers.**
- **This is equivalent to the area of Russia, from Europe to the Pacific or more than twice the area of all other South American countries together**



Frontier Basins

Using the area per well drilled as a measure of the exploratory effort to date, all basins listed in the table may be considered, to a higher or lower degree, frontier basins, with the exception of the small Recôncavo, Tucano and Jatobá basins, close to Salvador



(ANP Technical Seminar, STA-7, 2008)

Wells Drilled on Onshore Basins			
Basins	Basin Area (Sq. Km)	Number of Wells	Square Kms per Well
Parecis	355.400,0	2	177.700
São Francisco	379.357,0	4	94.839
Alto Tapajós	80.400,0	0	80.400
Parnaíba	668.858,0	33	20.268
Acre	150.000,0	11	13.636
Pantanal	87.700,0	8	10.963
Paraná	1.127.400,0	128	8.808
Tacutú	12.500,0	2	6.250
Amazonas	615.600,0	168	3.664
Marajó	53.000,0	16	3.313
Solimões	480.000,0	147	3.265
Tucano Central, Norte e Jatobá	28.500,0	24	1.188
Tucano Sul	7.000,0	96	73
Recôncavo	10.359,0	1038	10

(Modified from Bacoccoli and Guimarães, 2004)

Major Sedimentary Regions

Five major onshore sedimentary regions – the Amazonian basins (Acre, Solimões and Amazonas), Paraná, Parecis, Parnaíba and São Francisco - account for about 93% of the area of onshore basins.

All these large areas correspond to:
- Intracratonic Paleozoic basins;
- Basins with complex geological structures;
- Basins with igneous intrusives and/or extrusives

Some Characteristics of these Areas:
- All exhibit oil or gas seeps;
- HC fields, only Amazonian and Paraná basins;
- Discoveries in relatively localized areas.

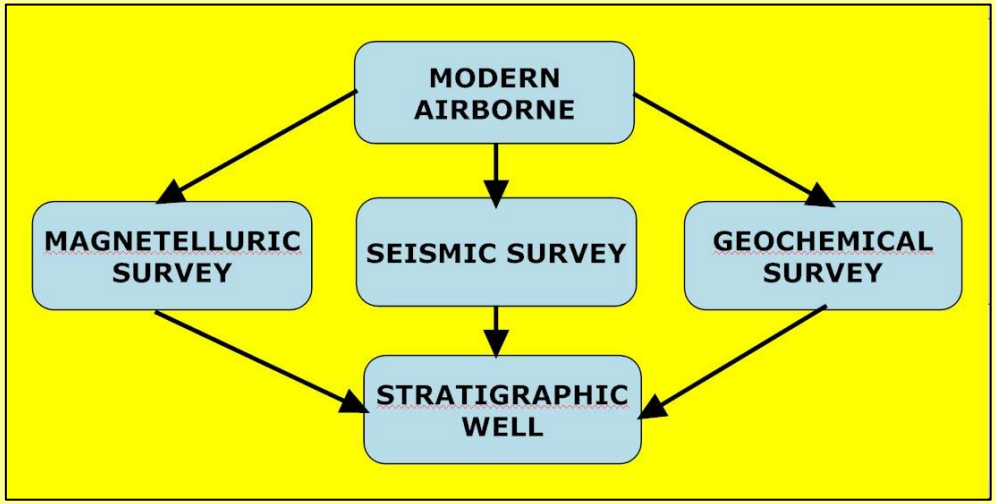
Reasons for Modest Exploratory Results:
- Large size of the basins;
- Low exploratory effort
- Geological complexity of the basins;
- Need to find localized favorable structures.

Barra Bonita gas well, Paraná

(ANP Workshop Técnico 2000)

Renewed Exploration Efforts and Methods

ANP (Brazilian National Oil and Gas Agency) started a few years ago the systematic regional survey of the large Brazilian frontier basins, using modern airborne potential methods followed by seismic, magnetotelluric and geochemical surveys and eventually by stratigraphic wells



The Amazonian and Parnaíba basins, and part of São Francisco basin have been surveyed. Paraná basin is being covered. Follow up has started.

