Modern Non-Exclusive Seismic Surveys Offshore Eastern Brazil

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ABSTRACT

A massive non-exclusive seismic data acquisition program is presently being conducted offshore the eastern Brazilian Coast. The series of 2-D survey projects consists of 80,000 kilometers and were designed by Schlumberger Geco-Prakla. The surveys are tailored for shelf and deep-water exploration and accounts for the current significant advances in seismic data acquisition, seismic data processing and data interpretation. These, together with advances in deepwater drilling technology, have extended exploration and production operations offshore Brazil towards the continental slope and rise.

Three modern vessels the M/V Geco Marlin, the M/V Akademik Shatskiy and the M/V Geco Tau are designated to undertake the project back to back. With Geco-Prakla's rapid processing turnaround time these data will be readily available for the forthcoming ANP bid rounds.

Seismic surveys will focus mainly in the three offshore basins that, historically, have the best hydrocarbon exploratory risk/reward ratio, the Santos Basin, the Campos Basin and the Espirito Santo Basin. Schlumberger Geco-Prakla has also designed comprehensive survey inventories of the Brazilian Continental Margin.

This modern seismic exploration of the eastern Brazilian Margin is geared towards the imaging of hydrocarbon plays of the pre-salt and post-salt sequences. Seismic resolution in these sequences have improved substantially with modern technologies now employed in data acquisition, data processing and data interpretation. Pre-stack time migrations with higher order NMO are applied to all lines whereas selected regional lines are pre-stack depth migration processed.

INTRODUCTION

During the last decade, Schlumberger Geco-Prakla has been actively involved in all of the major offshore basins of the world. Non-exclusive proprietary surveys (NEPS), both 2D and 3D, have been gathered massively in the Gulf Coast, North Sea, Southeast Asia, Australia and West Africa.

In the Gulf of Mexico, the consortium Geco-Prakla and TGS-Nopec acquired the highly successful "Phase 45" and "Phase 46" 2-D grid consisting of 110,000 kilometers of data. "Phase 45" acquired 99,000 km of data in the Central and Western GoM whereas "Phase 46" acquired 11,000 km of data in the eastern GoM. The grid essentially covered the entire Gulf of Mexico encompassing shelf and deep-water.

In the marginal basins of West Africa, where petroleum paleoenvironments and hydrocarbon plays correlate closely with continental margin basins counterparts off East Brazil (Fainstein et al, 1998, Mello et al, 1993), Geco-Prakla has collected more than 60,000 km of NEPS seismic data since 1988 (Platt et. al, 1993). These were gathered off Nigeria, Cameroon, Equatorial Guinea, Gabon, Congo, Angola and Namibia. Geco-Prakla has also pioneered deep-water seismic acquisition off the coast of Africa and has assisted in delineating risk acreage for the purpose of competitive bidding rounds. Geco-Prakla's interpretation of the West African Continental Margin has unraveled numerous oil and gas plays, which have led to the recent series of giant oil discoveries in deep water.

OFFSHORE BRAZIL: FUTURE EXPLORATION

Petrobras' first strike of oil offshore, Guaricema, was in the Sergipe-Alagoas Basin. In the Campos Basin offshore Rio de Janeiro the first oil strike, Garoupa, was made in 1974 with the drilling of the eighth well the 1-RJS-9 well (Ponte et al., 1977). Oil production started in 1977 and, so far, more than 60 oil and gas fields have been discovered in the Campos Basin, seven of which are giant oil fields, and all in deep water. Campos Basin produces roughly 70% of the daily Brazilian oil production. With its exploration and production operations in the Campos Basin, Petrobras developed worldwide leadership position in deep-water technology. Petrobras has concentrated most of its investment efforts in the Campos Basin off Rio de Janeiro and in the Reconcavo, Sergipe-Alagoas, Potiguar and Ceara basins in northeast Brazil, the basins, which account for most of the Brazilian oil production.

ANP's opening of exploration and production in all of the Brazilian basins acreage, through competitive bid rounds and through partnerships, have already effected an intensive renewal of geophysical exploration, which should continue into the foreseeable future.

Brazil has 28 major sedimentary basins and only nine of them have been consistently explored. In the eastern continental margin, the Campos Basin, with its giant deepwater fields, is a worldclass hydrocarbon province (Table 1). Still, the deep-water areas of Espirito Santo Basin, Santos Basin and even Campos Basin remains underexplored.

