



Will offshore discoveries change the course of Brazil's development? **Oil in Deep Waters**

Norman Gall



Ricardo Stuckert/Presidência da República

Celebration at the São Paulo Stock Exchange - September 2010

1. “A lottery prize”

After Petrobras, Brazil's state-controlled oil company, found giant fields of oil and gas in the Santos Basin, at great ocean depths in the South Atlantic, President Luiz Inácio Lula da Silva called the discoveries a *bilhete premiado*, a winning lottery ticket. In September 2010, concluding a \$70 billion stock promotion to finance a \$225 billion investment program announced by Petrobras, Lula and a clutch of high officials mounted the podium at São Paulo's Bovespa stock exchange in a blizzard of confetti, wearing bright orange jackets and white safety helmets adorned with Petrobras insignia as they posed for photos in the style of a victorious football team. “It was not in Frankfurt, nor in

London, nor in New York,” Lula proclaimed. “It was in São Paulo, in our green and gold Bovespa, that we consecrated the greatest capital-raising in the history of world capitalism.”

There have been cascading announcements of discoveries since Petrobras and its private partners, British Gas (BG), Repsol of Spain and GALP of Portugal, began reporting in 2006 that they found a cluster of giant fields up to 300 km. offshore, some 7,000 meters beneath the ocean's surface, trapped

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Norman Gall is executive director of the Fernand Braudel Institute of World Economics and editor of Braudel Papers.



**Fernand Braudel Institute
of World Economics**

Associated with Fundação Armando
Alvares Penteadó (FAAP)
Rua Ceará, 2 – 01243-010
São Paulo, SP – Brazil
Tel.: 55 11 3824-9633
e-mail: ifbe@braudel.org.br
www.braudel.org.br

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in the pores of limestone beneath salt beds more than 2,000 meters thick. When the first supergiant discovery, originally called Tupi, was declared ready for commercial development at the end of 2010, the field was renamed Lula in homage to the president who was retiring after eight years in office with an 80% approval rating in opinion polls.

Seven of the 10 biggest oilfields discovered in the world since 2001 are in the presalt beds of the Santos Basin, according to the oil consultancy Wood Mackenzie. "Brazil is the world's largest exploratory opportunity," the investment bank Credit Suisse reported, adding that "the presalt's full resource volumes are likely to be much higher than the volumes currently disclosed for licensed areas." After partnering in 29 wells drilled there, BG doubled its estimate of oil and gas reserves for its 27% share in five exploration blocks to 6 billion barrels of oil equivalent (BOE), which would raise the total for these projects to roughly 22 billion barrels, in only part of what now is seen as a vast oil province.

Petrobras is a state-controlled company whose shares are publicly traded in São Paulo and New York. Despite its huge discoveries, the stock of Petrobras has languished below the price at its \$70 billion stock flotation and even below levels prevailing before discovery in 2006 of the first giant field in the Santos Basin. Brazilian and foreign investors voiced concern over what they see as political interference that has distorted the company's priorities and limited its operational capacities as it pursues complex and costly efforts to produce oil and gas in the ultra-deep waters of the South Atlantic.

With its offshore discoveries since the 1970s, Petrobras is now among the world's most highly integrated major oil companies, dominating its large national

market with government support and with privileged access to huge reserves in deep waters of the Campos and Santos basins. Brazil is now the world's biggest market for equipment and services in the offshore oil industry and Petrobras the biggest single buyer. Petrobras is now a conglomerate, with interests in gas pipelines, supertankers, petrochemicals, electricity generation, fertilizers, ethanol and biodiesel. Yet in deep waters it still must overcome problems of geology, technology, logistics, safety, finance, politics, human resources, corporate governance and strategies of economic development.

This special issue of *Braudel Papers* attempts to analyze the scope and depth of these challenges.

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These great oil discoveries came at a climax in what has been called the best phase of Brazil's history. The decades since the end of military rule in 1985 have seen consolidation of democracy, curbing decades of chronic inflation and major gains in social justice. Democracy, stability with rising consumption gave Brazilians a benign view of their prospects. The Global Attitudes Survey of Washington's Pew Research Center found Brazilians more satisfied with economic conditions than the citizens of any of 22 countries except the Chinese. Some 77% think Brazil will become, or already is, a world power, although that concept remains vague.

The past quarter-century in Brazil coincides with what may be a high point of human development that accelerated during the six decades after World War II. Prodigious advances occurred on a planetary scale in longevity, nutrition, productivity, communications, logistics, science, public health, scholarship and many other fields of endeavor. Middle-class patterns

of consumption have been proliferating throughout the world. The challenge today is to sustain these advances. Brazil has much to gain or lose from these contingencies.

Brazil indeed may be a special case. Visiting Brasília in 1976, Takeo Fukuda, soon to become prime minister of Japan, told his hosts: "After the oil crisis, it has become clear that resources are limited. This is a big event in the history of mankind. Your country is a power in the 21st Century, a resources power." This kind of talk became woven into protocol in other countries' diplomacy with Brazil. Yet the talk is coming true. Brazil's cornucopia of resources has come to life as booming commodity exports as a world leader in, for example, iron ore, soybeans, beef, poultry, cellulose, sugar and oranges. Guided by Embrapa, the government agricultural research institute, application of new techniques transformed the rolling *cerrado* scrub forests of Brazil's Central Plateau, an area the size of the Great Plains of the United States, into one of the world's most productive farming regions.

The pre-salt euphoria bred in the political class the illusion of limitless resources on the horizon. Proposing legislation to create a new institutional framework for these discoveries, Lula's cabinet ministers cited "extremely low exploration risks and great profitability."

The giant oil discoveries in Brazilian waters come amid four changes that restructured the political economy of the world oil industry. **First**, control of the world's reserves by traditional oil majors such as Exxon, Shell and BP fell in recent decades from a dominant share to only 5%, with access to another 30%

through partnerships with state companies. The share of state companies in world oil industry revenues rose from 22% to 33% since 2002.

Second, the surge of speculative trading of oil on financial markets since the early 1980s exaggerated price fluctuations. Prices doubled in the 12 months to May 2008 as traders held hundreds of thousands of contracts for 849 million barrels, or 10 times daily world production, before prices peaked at \$147 a barrel a few months later.

Third, the financial fragility of global oil companies and contractors, coupled with the growing expense and difficulty of finding new reserves, led to mega-mergers over the past two decades that created super-majors like Exxon-Mobil, Chevron, Conoco-Phillips and BP-Amoco, as well as super-service providers such as Transocean, Halliburton and Schlumberger.

Fourth, these new discoveries are driven by a revolution in geophysics, enabling exploration beneath the massive salt beds of the Gulf of Mexico and the South Atlantic. Some analysts predict that the world's deep water output should double to 12 million barrels daily (BD) between 2010 and 2017, mainly in the new "Golden Triangle" of Brazil, the Gulf of Mexico and West Africa, but also in Australia and Indonesia. Exploration and production in these difficult environments demanded new technologies provided by an oligopoly of multinational providers of services and equipment, now the most profitable sector of the oil industry.

In her inaugural address, President Dilma Rousseff called the pre-salt discoveries

"our passport to the future" but warned against "hasty spending that leaves for future generations only debts and desperation." Nevertheless, the new production-sharing regime fortifies a politically-protected state capitalism with broad discretionary powers and little transparency. A reinforced Petrobras monopoly would reduce chances for competition and for spreading risk among several companies. The new laws oblige Petrobras to become the operator, with a 30% minimum stake, of all exploration blocks in "strategic" deep-water areas embracing 149,000 km², an obligation that would strain Petrobras's already stretched manpower, financial and technical capacities. All operating decisions, including contracting of personnel, suppliers and service providers, would be subject to veto by political appointees in a new state company, PetroSal Petróleo, supervising these ventures.

The idea of Brazil as a "resources power" was reinforced by a new frontier in petroleum discovery, among the last of such frontiers on this planet. While Brazil's deep-water oil discoveries are a major target in the worldwide search for new reserves, Petrobras may have to move more slowly and cautiously in overcoming limitations in financial, technical and manpower capacity.