The choice of modern airborne prospecting methods for the initial exploration program was a consequence of the sheer size of the basins and the recognition of the increased power of airborne potential surveys.

Modern Airborne Geophysics

Developments in computer power and GPS ushered a new era in aerogeophysics

- **GPS made possible airborne gravity and gravity gradiometry**
- **Computer power allowed for faster and more powerful algorithms, real time processing, visualization and interpretation**

Modern airborne geophysics exploration yields simultaneously two types of data:

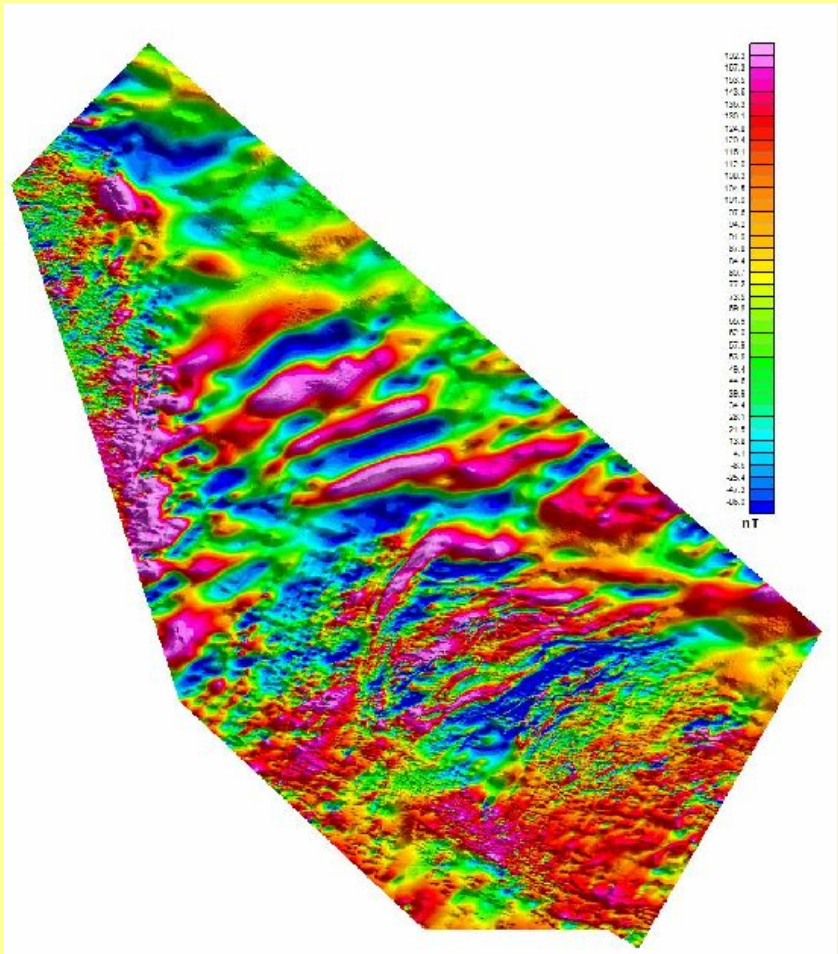
- **Gravity and/or gravity gradiometry**
- **Magnetometry**

Previously, airborne surveys for oil produced only aeromagnetic maps. Most onshore basins are at low magnetic latitudes. Resulting maps difficult to interpret