This article outlines the inception of modern non-exclusive seismic exploration offshore Brazil. Future exploration will be based on accurate geological imaging of structure and stratigraphy to guide the drill bit of exploration wells into the focused target reservoirs as interpreted directly from seismic data. This will be ensured by the modern acquisition and processing techniques, hence increased seismic resolution provided by the Geco-Prakla NEPS data.

EAST BRAZIL OFFSHORE BASINS

The principal continental margin basins off Eastern Brazil are, from north to south, the Camamu-Almada Basin, the Jequitinhonha-Cumuruxatiba-Mucuri Basins, the Espirito Santo Basin, the Campos Basin and the Santos Basin.
The stratigraphic columns of all these basins are generally similar, with lacustrine sediments of the rift stage being covered by evaporites and carbonates of Aptian and Albian age and then blanketed by an overburden of open marine sediments (Asmus and Ponte, 1977; Figueiredo, 1985). The stratigraphy of the eastern Brazil continental margin basins also reflects the evolutionary phases of continental separation and marginal basin accretionary processes during the continental drift of Brazil and Africa. Sedimentary sequences may be grouped within four major distinct units: a) the lower basal unit, which correspond to pre-rift sequences, consist mostly of continental red shales and conglomerates; b) the syn-rift sequences consist of lacustrine deposits. These are hydrocarbon-rich, source-rock shales interspersed with stacked coarse to fine-grained sandstones. c) The evaporitic-gulf sequence was deposited during the Albian-Aptian time of restricted ocean circulation south of the equatorial south Atlantic. These are widespread deposits of halite and anhydrite, however clastics and carbonates are also present. d) The marine sequence, which may be sub-divided into two sub-sequences: the first are predominantly shallow marine platform carbonate deposits and the second are predominantly open marine sediments.
Several distinct petroleum systems occur within the eastern Brazilian marginal basins and are associated with: a) lacustrine syn-rift source rocks; b)-restricted marine and transitional environments and c) open marine transgressive sediments. The best source rocks are within the syn-rift sequence. Reservoirs and seals occur within the syn-rift, transitional and marine sediments.
A fairway of salt layers and salt diapirs offshore east Brazil runs from Santos Basin to Sergipe-Alagoas Basin. Massive salt domes occur in the Sao Paulo Plateau off Santos Basin. The salt fairway becomes progressively narrower towards north (Leyden et al., 1976). Salt diapirs cause hydrocarbon prospective structures along the entire eastern margin.
Besides salt tectonism, structures along the eastern continental margin of Brazil consist of seaward tilted faulted blocks where anticline features are formed in association with block bounding listric faults.
In the main hydrocarbon-producing basin, the Campos Basin, a regional unconformity marks the boundary between the Cretaceous and the Tertiary. Below this unconformity, a transitional environment lithology of carbonates and salt layers is generally encountered above the highly compartmentalized syn-rift section. Above this unconformity, in the Tertiary overburden, occurs a pervasive distribution of thick turbidite sand reservoirs, particularly in deep-water (Table 1).
By contrast, in the Espirito Santo Basin to the north of Campos Basin, the section is further complicated as salt domes are interspersed with volcanic dykes (Fainstein and Summerhayes, 1982). In the Santos Basin, the section is rich in massive salt layers, which in many instances preclude hydrocarbon migration from the syn-rift source rocks into the Upper Cretaceous and Tertiary reservoirs.

Field	Basin	Reservoir (Turbidites)	EstimatedReserves (MMBO)
Albacora and Albacora-East	Campos	Miocene Oligocene	2,000
Marlim	Campos	Oligocene	2,000
Roncador	Campos	Cretaceous	1,500
Barracuda	Campos	Oligocene Eocene	800
Caratinga	Campos	Oligocene Eocene	700

Table 1: Largest deep-water fields of Campos Basin

THE DEEP WATER PLAYS

Substantial oil reserves have been found recently in the deep and ultra-deep waters offshore Brazil and Africa. Among the deep water fields of Brazil are Marimba, Espadarte, Caratinga, Barracuda, Albacora, Marlin and Roncador. All are within the Campos Basin. Estimated recoverable reserves for the three giant oil fields in ultra-deep water, Albacora, Marlin and Roncador, exceed five billion barrels. Once in full production, these three fields should account for a large percentage of the entire Brazilian oil production.