Lula's popularity was based on a huge consumption boom. The boom was fueled by big increases in government employment and salaries as well as a tripling of transfer payments, including the *Bolsa Familia* program that pays small monthly sums to mothers to keep their children in school. The transfer payments and a big increase in formal employment

contributed to the lifting of some 29 million Brazilians out of poverty. Brazilians are enjoying the fast growth of consumer credit to buy domestic appliances, computers, motorcycles, cars and new homes, with personal loans growing by 26% yearly since 2003, at interest rates exceeding 40% that now absorb as much as 40% of monthly income of indebted families. Lula's big bet on consumption rather than investment deprived Brazilians of a long-term strategy. It has weakened the fabric of democracy by using easy credit to raise unrealistic expectations.

Brazilians many times have taken benign outcomes for granted. Hence this warning in 2009 from the late Italian-born geologist Giuseppe Bacocoli in his book *O Dia do Dragão* [*The Day of the Dragon*], a reflection on his three decades of exploration for Petrobras:

Many have spoken of the low exploration risk of the pre-salt. Not so! Even in the cluster of fields in the Santos Basin where Tupi [Lula] was found, it is necessary to operate in waters 2,000 meters deep and drill through thick beds of salt.

Discoveries 6,000 meters deep also occurred in the Gulf of Mexico, but there is nothing else like ours. We are in one of the deepest oilfields ever found.... In Brazil long years of patient ant-like work have gone into proving that we have a competent state oil company; that we developed competitive knowledge and technology; that we have a good regulatory regime; that we offer political stability with clear rules without tearing up contracts. We cannot risk losing all this when, hearing the ephemeral song of a grasshopper, we precociously exult about winning a lottery prize.

2. The ascent of Petrobras

Petrobras is one of the world's most successful state oil companies. Its creation in 1953, after intense political debate, came as nationalism surged among Latin America's extractive industries. Brazil's first state oil monopoly, the National Petroleum Council (CNP), was created by decree of President Getúlio Vargas (1930-45; 1951-54) in April 1938, barely a month after the nationalization of private oil companies in Mexico. The CNP was modeled after Argentina's YPF (*Yacimientos Petrolíferos Fiscales*), organized in 1922 as Latin America's first state oil company. In July 1938, Brazil's Academy of Arts and Science awarded a gold medal to YPF's founder, General Enrique Mosconi, a prophet of Latin America's oil nationalism who became a guiding figure for the Brazilian military leaders who played a key role in persuading Vargas to create first the CNP and then, in 1954, *Petroleo Brasileiro S.A.* (Petrobras).

In August 1954, President Vargas shot himself in the heart following disclosure that one of his aides was involved in an assassination attempt

against Carlos Lacerda, a journalist who was his main political enemy. In his suicide note, Vargas charged that "a subterranean campaign of international groups joined with national groups" had tried to block creation of Petrobras four months earlier. While this "subterranean campaign" was never explained further, mistrust of foreigners and dependence on them remained one of the themes underlying the many controversies surrounding the development of Petrobras.

Petrobras thrived in the crosswinds of nationalism and internationalism. By the early 1980s, it became the largest company in South America, with \$18.3 billion in revenues and ranking 18th among all companies, public and private, outside the United States. By 2009 Petrobras and its 81 subsidiaries had formed a sprawling conglomerate that earned R\$230 billion (US\$132 billion) in revenues, equal to 7% of Brazil's GDP, which would rank it the 18th largest company in the *Fortune Global 500*.

Created six decades ago as Brazil's

answer to the foreign oil "trusts," Petrobras grew rapidly both as a conglomerate and a vertically-integrated major oil company at a time when that kind of private enterprise had been falling into eclipse. In Brazil, Petrobras today exercises far more political and economic power than that attributed to John D. Rockefeller's Standard oil trust at the time it was broken up in 1911, in an anti-trust case decided by the United States Supreme Court. Despite many controversies, Petrobras won acceptance as a vital national institution performing critical functions. In his *Oil and Politics in Modern Brazil*, the Canadian historian Peter Seaborn Smith observed:

Petrobras came to the fore as apparently the only solution to the problem indicated by the myths: how to develop Brazil's reputedly vast oilfields without having 'the trusts' seize control of them. Indeed, from an entirely realistic standpoint, Petrobras was the only viable solution, even if the problem were only to carry out a thorough

exploration of Brazil's sedimentary basins. Foreign companies had not, with few exceptions, indicated any interest.

When Petrobras was founded, its technological dependence on foreigners was dramatized by the hiring of Walter Link, former chief geologist of Standard Oil of New Jersey (now Exxon), to organize the new Petrobras exploration department. Link's then fabulous salary of \$100,000 per year aroused such indignation in some political circles that the finance minister refused to provide the foreign exchange to pay him, so the army disbursed the money. In 1954 Brazil had no university courses in geology. Standard Oil's Venezuelan subsidiary (Creole) and Davy McKee, one of its leading contractors, agreed to train Petrobras technicians.

When I interviewed Link at this home in Laporte, Indiana in 1975, he explained: "There were only 64 geologists in Brazil when I got there in 1954. We immediately sent 26 Brazilians to universities in the United States for training. Petrobras set up a geology department at the University of Bahia, near where oil was first found in Brazil, and then other Brazilian universities followed suit. We wanted to explore in the Amazon, where the big problem was access. We even lacked boats to move supplies along the jungle rivers. So we bought 22 boats in New Orleans in order to begin geophysical work."

Discoveries in Amazônia

Between 1954 and 1960, Petrobras spent US\$300 million on exploration, described at the time as the largest single such investment in the world. Great excitement spread through the country when, in November 1955, Petrobras struck oil at Nova Olinda on the Madeira river, one of the Amazon's main tributaries, in a well started

by the CNP in 1951 that went beyond 2,700 meters in depth before penetrating a thin formation containing light crude.

The hopes of many Brazilians who believed that the heartland contained abundant oil seemed vindicated. Some foreigners supported this view. The American geologist F. B. Plummer surveyed the north-east for the CNP in 1947 and then wrote: "The Piauí-Maranhão basin will supply petroleum for all Brazil and for Mexico and the Midwest of the United States. The region contains thick sediments of schists and

Link family



Walter Link, 1954

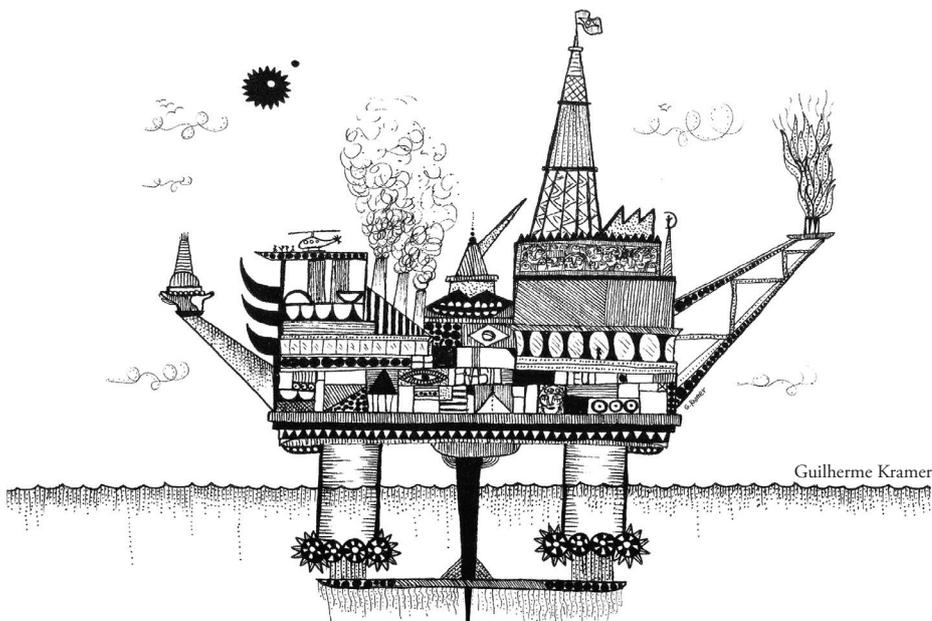
limestone, with great domes and anticlines."