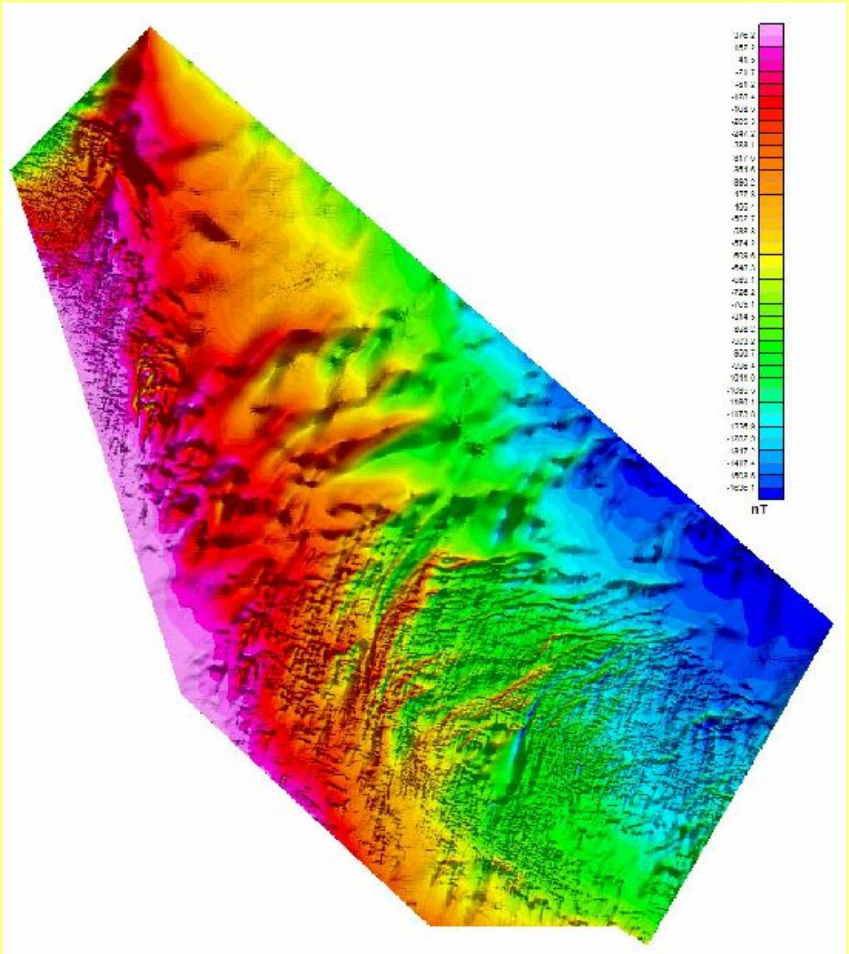
Recent developed algorithms allow reliable RTP transformation of magnetic maps, leading to the precise superposition of gravity and magnetic anomalies. The shape and nature of subsurface structures are defined in terms of their density and susceptibility

The next slides show examples of the modern interpretation methods

Magnetic Maps at Low Latitudes - RTP



Aeromagnetic Map (TMI)



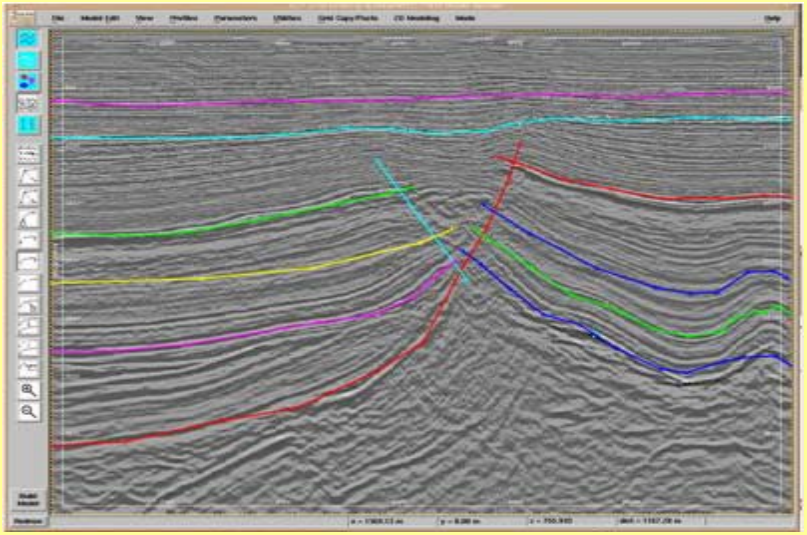
Reduction-to-the-Pole (RTP) of TMI
Resemblance to a gravity map