Main oil reservoirs of these deep water discoveries off Brazil: a) shelf derived turbiditic sands, encountered in the upper and lower continental slope and b) distal marine turbiditic sand bodies transported via channels to the lower slope (Dolivo, 1997; Fainstein et al., 1998). These are generally found in the Upper Cretaceous and Tertiary sequences. It is interesting to note that there are two prolific deep-water trends on both sides of the South Atlantic, the Lower Campos Basin and the Lower Congo Basin, and that these approximately match upon continental reconstruction.

MODERN SEISMIC TECHNOLOGY

The future seismic exploration in the Brazilian continental margin will aim at the precise imaging of hydrocarbon plays in the pre-salt and post-salt sequences. The imaging of deep-water reservoirs has also been accomplished with new 2-D and 3-D technology. Improved multiple attenuation and migration algorithms provide better imaging of the whole sedimentary section, hence seismic resolution.

Modern seismic technology includes more accurate navigation data through the use of GPS, reduced towing noise due to smaller diameter streamers, smaller separation between streamers, longer streamers yielding improved velocity information, increased footprints possible due to monowing technology and improved real-time data quality checking.

Prior to acquisition of an offshore non-exclusive survey a survey evaluation and design is performed to best select the acquisition parameters that would optimally resolve the intended structural or stratigraphic targets. Raypaths and wavepaths theoretical simulations, based on available surface and borehole surveys from a given area, are used to derive the key acquisition parameters, the most important of which are: size and depth of the source array; streamer length and towing depth; shot-point spacing; optimum CMP fold; sampling rate and adequate two-way reflection recording time.

OFFSHORE EAST BRAZIL NON-EXCLUSIVE SURVEYS

On the Brazilian continental margin, Geco-Prakla has established an inventory of 2-D and 3-D NEPS surveys covering the most prospective offshore basins. Along the eastern margin, the regional 2-D NEPS exploration grid of 80,000 kilometers (see Figure 1) covers the entire eastern continental margin encompassing the Santos Basin-Sao Paulo Plateau, Campos Basin, Espirito Santo Basin and also Jequitinhonha and Camamu-Almada Basins. By contrast, the NEPS 3-D surveys are focused in deep-water blocks of Campos and Santos Basin.

The desire of exploration and production companies to access prospective acreage in the shelf and in deep water off the coast of Brazil is also stimulating greater demands upon seismic imaging. Geco-Prakla research and development is constantly investing in new acquisition, processing and interpretation computer methods and technology.

In Brazil, Geco-Prakla is committing the most advanced seismic data acquisition technology, with eight (8) kilometer streamer and long, variable TWT recording. The seismic acquisition capabilities includes the Nessie III and Nessie IV streamers, the Trinav navigation package (online and offline), the Triacq data recording system with data multiplexed in sections in the cable, real time (QC) monitoring and the Tripro onboard processing.

Data Processing is performed onshore with the SEISMOS system, which is a powerful unifying framework for all surface seismic analysis. Pre-stack time migration with higher order normal move-out is applied routinely to all lines during processing. Rapid data processing turnaround time will enable this massive data set to be utilized by exploration companies in their geologic evaluations of the forthcoming ANP bid rounds.

The non-exclusive data is licensed subject to the terms of Geco Prakla's Exploration Services. Details of licenses may be accessed through the web site www.connect.slb.com/Brazil, or by contacting fainstein@rio-de-janeiro.geco-prakla.slb.com and gregory@houston.geco-prakla.slb.com in North America.

DATA INTERPRETATION

SEG-Y tapes for the migrated lines and navigation tapes may be loaded into a workstation licensed with Charisma or IESX interpretation software, CPS-3 mapping software and reservoir geophysics software. Comprehensive geophysical interpretation and petroleum geology reports of the East Brazil continental margin are to be issued with basis on this modern non-exclusive data acquisition.

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LIST OF FIGURES:

Figure 1: Line tracks of the 2-D regional NEPS survey offshore eastern Brazil. The survey conducted by Schlumberger Geco-Prakla includes the massive data acquisition of 80,000 km, covering shallow, deep and ultra deep-waters off the east Brazilian Coast.