The region surveyed by Plummer never produced significant amounts of petroleum, even though nearby areas of the Amazon delta and the continental shelf later were explored by foreign companies under "risk contracts" with Petrobras. Moreover, after 4,000 barrels of oil flowed from the Nova Olinda well during tests, the discovery was declared non-commercial, though somewhat more productive than much more shallow wells drilled by government crews along other Amazon tributaries (at Itaituba and Bom Jardim) in 1926-32 that brought forth oil shows and

produced some natural gas. Between 1953 and 1967, Petrobras drilled 156 wells in Amazonia, mostly in the Middle Amazon region of the Nova Olinda discovery. However, exploration was still confined largely to the banks of big rivers. Surveys deeper into the jungle had to await development of large helicopters during the Vietnam war, which later carried heavy drilling equipment into more remote areas, as well as development of lighter and waterproof geophysical equipment that enabled seismic crews to roam more widely to seek structures that could bear oil or gas. The search for oil and gas in Amazônia continues, by Petrobras and by HRT, a new private company staffed by former Petrobras technicians.

Initially, little attention was paid in Brazil when Link and the Colombian chief geologist of Petrobras, Luis Morales, presented papers at the Fifth World Petroleum Congress in 1959 that took a pessimistic view of the prospects of finding large quantities of oil on the Brazilian mainland. However, Link voiced more optimism about oil prospects offshore on the continental shelf, and even expressed guarded hope for eventual discoveries in the Paraná basin in southern Brazil, which is covered by a thick layer of basalt that limits the quality of geophysical surveys. Major offshore discoveries had to await development of more advanced technology for seismic surveys and more powerful computers for processing the geophysical data.

The *Oil and Gas Journal* published a shorter version of Link's paper that also went unnoticed in Brazil. In 1960, when Link resigned and presented his final report to the President of Petrobras, his views were leaked to the Brazilian press, provoking political controversy but gradually winning acceptance. Brazil did not show promise of becoming



self-sufficient in oil until the early 1980s, when ethanol began making deep cuts in petroleum product consumption and when offshore activity, begun in 1967, led to big production increases.

When Petrobras was founded in 1954, Brazil's oil production was only 2,721 BD, less than 2% of the country's consumption, and estimates of reserves hovered around 100 million barrels. During its years of infancy (1954-60), Petrobras increased production to 80,910 BD by developing the CNP's 1939 Bahia discovery. But consumption rose at the same time from 150,000 BD to 264,000 BD. Production ran a losing race with consumption until consumption peaked at 1.1 million BD in 1980 and then began to decline.

During the formative years of Petrobras, the cost of big annual increases in consumption was cushioned by the glut in world oil markets. Although the volume of Brazil's crude oil imports rose from 112,000 BD to 282,000 BD between 1957 and 1969, total foreign exchange outlays for these imports remained flat in nominal terms and fell in real terms. According to the International Monetary Fund (IMF), oil import costs declined steadily from US\$262 million in 1957 to US\$199 million

in 1965 before rising to US\$274 million in 1969.

A buyer's world market

Exploiting its monopoly purchasing power for Brazilian imports in a buyer's world market, Petrobras obtained discounts in different ways. In 1960, *Platt's Oilgram* called Petrobras the "largest outside buyer of crude oil today". In 1965, *Petroleum Intelligence Weekly* reported that Petrobras "buys crude at prices as low as or lower than virtually any other oil importer", after it unilaterally extended payment terms from 120 to 180 days and, in June 1964, the new military regime decreed that Brazil's suppliers would have to take at least 20 per cent of the contract price in Brazilian exports rather than cash. Sellers of crude to Brazil wound up giving cash discounts of up to 4%.

"We placed our most important orders in March or April, at the end of the Northern Hemisphere winter, the time of the year when world demand for oil is weakest", explained Shigeaki Ueki, former president of Petrobras (1979-84), in an interview. As commercial director of Petrobras earlier in his career (1969-74), Ueki was responsible for all Brazil's oil trading before becoming Minister of Energy and Mines (1974-79), developing

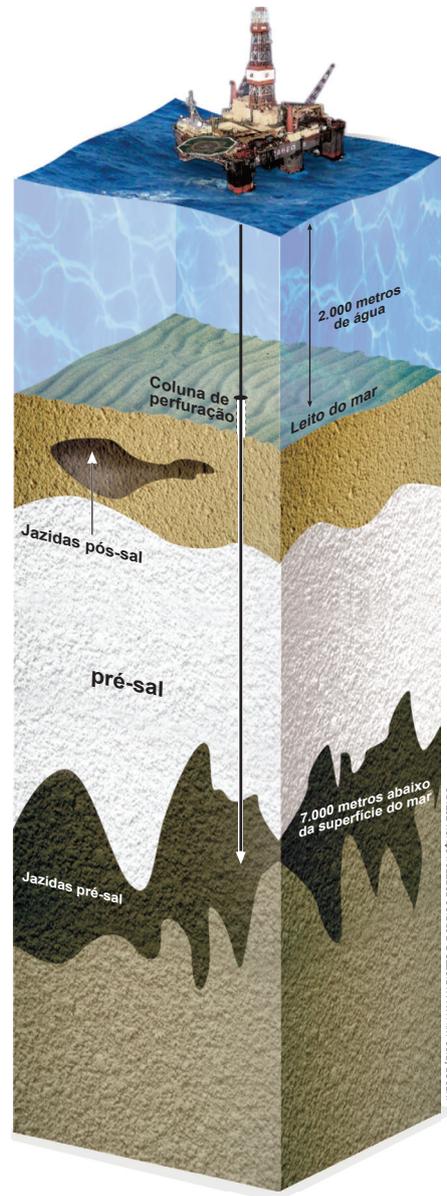
a close working relationship with General Ernesto Geisel during the 15 years in which Geisel dominated Petrobras' activities. "In 1969 we even managed to buy oil at 99 cents a barrel from Egypt at a time when the Nasser regime was having foreign exchange problems after its defeat in its 1967 war with Israel. Petrobras was a much-solicited customer in those years, both by the majors and by independents, which had emerged as big players in the world oil market during the crude glut of the 1950s and 1960s."

The military takeover of April 1964 was a turning point in the development of Petrobras. Coming at the end of the state company's first decade, it ended the political struggles and rapid turnover of company presidents that plagued its operations. The military set the course for its professionalization and expansion over the next two decades. By 1961, the unions had become strong enough to impose their own candidate for company president and by early 1964, after a series of strikes, had forced the nationalization of the small refineries that remained in private hands. In *Oil and Politics in Latin America*, George Philip of the London School of Economics wrote:

The 1964 coup was technocratic rather than economically liberal at least in terms of its effect upon Petrobras, ending the search by Petrobras managers and workers for a base outside the organization as a weapon in internal political conflicts, and the consequent substitution of political for organization criteria in internal decision-making... There was a limited amount of purging and the relatively stable and authoritarian political climate discouraged disgruntled Petrobras employees from pressing their grievances through political action. However, the economic liberals, who had

been prominent in fomenting the 1964 coup, made very little progress in changing the structure of the oil industry.