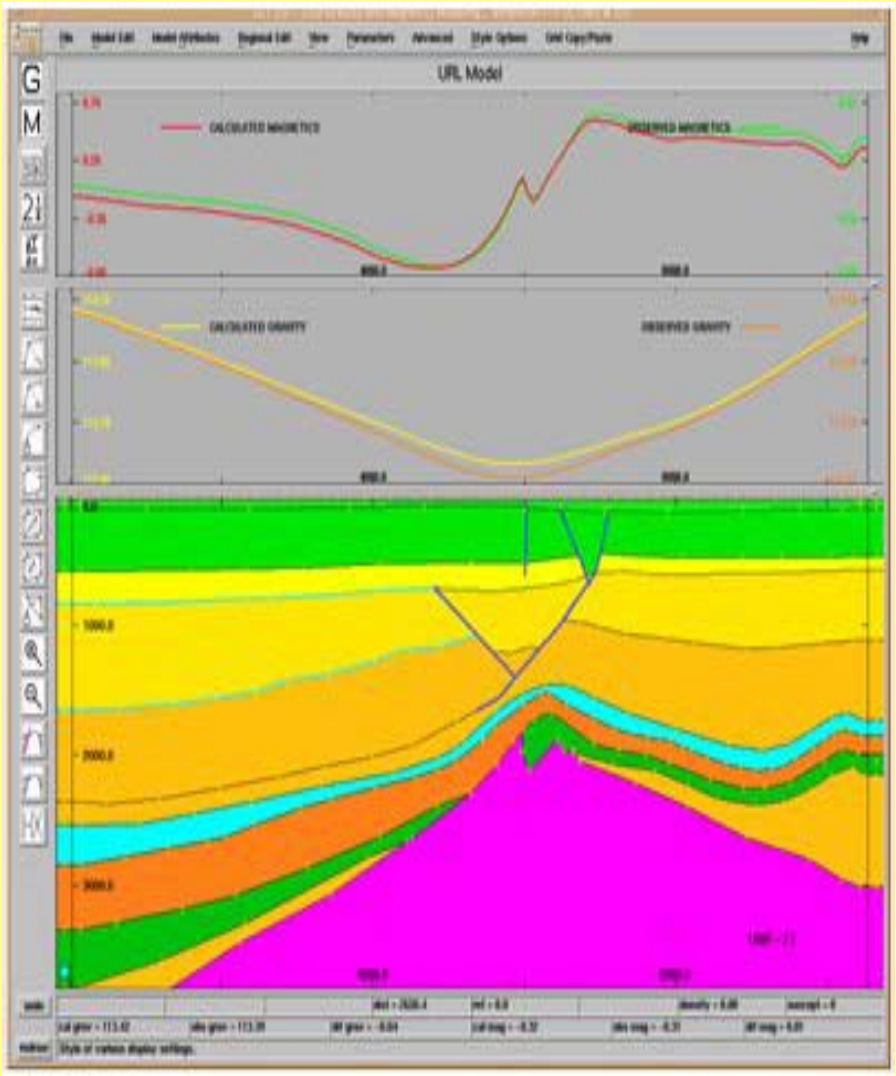
Modeling – Partial Section of Solimões Basin

Modified from Eiras, 1999

Inversion from Seismic Interpretation

Seismic interpretation used as initial input for inversion. Process allows for changes in velocity, thickness and depth of selected layers of seismic section in order to match gravity and magnetic values



