

HOW MUCH OIL AND GAS FROM DEEPWATER? THE EXPERIENCE OF BRAZIL

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I. FROM ONSHORE TO DEEP WATER EXPLORATION

The first petroleum discovery in Brazil dates from 1939, when a small oil accumulation was found in Lobato, nearby Salvador City, northeastern Brazil. This finding represented the beginning of a phase of oil exploration and production (1939-1967) mostly focused on the onshore basins from northern- and northeastern Brazil. Oil fields that individually contain original reserves over 400 million bbl were found during this phase, but the Brazilian oil production and oil reserves never exceeded 200,000 bopd and 1,2 billion bbl, respectively.

Offshore oil exploration started in 1968, when a first (dry) well was drilled in the Espírito Santo Basin (southeastern Brazil), followed by a well drilled in the Sergipe Basin (northeastern Brazil), which found Guaricema, the first Brazilian offshore oil field.

The first oil discovery in the very prolific Campos Basin (offshore southeastern Brazil) dates from 1974, when the ninth well drilled found Albian carbonate reservoirs (Garoupa Field) under a water depth of 120 m. This first finding in the Campos Basin was extremely important for a country with an oil consumption of 500,000 bopd and a production of only 170,000 bopd. Oil production from the Campos Basin started in 1977, from the Enchova Field, which produced to a semi submersible platform moored at a water depth of 124 m. This was the beginning of a successful history that led Petrobras to become a world leader company in petroleum exploration and production in deep (300 – 1,500 m) and ultra-deep (>1,500 m) waters. Forty-four oilfields were found in the Campos Basin, between 50 and 140 km off the Brazilian coast (under water depths between 80 and 2,400 m), which produce from a variety of reservoirs, including Neocomian fractured basalts, Barremian coquinas, early Albian calcarenites, and (mostly) late Albian to early Miocene siliciclastic turbidites.

Deep and ultra-deep water giant fields started to be discovered only in 1984. There was a succession of large discoveries, including Albacora, Marlim, Albacora Leste, Marlim Sul, Barracuda, Caratinga, Roncador and, more recently, Jubarte and Cachalote. Turbidites are, by far, the most important petroleum reservoirs in the Campos Basin. They comprise reservoirs in 40 oilfields, including Marlim, Marlim Sul, and Roncador fields, with original oil reserves of 2.7, 2.5, and 2.3 billion bbl, respectively.

II. TECHNOLOGICAL CHALLENGES FOR RESERVOIR CHARACTERIZATION AND MANAGEMENT IN DEEP WATERS

The development of deep and ultra-deep water fields has continuously provided new challenges for reservoir characterization and management. These fields are developed with fewer, horizontal and high angle wells, drilled into poorly consolidated reservoirs. The extensive use of 3D seismic as a reservoir characterization tool has optimized well location and allowed the reduction of geological risks. Integration of high-resolution stratigraphic analysis with 3D seismic inversion, geostatistic (stochastic) simulation of reservoir properties constrained by seismic, well log and core data, 3D visualization, and voxel-based automatic interpretation has guided the positioning of long (>1,000 m) horizontal wells through thin (<10-15 m) reservoirs. Additionally, 3D visualization techniques have provided a new environment for teamwork, where seismic, well log, and core data are interpreted and added to detailed 3D geological models and, subsequently, to robust reservoir simulation models.

The deepwater subsea wells must be designed to allow high production rates (typically >10,000-15,000 bopd), with lifetime completions to avoid costly interventions. In order to assure high productivity, pressure maintenance must be

efficient; if water injection is planned, the hydraulic connectivity between injector and producer wells must be guaranteed by high-quality 3D seismic, well log correlation, and observed pressure profiles. Detailed studies have been made in order to define the distribution and number of wells, since the number of wells strongly affects the net present value of deepwater projects. Wells with expected oil recovery of less than 10-15 million bbl are not drilled in the beginning of the projects, and remain as future opportunities to increase oil production and recovery.

About 16 billion bbl of heavy (13-17°API) and high viscosity (20-400 cp at the reservoir conditions) oil have been found in the deep and ultra-deep waters from the eastern Brazilian continental margin. The economic oil production from these accumulations relies on a group of new production technologies including mainly: (1) long horizontal or multilateral wells (producing with high power electric submersible pumps, hydraulic pumps or submarine multiphase pumps) to compensate the decrease in productivity caused by the high oil viscosity), (2) efficient heat management systems, and (3) compact oil-water separation systems. In October 2002 was created the Petrobras Offshore Heavy Oil Program (PROPES), who is responsible for the development of new technologies to optimize the development of the large volumes of heavy oil discovered in offshore Brazil.

Some of the new technologies devised for the characterization and development of deepwater oilfields include reservoir imaging with pre-stack, depth-migrated seismic, 4D seismic, real-time well steering and updating of geological/reservoir models, extended reach wells, selective completion in gravel-packed wells, isolation inside horizontal, gravel-packed wells, intelligent completion, subsea oil-water separation, re-injection of produced water, scale prevention and treatment, and improved recovery techniques for heavy and/or viscous oil.

III. ASSURING INCREASING PETROLEUM PRODUCTION AND RESERVES

Deep and ultra-deep water fields are responsible for about 70% of the current Brazilian oil production of 1.7 million bopd, which should grow to 2.3 million bopd by the year 2010. Meanwhile, the Brazilian self-sufficiency in oil should be achieved in 2006.

Despite a total cumulative production of 9.1 billion boe, the Brazilian proven reserves have continuously grown since the first oil discovery in the country, reaching 13.0 billion boe in 2004 (84% oil / 16% gas; 80% in deep- and ultra-deep waters). Also in 2004, the reserves/production ratio reached 21.7 years. In the last 3 years, despite the production of 1.8 billion boe, Petrobras proven reserves have increased by 3.4 billion boe (a growth of 35%). Petrobras strategic plan forecasts that this trend of growing proven reserves will persist for at least the next 5 years, reaching 17.3 billion boe in 2010.

Large deep and ultra-deep water petroleum discoveries recently made outside the very prolific Campos Basin (including light oil in the Sergipe and Espírito Santo basins, and gas in the Santos Basin), make very difficult to forecast when the petroleum production and reserves will reach their peak in Brazil.

In order to assure the historical trend of increasing petroleum production and reserves in Brazil, Petrobras intends to keep (1) strengthening expertise in deep and ultra-deep waters, (2) producing oil and gas from onshore and shallow-water fields with the focus on profitable opportunities, (3) implementing practices and new technologies in areas with high exploitation degree in order to optimize recovery factor, and (4) developing exploratory efforts in new frontiers in order to guarantee a sustainable reserves/production ratio.