Petrobras continued to grow under both civilian and the military rule. Its oil import monopoly was decreed in 1960. One of the last acts of President João Goulart before fleeing the country in 1964 was to sign a decree nationalizing the remaining private refineries, a move not rescinded by the new military regime. A new petrochemicals subsidiary, Petroquisa, was formed in 1967 to dominate this fast-growing industry by monopolizing production of basic feedstocks and entering into downstream joint ventures with private firms. In 1971, another subsidiary, Petrobras Distribuidora (BR), was set up to compete with foreign oil companies that, between them, still had the lion's share of retail sales. Between 1970 and 1978, both net sales and net income, expressed in current dollars, multiplied roughly tenfold, rising to exceed US\$1 billion, even as Brazil had to borrow abroad to continue importing increasing quantities of expensive oil, contributing to the debt crisis of the 1980s. But the surge of oil prices hugely expanded Petrobras' cash flow and profits, as it did for big oil companies all over the world. As did the majors during the 1970s, Petrobras appeared to shift the focus of its business, as well as the purpose of its monopoly role, from the old mystique of achieving self-sufficiency for Brazil in oil production toward expansion into downstream enterprises – from refining and transport to petrochemicals, fertilizers, mining and promotion and trading of Brazilian exports – that made it look like an energy-related conglomerate. However, after the second oil shock, which shook the world industry much more than the first, Petrobras



returned to its old mission with added desperation and zeal as the average price of imported crude rose from US\$13 a barrel in March 1979 to a peak of US\$34 in October 1981. In those years, however, Petrobras' investments in offshore exploration and development were beginning to mature, giving new strength to the old dream of self-sufficiency.

Bahia and Angola

The career of Armando Guedes Coelho embodied the ascent of Petrobras in the world oil industry. Born in the interior of Goiás State, he joined the company in 1964 as a refinery engineer in Bahia to become later head of logistics, then commercial director during the oil crises of the 1970s,

then industrial director, then successively head of Petroquisa (petrochemicals subsidiary), BR (domestic distribution) and Interbras (international trading) before serving as company president in 1988-89. Searching for oil in the Middle East, Petrobras in 1975 discovered the supergiant field of Majnoon (12 billion barrels reserves) in the marshes near Basra in Iraq, at the disputed border with Iran, drilling 20 wells before being forced to abandon Majnoon after the outbreak of the Iraq-Iran war.

“I went to the Middle East more than 500 times: Iraq, Saudi Arabia, Iran, Algeria, also Nigeria. Brazil had no credit and I had to buy large volumes of petroleum, 800,000 barrels a day,” Guedes recalled. In those years, he was able to barter Middle East crude oil for Brazilian products such as military hardware, frozen chickens, canned beef, soybean oil and sugar. Long before that, as a young chemical engineering graduate, he received a hint of the Brazilian oil industry's future in his first job analyzing crude oil in the laboratory of the Landulfo Alves refinery in Bahia. “A supervisor gave me a sample of crude oil to analyze for processing in refineries and asked me where the oil came from. I tested the oil for a couple of days and sent a report saying that the oil came from the Carmópolis, Brazil's first giant field, discovered in 1963 in the neighboring state of Sergipe. ‘Wrong,’ said my supervisor. ‘This oil comes from Cabinda in Angola. If you join the maps of South America and Africa, Carmópolis and Cabinda would lie right next to each other.’ That was before the separation of the two continents was confirmed by geological research.” That also was four decades before supergiant oilfields were discovered below the massive salt beds of the Santos Basin, inspiring a new wave of hope.

3. Below the salt

“When we drilled beneath the salt, we entered the realm of the unknown,” said Peter Szatmari, a soft-spoken, erudite Hungarian-born geologist of poetic inspiration who works at Cenpes, the research center of Petrobras. “We were finding something entirely new beneath the ocean, as when Columbus was discovering a new continent.”

Szatmari is one of many foreigners who, over the centuries, found a new world in Brazil. Having studied salt formations since his escape from Communist Hungary in the 1950s, at the universities of Edinburgh, Princeton and Columbia, Szatmari came to Rio de Janeiro in 1973 to teach salt tectonics to Petrobras geologists. “The ancient continent of Gondwana divided and made way for a primeval sea,” Szatmari told me. “The salt from that sea evaporated to form beds which sealed the concentrations of microbiolate fossils for millions of years.” Around the time that South America and Africa became separate continents, dinosaurs roamed the ancient Brazil Shield, billions of years old. The process of separation of Africa and South America continues today at the rate of a few centimeters every year.

The discovery of supergiant oil fields below massive salt beds under the South Atlantic is fruit of a long and tortuous accumulation of knowledge on a global scale, viewed through a prism that focuses on the very remote past. A century after Columbus sailed to what still is known as the New World, Abraham Ortelius, scion of an Antwerp merchant family and author of the first modern atlas, *Theatrum Orbis Terrarum* (*Theater of the World*), wrote in 1596 that the Americas were “torn away from Europe and Africa... by earthquakes and floods,”

adding: “The vestiges of the rupture reveal themselves, if someone brings forward a map of the world and considers carefully the coasts of the three [continents].”

But it was not until 1912 that a coherent theory of continental drift was formulated by an intrepid astronomer named Alfred Wegener, the son of an evangelical pastor. Wegener published a paper in a German journal of geography rejecting the idea that the Mid-Atlantic Ridge beneath the ocean, the longest mountain range in the world, was a relic of a land bridge between South America and Africa. He argued that the great ridge “should be regarded as the zone in which the floor of the Atlantic, as it keeps spreading, is continuously tearing open and making space for fresh, relatively fluid and hot [rock rising] from depth.” Wegener survived battle wounds in the arm and neck after being drafted into the German army at the start of World War I, only to freeze to death in 1930 while exploring the Greenland icecap. But he left behind a path-breaking book, *The Origin of Continents and Oceans* (1915; 1928), on the separation of great land masses from the primeval continent that he called Pangaea, from which the present continents emerged. Continental drift explained the jigsaw-puzzle match between the coasts of South America and Africa, with its closest fit near the Brazilian city of Fortaleza and Accra in Ghana, correlated by fossil remains on the two continents.

Wegener’s radical ideas were rejected by many scientists until proven by new radioactive dating techniques, applied widely in the 1950s and 1960s. Tests of radioactivity in rocks 2 billion years old in Northeast Brazil and West Africa by geologists at MIT and the

University of São Paulo showed that these regions were once part of the same land mass.

“The opening up of the oceans, the fruition of geophysics as a field method, the advent of the airplane as a field vehicle, and the wide availability of government support have combined to bring about this new age of exploration,” Robert Phinney of Princeton University observed in 1968. These searches produced a mature theory of plate tectonics, holding that the Earth’s outermost layer is fragmented into a dozen or more large and small plates that are moving relative to each other as they ride atop hotter, more plastic rocks mobilized by heat surging from the planet’s core. The process of separation of South America from Africa took nearly 40 million years.

“Ring of Fire”

The breakup of Gondwana began 150 million years ago with a series of cataclysmic events, perhaps larger than the great Asian earthquakes and tsunamis of 2004 and 2011 that spread havoc along the “Ring of Fire” in the Pacific and Indian Oceans in bursts of energy that temporarily altered the Earth’s rotation. The breakup began as two giant plumes of molten magma erupted from the Earth’s mantle – the St. Helena plume to the north and at Tristan da Cunha to the south – forming what is now the chain of submerged mountains and volcanoes known as the mid-ocean ridge. The plumes of magma emerged as heat from the interior of the planet caused a thinning, weakening and swelling of the continental crust in what is now the southernmost part of South America, creating hot spots in the crust and a series of fractures. The fractures opened a breach that split in two the tectonic plate of

the supercontinent of Gondwana, creating two plates: South America and Africa. The breach widened over millions of years as the magma cooled to become denser continental formations that sagged to form basins that became lakes where microorganisms flourished, only to be buried under the beds of salt that remained after the waters evaporated.

Scientists still debate the origin of water on our planet. But most now agree that, as a team of Petrobras geologists state in an encyclopedic work, *Sal: Geologia e Tectônica: Exemplos das Bacias Brasileiras*: “With the cooling of the planet [billions of



Portrait of Abraham Ortelius by Rubens

years ago], water in the atmosphere began to precipitate to form the sea during the initial phase of the Earth’s history and led to the subsequent formation and transformation of evaporites, or salts deposited by periodic evaporation of seas and lakes.” The process moves slowly, but on a colossal scale. A salt bed 100 meters thick needs evaporation from accumulations of water totaling 6,000 meters, depths not seen today except in oceanic trenches where tectonic plates have submerged. In other words, the salt beds, 2,000 meters thick, capping Brazil’s deep-water oil and gas discoveries in the South Atlantic, would need successive water accumulations totaling

120,000 meters in countless cycles of replenishment and evaporation.