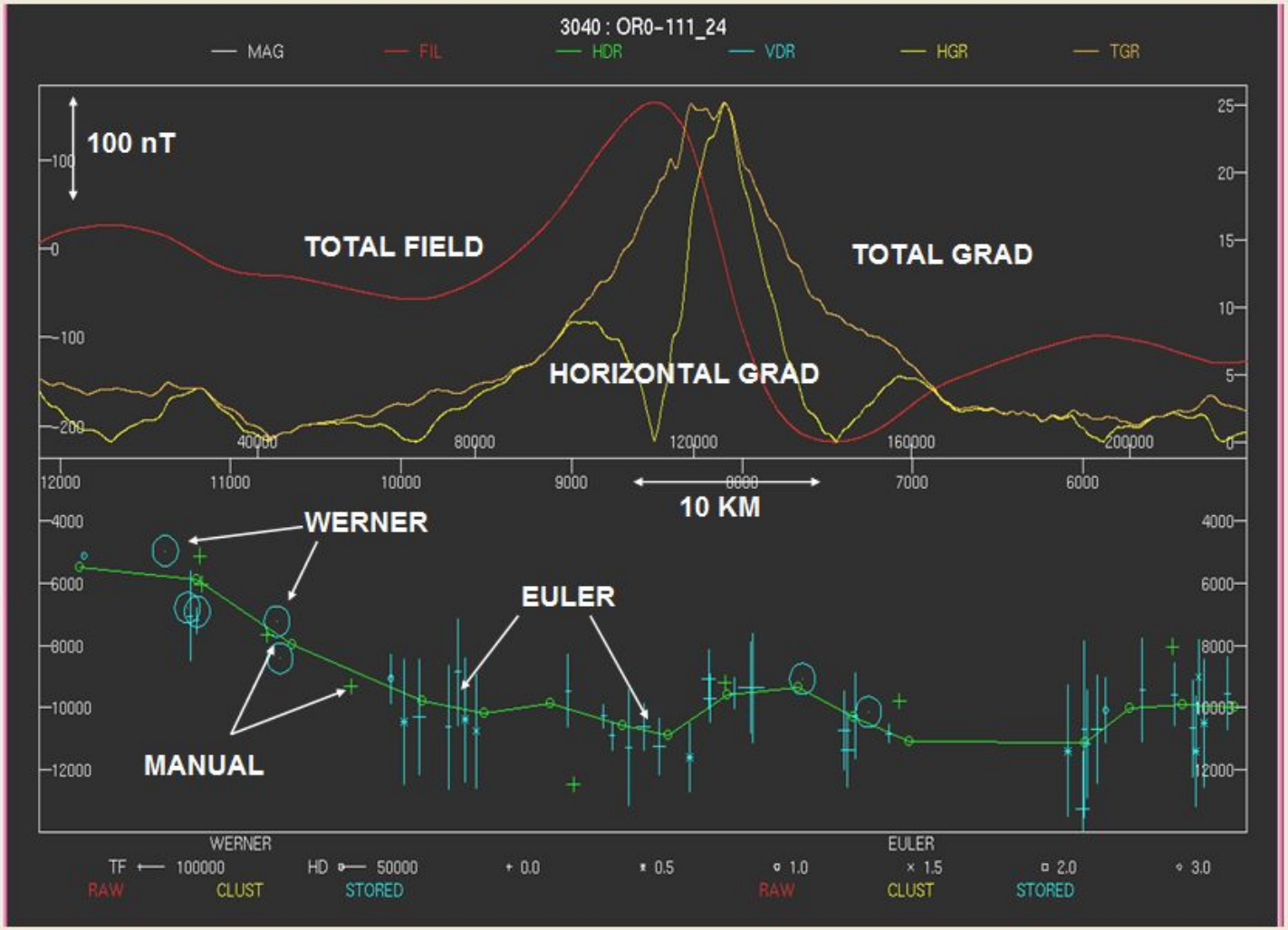


Examples: determination of thickness of basalts in Faroe Islands and bottom of salt in Gulf of Mexico

FGMS, 2009

Multi-Method Classic Depth Determination

- Werner
- Euler
- Naudy
- Phillips
- Spectral analysis
- Manual methods:
  - Peter's Half Slope
  - Bean Half Slope
  - Bean Ratio A
  - Bean AC method
  - Straight Slope
  - Sokolov