Salt is a common substance, basic to the metabolism of living cells. Although it long had been a commodity of trade and a prize of warfare in preindustrial societies, the evolution of modern drilling techniques by the late 18th Century showed that salt deposits lay beneath large swaths of the Earth’s surface, conspicuously at the edge of present or primeval continents, as in the Persian Gulf, Iran and the Caspian Sea of Central Asia, where larger volumes of oil have been found.

One salt belt spreads below much of central and northern Europe, capping the huge deposits of oil and gas found in sandstones beneath the North Sea in the 1950s and 1960s, as oil companies developed drilling techniques that could reach 10,000 feet below the seabed. Another belt stretches across the entire Great Lakes region of North America, embracing a salt dome near the village of Titusville, Pennsylvania where “Colonel” Edwin Drake drilled 69 feet in 1859 to find “rock oil,” used for illumination and medicinal purposes, launching the first stampede of prospectors in what became the modern petroleum industry.

Salt domes and other subsurface bulges of salt, known as diapirs, became a prime target of oil exploration as impermeable traps for petroleum embedded in the pores of reservoir rocks below. Another visionary, a one-armed mechanic named Patillo Higgins, became obsessed with the potential of a salt dome in Texas near the Gulf of Mexico, called Spindletop, that in 1901 produced a gusher spouting 75,000 barrels daily. Beneath the Gulf of Mexico, created some 60 million years ago by invasion of waters from the Pacific Ocean as the western portion of Pangaea divided to separate the continents of North and South America, salt deposits

cover 85% of the continental shelf. Being lighter, more plastic and more buoyant than surrounding sedimentary rocks, the salt is forced upward by tectonic movements, like toothpaste extruded from a tube, to form giant submerged canopies. The resources hidden under extensive canopies of salt revealed their potential in 1996, when Phillips Petroleum found oil from its Mahogany platform beneath a salt sheet some 3,300 meters thick. In the Gulf of Mexico, wells were drilled more recently in waters more than 2,000 meters deep, at similar depths to the Petrobras discoveries in



Alfred Wegener

Alfred Wegener Institut

the Santos Basin, and prospects have been located beneath salt canopies more than 6,000 meters thick.

The penetration of oil exploration below the salt was made possible by a revolution in geophysics. Salt plays havoc with seismic sound waves, which can travel twice as fast through salt than through surrounding sediments, distorting images the way a pencil seems bent when placed inside a glass of water, “like a blurry, snowy TV picture,” said one geophysicist. The pioneering discovery of the subsalt Mahogany field by Phillips was made possible by innovation in processing by supercomputers of 3D seismic surveys, developed by Texas-based Anadarko, the only foreign



World Map by Abraham Ortelius, 1570

independent company now exploring Brazil's presalt formations. "We are at the dawn of the global subsalt play," said Clint Moore, who pioneered Anadarko's seismic processing in the 1990s. "Now that we have a new tool to see under and within the salt basins of the world, it will make a huge difference in the amount of oil and gas that can be discovered in these complex geological basins." Petrobras absorbed these new techniques in its deep-water discoveries.

Step by step, Brazil's exploration horizons widened to find new prospects over several decades, from dry land to offshore, then from shallow to deep and ultradeep waters before reaching the presalt discoveries of the Santos Basin. In the 1930s and 1940s, the National Department of Mineral Production (DNPM) made several minor discoveries in the Recôncavo Basin of Bahia. Following rift trends northward into the Sergipe

Basin, Petrobras found its first giant field at Carmópolis in 1963. In a desperate search for self-sufficiency as oil consumption and imports surged, Petrobras increased its exploration budget by 32% in 1967, leading to a strategic decision: ordering a seismic survey of all 17 sedimentary basins along its coast, covering some 4 million square kilometers, using the still-rudimentary 2D technology.

Drilling crews were probing beneath shallow waters of the continental shelf, into ancient river deltas buried millions of years ago, where low-quality seismic surveys conducted under Walter Link's supervision in the 1950s suggested the presence of salt domes. "We debated among ourselves whether the anomaly we detected was an upward thrust of magma or a salt dome," said Wagner Freire, who was chief of geophysics at the time. "But the seismic waves traveled so

fast through the formation that we were sure it was salt, raising hopes that we were finding another Gulf of Mexico." However, they found only dry holes off the coast of Espírito Santo State before moving north to the Sergipe-Alagoas Basin, where in 1968 they found the Guaricema field below 30 meters of water off the delta of the São Francisco River, Petrobras's first offshore discovery.

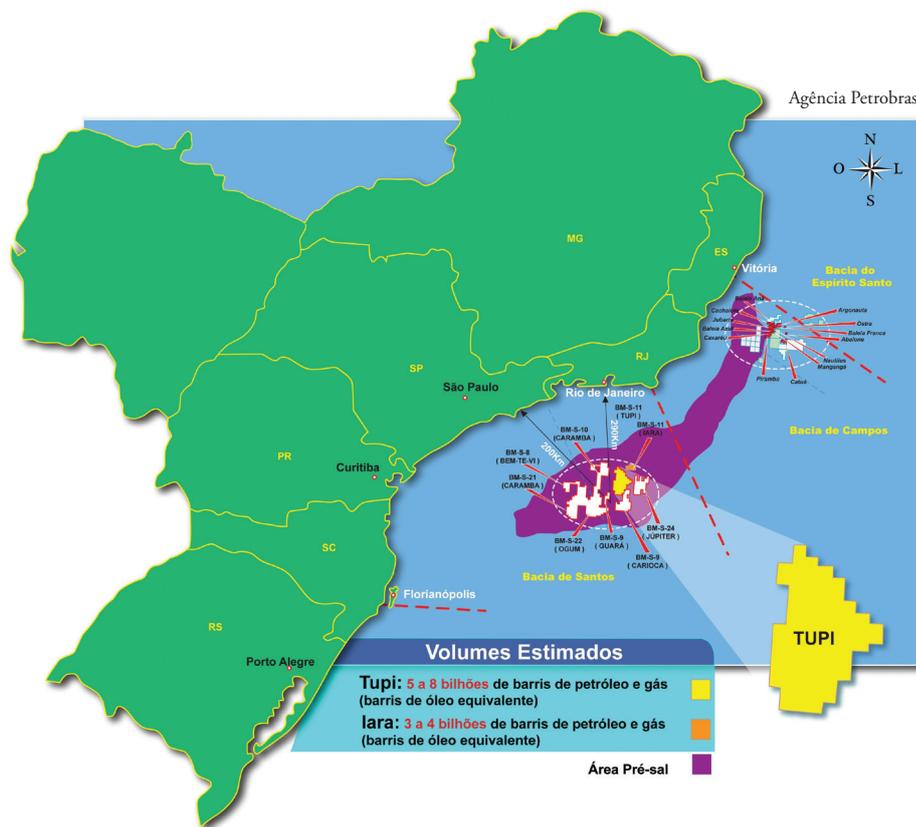
Advances in seismic imagery

During the 1970s, extensive oceanic belts of salt were found by seismic surveys along the coasts of South America and Africa. Before then, these beds were drilled on land in 1959 and in Brazil's first offshore exploratory well in 1968. After drilling eight dry holes, the crews found the Garoupa field in 1974 under 120 meters of water, overlaying the salt, leading the rigs to move into ever greater ocean depths along the

continental slope as it descended toward the abyssal plain of the South Atlantic. In the Campos Basin, now Brazil's main producing region, more than 1,100 wells were drilled and 50 fields discovered since then.

The advances in imagery derived from seismic soundings led to offshore petroleum discoveries at ever-greater depths, in a process akin to medical tomography, enhanced over the past half-century by ever-more sensitive equipment and faster computers. Seismic surveys in two dimensions (2D) in search of petroleum began on land in 1915, by bouncing sound waves off subsoil formations for mapping their density. These early seismic surveys could identify larger profiles of formations without getting detailed information about the imaged rocks or the pore fluids inside them. With commercial development of 3D surveys in the 1970s, along with more powerful computers, better sensors and unmanned vehicles operating in deep waters, geophysicists were able to map more detailed cross-sections of extensive oceanic salt belts beneath the continental margins. In 1975 Petrobras started sending professionals to foreign universities to earn advanced degrees in geophysics. Since 3D seismics were introduced in Brazil in 1978, the "information density" of these surveys (seismic traces per square kilometer) surged from less than 100,000 to one million.

In 1994, 4D seismic surveys began, which are reruns of 3D surveys of the same territory with enhanced equipment, enabling geophysicists to reduce drilling risk by detecting movement of oil, gas and water through a reservoir over time as extraction escalates. These can be large-scale operations. In a 4D survey of 1,520 km² of oceanic territory in the Campos Basin, Brazil's main producing area, a seismic vessel bounced sound waves off complex geological formations



as it towed 10 cables, each 6 km. long and connected to detectors on the seabed, generating data to be processed in a large computer. Newer seismic techniques, called borehole geophysics, have enabled surveys to monitor the progress of drilling thousands of meters into salt beds and detect changes in the nature of formations ahead of the drill bit. Petrobras had been probing shallow waters of the Santos Basin since 1969, making minor discoveries over the years. As exploration went to ultra-deep waters over the past decade to reach below the massive salt beds that trapped fossilized microbes after the continents divided, new technological obstacles had to be overcome. Drilling rigs had to handle the greater weight and volume of pipe, risers, drilling fluids and cement to complete wells penetrating beneath 7,000 meters of water, salt and sedimentary rock, hundreds of kilometers offshore. Oil industry chemists had to develop drilling and completion fluids that could perform

in abrupt thermal gradients, from the extreme heat of the reservoirs to near-freezing temperatures at the subsea wellheads to the tropical atmosphere on surface rigs. These challenges led to innovations such as expandable casing, heated flowlines, advanced chemistry and super-sized drilling vessels.

Petrobras processed 3D seismic surveys covering an area of 25,000 km² to analyze the enormous salt beds in the Santos Basin, at some places 5,000 meters thick, that trapped huge volumes of oil and gas in pores of sedimentary rocks below that were the target of the Tupi/Lula discovery. These salt beds were formed in a narrow gulf or lagoon some 1,800 kms. long by evaporation of a series of floods during a brief period of geologic time, some 500,000 years, coinciding with the crunching of the primeval landscape by the surges of magma from the Earth's core that separated the continents of South America and Africa. Petrobras geologists said they still cannot explain why these thick salt beds were deposited over an area of 50,000 km², arguing that "the real

tectonic-sedimentary significance of these salt deposits is the key to a better understanding what drove the opening of the South Atlantic.”

The dimensions of these geological features are enormous. “In the Santos Basin, the continental crust extends offshore for 700 kilometers in the

region of the São Paulo Plateau,” a submerged volcanic rise, Petrobras geologists told the Offshore Technology Conference (OTC) in Houston. “The final breakup between South America and Africa was not symmetrical –the zone of stretched continental crust is wider along the

Brazilian margin than along the African margin. Using new strategies in seven years of work in pursuing innovative procedures, adjusted to the geological challenges of the area, Petrobras obtained a tremendous exploratory success and a world-class petroleum province was found.”



Agência Petrobras

FPSO Cidade de Angra dos Reis, deck crammed with processing machinery

4. Risks and promises

Developing deep-water discoveries in the Santos Basin is forcing Petrobras to wrestle with frontier challenges in technology and logistics on a scale without precedent in the oil industry as it leaps into the future. Although Brazilian officials promised “extremely low exploration risks and great profitability” in seeking to increase the state company’s control of the giant oil fields found in the South Atlantic, the risks are now appearing. While Petrobras President José Sérgio Gabrielli justified low exploration risks by the high success rate in

drilling for deep-water oil, he later admitted to substantial “development risks” in bringing these resources into production.

The world of deep-water oil is inhabited by arrays of colossal machines and installations, engineered to such demanding tolerances as to permit continuous operation at varying temperatures and pressures of ocean depths for decades at a time. Gigantic specialist vessels, some carrying cranes with a lifting capacity of 10,000 tons, move huge subassemblies over thousands

of kilometers between shipyards and factories on different continents and lay hundreds of kilometers of flexible pipe, tubing, risers and insulated electrical wiring to connect drilling and production platforms with exotic apparatus thousands of meters below on the seabed.

Floating a huge component to the place of assembly can be more expensive than its fabrication, with rentals of some deep-water construction ships costing \$500,000 a day. A subsea Christmas tree (the system of valves and electronics used

to control the flow from wells) can weigh 30 tons, a manifold 200 tons. Suction anchors installed in arrays on the seabed can weigh 160 tons each and rise to the height of a small apartment building. Inspection and repair of subsea equipment is done by large robots housed in undersea garages.

Petrobras has set an ambitious goal to produce 6.4 million barrels daily of oil equivalent (BDOE) by 2020 in Brazil and internationally (mainly offshore in the Gulf of Mexico and West Africa). This would be 132% more than in 2010. Brazil would produce 4.9 million BDOE, including 2 million BDOE from the Santos Basin. But private analysts have been skeptical of these goals, since historically Petrobras has fallen short of its announced goals by 13%. The investment bank Credit Suisse forecasts 2020 production at 4.6 million BDOE, 28% below the Petrobras target.

Depletion

If Petrobras were to reach these goals, it not only would be doubling output but also be compensating for depletion of 2 million barrels daily of current capacity at the rate of 10% yearly over the current decade. Production from the seven major fields of the Campos Basin, with 44% of the domestic output of Petrobras, has been falling steadily over the past two years, at annual rates of up to 20%, after more than two decades of operation.

Depletion was signaled by increasing amounts of water produced along with oil and gas from the wells. The most dramatic example is the giant Marlim field, where production fell from 645,000 BD of oil and gas in 2002 to slightly more than 200,000 BD after declining by 30% in 2010. Meanwhile, other Campos fields are reaching or already reached peak production

and may soon decline, notably Marlim Sul, which in 2010 produced 253,000 BD, or 13% of Petrobras output. To meet this challenge, Petrobras has launched the Varredura (Search) program in the Campos and Espirito Santo basins, identifying 284 prospects with recoverable volumes of 2.2 billion BOE that could be tied to existing infrastructure from older fields.

Consultants say that Petrobras may spend \$1 trillion in coming years in capital and operating costs of deep-water projects, a sum equal to half of Brazil's GDP for 2010, in by far the biggest industrial undertaking in Brazil's history. Petrobras's annual capital spending for the current decade, at more than \$50 billion, is much more in constant dollars than NASA's yearly budget in the 1960s, when the United States was preparing to send a man to the moon. Few public agencies in the world can match the scale and scope of its contracting activities.

In the Santos Basin, bases for large fleets of helicopters and support ships should change the ecology of the seashore, with the port city of Santos becoming a new managerial hub for offshore development. Guilherme Estrella, Petrobras's director of exploration and production, imagines 50 platforms harvesting the initial discoveries, each consuming 100 megawatts of electricity, totaling 5,000 megawatts of capacity generated by 200 gas-fueled turbines, equal to the consumption of Greater São Paulo, with its roughly 20 million inhabitants.

"In the pre-salt discoveries, we have two kinds of logistical problems," Gabrielli explained in an interview. "The first is about people, which is a problem of distance. In the Campos Basin, currently our main producing area, we transport more than 60,000

people each month to and from the platforms 150 kilometers offshore by helicopter. But the pre-salt clusters in the Santos Basin can be 300 kilometers away, too far for large-scale helicopter transportation. So we first have to reduce the number of people working on the platforms by intensifying automation. We have to build offshore platforms midway between the coast and the pre-salt discoveries to serve as logistical hubs with sleeping quarters, so that workers arriving aboard boats can be distributed by helicopter to the operating rigs and platforms after overnight stays on the logistical hub. The second logistical problem is the delivery of supplies to offshore operations. You need transportation of chemicals, machines, electricity. We probably will have specialized platforms dedicated to generating electricity and others to mix chemicals for drilling fluids."