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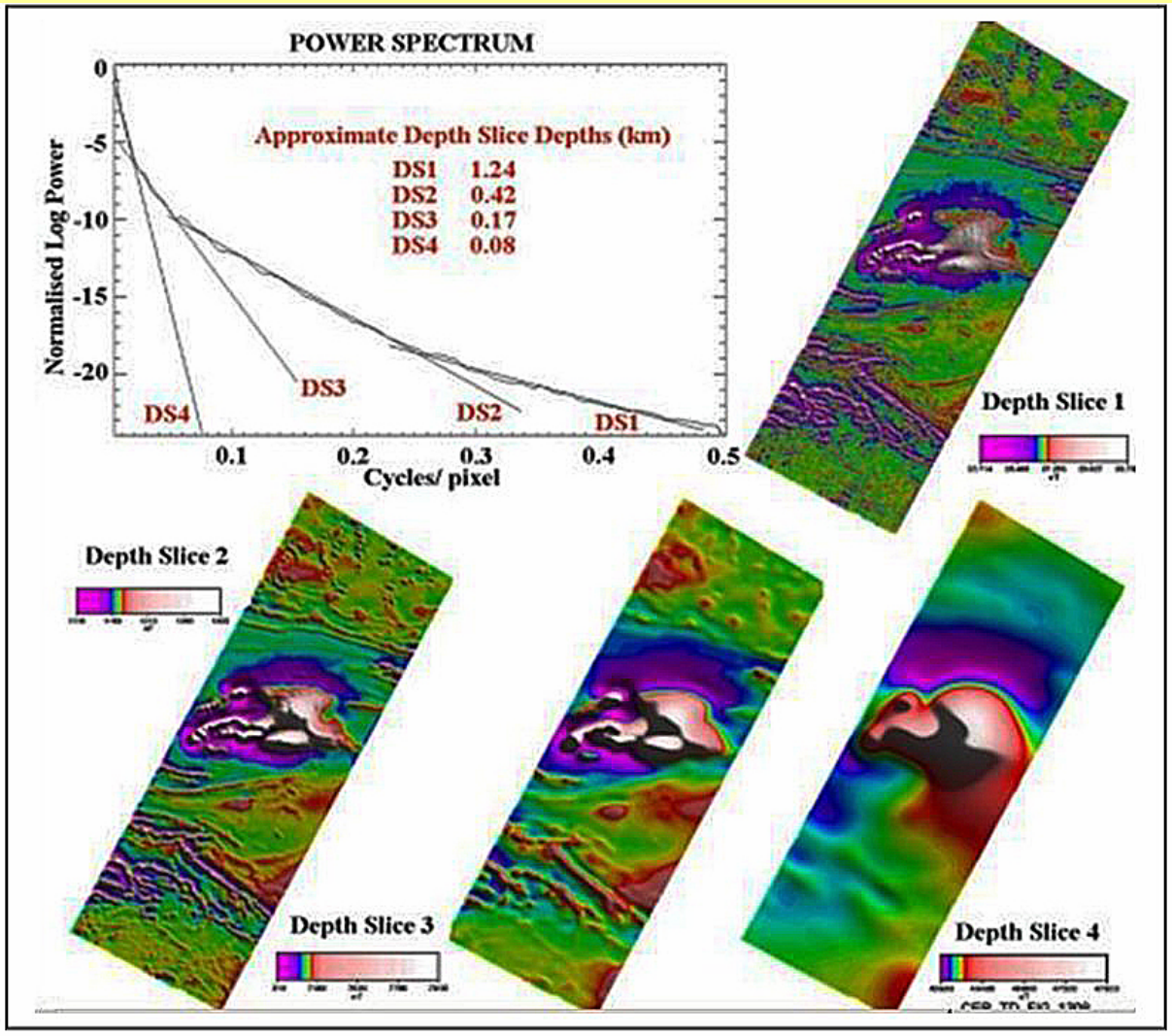
Digital Depth Interpretation – Depth Slice



FGMS, 2009

The Future of Onshore Frontier Basins

The first stage of ANP systematic regional geophysical mapping program of the onshore frontier basins of Brazil, using modern airborne geophysics, is almost complete. A wealth of geological data was obtained in these basins, leading to the selection of the ground follow-up areas by other methods.

The second stage, that is, the ground follow up by seismic surveys, magneto-telluric soundings and geochemical surveys is already under way.

Shortly, the start of the drilling of stratigraphic wells will complete the regional exploration cycle. Concrete stratigraphic and petroleum system data will then become available in these basins.

In parallel, the annual bidding rounds will bring oil and gas exploration companies, yearly, into the now better known basins and less expensive to explore than the deep offshore basins, reinforcing the knowledge of their potential.

In this scenario we expect that true frontier basins will gradually cease to exist in a relatively short time. The index of area per well may not diminish rapidly. But the exploration risk will have greatly decreased.

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