One difficulty of creating these hubs is assuring enough stability in rough seas to permit efficient mooring, landing and departure of ships and helicopters. "Everyone thinks it's easy, but it isn't," said José Formigli, Petrobras's manager of pre-salt operations. "And what's the price? We even were offered the use of aircraft carriers as hubs. But aircraft carriers have the bad habit of swerving from side to side. They have thin hulls that they need for speed, so when they stop forward motion they sway and helicopters can't land on them."

At the OTC Conference in Houston in 2009, Formigli explained why Petrobras must innovate to develop the pre-salt cluster, given the scale of production and the "unique characteristics" of the area: "ultradeep water, remote location, contaminants in producing fluids, high gas-oil ratio, etc." The main contaminants are carbon dioxide

and hydrogen sulfide. One major obstacle, Formigli said, is the lack of space on the decks of converted supertankers (FPSOs) used as production hubs, crowded with machinery because of the amount of specialized equipment needed to separate and process the natural gas contained in the crude oil, removing contaminants and reinjecting large volumes of gas, carbon dioxide and water back into the reservoir to maintain well pressure. This is one reason why the world oil industry is seeking to place more production equipment on the seabed.

Scientists and engineers at Cenpes, the research center of Petrobras in Rio de Janeiro, are trying to find a way of placing automated processing plants to separate oil, gas and water on the seabed, some 2,000 meters beneath surface waters. The plants would be powered by undersea electrical generators that also would pump oil and gas through pipelines laid along the bottom of the South Atlantic to gathering stations and terminals hundreds of kilometers away. Subsea pumping systems, gas/liquid and oil/water separation and raw water injection into wells are in the experimental prototype stage on the seabed of Brazil's basins.

Perdido

The industry's biggest conquest so far in installing production equipment on the seabed is Shell's \$3 billion Perdido platform in the Gulf of Mexico, mounted atop a moored floating steel cylinder at roughly the same distance from the coast as the Tupi discoveries. "Perdido opens up a whole new frontier in deep-water oil production," said Tyler Priest, an oil industry historian at the University of Houston. "It is the most technologically advanced facility in the world." Perdido

drills, gathers and separates oil and gas from some 35 wells spread over 80 square kilometers on the sea floor, housing sensitive equipment in a pressurized shed the size of a football field that is planted on the seabed to protect against undersea currents and avalanches. Data from the operation of the Perdido complex, as well as from Shell's BC-10 project in Brazil's Campos Basin, is monitored and analyzed at a remote control center in New Orleans. In the deep-water Parque das Conchas field in the Campos Basin, Shell in 2009 installed the first full-field development using subsea oil and gas separation and subsea pumping, even before this technology was incorporated in the Perdido complex that began operations in 2010.

To produce oil from deep waters 300 kilometers from the coast in the Santos Basin, Petrobras must overcome technical and logistical problems more severe than those faced by companies in the Gulf of Mexico, now the source of one-fourth of U.S. oil production, where underwater salt deposits cover 85% of the continental shelf.

The salt beds in the Santos Basin are very thick, in some places reaching 5,000 meters. They are plastic, mobile and heterogeneous, containing different kinds of salt, shifting position as drilling proceeds. "Drilling into the subsalt reservoir presents daunting challenges," Petrobras engineers observed in Houston. "Of all these challenges, salt creeping is the most common and difficult to manage." The salt beds are unstable and can collapse the casing that encloses the drill pipe and engulf the drill bit. "Microcarbonate reservoirs still are poorly known," said one veteran reservoir engineer. "The oil emerges from the reservoir very hot into a cool environment at only 4^o centigrade, congealing as wax to clog the pipe unless

special chemicals are added and the pipe is continuously lubricated." The instability of salt beds impedes horizontal drilling to increase recovery from reservoirs immediately below the salt.

Laying the pipe to send gas to the mainland is one of the complex engineering challenges that Petrobras faces in scaling up production. Oil can be shipped to market on shuttle tankers, but gas needs pipelines. The presalt discoveries forced Petrobras to think of expanding the gas market because of the huge volumes of gas in the flow of oil from these giant fields. Flaring of gas is now forbidden by law. Gas can be pumped back into the wells to sustain reservoir pressures, but not in the volumes expected when presalt production escalates.

So the Allseas Solitaire, the world's largest pipe-laying vessel, plied the Santos Basin in 2010 to install 200 kilometers of 18-inch pipe on the seabed 2,200 meters below to connect the Tupi/Lula discovery with the shallow-water gas field of Mexilhão and a coastal processing plant.

Over the past decade, pipeline companies followed petroleum exploration into greater ocean depths, negotiating the irregular subsea terrain, stretching over hills, valleys and trenches, to lay huge pipes over several hundred kilometers. The tubes are engineered to resist corrosion, pressure, hurricanes, earthquakes, mudslides, erosion and deep-sea pressures, for which careful geological surveys are needed to design the pipeline. The pipe sections are coated with heavy concrete and epoxy, to protect against floating as well as damage by seabed fauna such as barnacles, and are welded on the ship before lowering into the ocean. The Allseas Solitaire is 300 meters long, roughly the length of the biggest

aircraft carriers, not counting a 100-meter pipe-laying crane called a stinger that releases the tubing under water. The ship, which can carry 22,000 tons of pipes aboard, is kept on location by dynamically-positioned thrusters. At least 10 other pipelines like this will be needed for the Santos Basin as development accelerates. By 2020 Petrobras plans to drill a thousand wells, 40% for exploration and 60% for production, at a total cost of \$100 billion.

The devil is in the details

The laying of pipe is only one of the hundreds of complex operations needed to bring Brazil's deep-water discoveries into production. The demands of project management are testing Petrobras as few companies have been tested in the history of the oil industry. In the management of these mammoth projects, with many risks, the devil is in the details.

The risks of exploration and production in deep waters were dramatized in April 2010 by the blowout in BP's Macondo well in the Gulf of Mexico, an accident with many political, economic and ecological ramifications, caused by faulty maintenance and errors in responding to a gas leak that fueled an explosion. The \$560 million Deepwater Horizon was a 33,000-ton rig floating on pontoons and dynamically positioned by huge thrusters, with a derrick rising 20 stories above its top deck. It was a workhorse of the fleet of Transocean, the world's largest drilling contractor, which was operating 11 rigs in the Gulf of Mexico and another 11 offshore Brazil. A year before it exploded, burned and sank while trying to seal the Macondo well, killing 11 crew members, Deepwater Horizon set a world record by drilling 10,683 meters below surface waters in

BP's nearby Tiber field. Human and mechanical failures, including neglect of maintenance protocols for complex equipment, overcame redundant safety systems installed to prevent disaster. On the day of the accident, Transocean and BP managers on the rig were discussing a maintenance backlog from a BP safety audit listing 390 items demanding 3,345 man-hours of work.

"Modern oil and gas drilling rigs and producing platforms are enormous floating machines, with powerful engines and responsible for keeping within geologic formations large volumes of highly combustible hydrocarbons at high temperatures and pressures," according to a report on the accident commissioned by President Barack Obama. "Drilling rigs are dangerous places to work, dense with heavy equipment, hazardous chemicals and flammable oil and gas – all surrounded by an open sea environment far from shore, where weather and water conditions can change rapidly and dramatically." The commission added that the causes of the Macondo accident "were rooted in systemic failures by industry management, extending beyond BP to contractors" that operate worldwide.

Macondo

Disasters on the scale of Deepwater Horizon are rare, but near-misses are common. In the months before the Macondo accident, a blowout in Australian waters poured oil into the Timor Sea for weeks. In the Gulf of Mexico on a rig owned by Noble, a drilling contractor with a worldwide fleet of 71 rigs, an out-of-control well dislodged a two-ton piece of equipment on the deck, sending workers scurrying for safety. A gas leak on a North Sea production platform in Norwegian

waters lacked only a stray spark to set off a disaster like Macondo.

During 2009 in the U.S. Gulf of Mexico there were 28 major oil spills, gas surges and episodes of workers losing control of wells, a two-thirds increase over 2006. In the British North Sea there were 85 serious incidents over the past year, a 39% increase over 2009. In Norway, there were 37 such cases in 2009, up 48% from 2008. In Australia, there were 23 near blowouts in the first half of 2010, occurring at twice the rate of 2009. The accident records, supplied by the governments of these four countries, appeared in a survey by *The Wall Street Journal*, to which Brazilian authorities refused to contribute data.

The deep-water discoveries in the Santos Basin are roughly 300 kilometers from the coast, twice as far from shore as BP's Macondo well in the Gulf of Mexico. Gabrielli warned: "The industry has developed neither technology nor equipment for a rapid and adequate response to an accident of these proportions," adding that "containment barriers do not function adequately, the drilling of alternate relief wells takes too much time and the oil gathering technologies are insufficient. We must improve the mobilization capacity outside the company, of the armed forces, state and municipal governments and civil defense."

Petrobras is seeking to avoid trouble of this kind after suffering four major offshore accidents in recent decades, with scores of deaths and the loss in 2001 of the P36 platform in the Campos Basin. Gabrielli argued that the Santos Basin discoveries are so far from shore that a major spill may not damage coastal ecology, although this distance would frustrate rescue efforts by ships and helicopters to preserve lives and equipment.

5. The industrial challenge

José Sérgio Gabrielli de Azevedo, 61, may soon become the longest-serving CEO in the history of Petrobras. Many of his 33 predecessors as president over the past 57 years lasted months rather than years. They have been army generals, politicians, labor leaders, lawyers, bankers, engineers and geologists. An economist with a doctorate from Boston University and a member of the governing Workers Party (PT), Gabrielli was named by Lula to head Petrobras in 2005 after serving for two years as director of finance and investor relations. A tireless international traveler who eloquently proclaims the achievements and prospects of Petrobras to investors and the press, Gabrielli also skillfully navigates the rough waters of Brazilian politics, where his future may lie. Meanwhile, he tells audiences that the Petrobras investment program is the biggest in the world oil industry today, yet also voices concern about “critical areas, strangulation” in the supply chain.

“One of them is drilling rigs,” he said. “A rig takes three or four months to drill a well through 2,000 meters of water. A converted supertanker known as an FPSO (Floating Production Storage Offshore) becomes the hub of a production system, using 15 or 20 wells. So with one rig it takes four years to create a production system. Rigs are critical and Brazil doesn’t produce them yet. We also lack subsea systems, tubing to connect the ocean floor to the surface. We must advance in the area of large turbo-compressors, which are floating gas-fired electricity generators. We are talking about gigantic quantities of equipment. Each system produces from 100,000 BD to 180,000 BD. So if we are going to produce 4.5 million BD by 2020, we need 41 of these systems. Each system costs about \$3 billion. To operate, each one needs an average of

five support ships.” Petrobras plans to add 810 vessels of different sizes and complexity, including tankers and support ships (tugs, anchor handling, fire fighters, etc.), to its fleet by 2020.

In August 2011, Gabrielli told investors in London that Brazil’s presalt discoveries would be “at the same slope of production as in the first 10 years of the North Sea,” which peaked at 6 million BD in 1999. As a matter of fact, it took not one but four decades for North Sea production to peak after discovery in the Netherlands of the Groningen gas field in 1959.

Brazil and the North Sea

But there is a critical difference between deep-water oil in Brazil and the North Sea. While offshore Brazil is dominated by one company, Petrobras, as operator and buyer of equipment and services, development of the North Sea, as well as the Gulf of Mexico, was activated by scores of companies, sometimes competing and sometimes cooperating, engaging thousands of the best minds in geology and engineering to evolve new technologies and work methods for producing oil and gas in an extremely harsh marine environment. These companies included the majors – Exxon, Shell, BP, Texaco, Gulf, Mobil and Socal – as well as Norway’s Statoil and Norske Hydro and dozens of smaller independents like Phillips, Occidental, Conoco, Sohio, Hess and Ashland. These companies in turn created an intensely competitive market for hundreds of firms offering oilfield supplies, services and equipment, as clusters developed in the ancient fishing ports of Stavanger (Norway) and Aberdeen (Scotland). By contrast, Brazil’s emerging offshore supply industry is largely dependent on orders from a single buyer and on government finance.

“Strangulation and risk”

Brazil is now the world’s biggest market for goods and services in the offshore oil industry and Petrobras the biggest single buyer. Yet the scale, cost and complexity of these needs pose challenges to Brazilian industry in seeking a greater share of business opportunities. “The great strangulation and risk for pre-salt development is the incapacity of suppliers to deliver ships, equipment and machines on time and at reasonable cost,” Gabrielli warned. “When I speak of equipment I mean thousands of systems, some of them absolutely critical.”

According to a study by the consultancy Booz & Co., Petrobras will buy or rent \$400 billion in equipment and services during the current decade. For deep-water exploration and development over the next few years, Petrobras is expected to order 330 turbine-generators, 610,000 valves, 10,000 kilometers of subsea electrical cables (umbilicals), 17,000 kilometers of flexible tubing (risers), 4.8 million tons of steel, thousands of pieces of complex subsea equipment, demanding 68 million man-hours of engineering and a billion hours of construction and assembly labor. It remains to be seen whether Petrobras can mobilize sufficiently qualified technicians to formulate and manage efficiently orders of this size and complexity, without breeding stories of corruption and leaks of inside information.

As of 2009, orders from Petrobras dominated the world market for deep-water floating production systems, mainly FPSOs that receive, store and offload oil and gas from the seabed, with 23 of the 49 FPSOs operating worldwide, along with 10 of the 17 semi-submersible production platforms used globally. By 2020, Petrobras operations would

absorb 58 more drilling rigs (costing more than \$600 million each), 45 more production platforms and 309 supertankers and support ships. Ultra deep-water rigs are leased to oil companies at roughly \$500,000 daily to drill exploration wells costing \$100 million each, including geophysical and logistical support services.

The scale and complexity of deep-water operations engages an industry populated by thousands of contractors, ranging from multinational giants offering oilfield services, like Schlumberger and Halliburton, to small companies occupying technological niches. Others provide supply boats and still others housekeeping and food services for workers at sea for weeks at a time on rigs and platforms.

Petrobras is urging ABIMAQ (Associação Brasileira da Indústria de Máquinas e Equipamentos) to induce foreign manufacturers to establish operations in Brazil, mainly through partnerships with local companies. This strategy differs from those adopted by Norway, Britain, Korea and the United States to develop industrial suppliers for offshore activities. Weaknesses in basic education and research, both public and private, have left Brazil with a shortage of skilled manpower that has impeded adoption of the strategies of advanced nations.

The most technically advanced equipment and services are provided by multinational oligopolies controlling 90% of their specialized markets. Most of them either created local subsidiaries or bought or partnered with Brazilian companies to comply with local content rules. Rolls-Royce is investing \$60 million to build a factory to supply turbo-generators for offshore platforms, which will require key components from Brazilian suppliers. General Electric is investing \$120 million to grow its capacity to build subsea Christmas trees and risers after spending \$1.3 billion to buy

Wellstream, a British company that produces advanced tubing in Brazil. Caterpillar will build generators and motors for supply boats.

As the world oil industry migrates into deeper waters, technological challenges drive Petrobras and its main suppliers toward continuous innovation. The strongest multinationals, such as Schlumberger, GE, Baker Hughes and FMC, are establishing laboratories adjacent to Cenpes, the Petrobras research center in Rio de Janeiro.

The Booz study found that Brazilian suppliers could be competitive in shipyards, electrical systems, basic engineering, logistical support for offshore operations and construction/assembly of large systems and modules. The construction companies Camargo Correa and Queiroz Galvão have government contracts to build tankers and rigs at their Atlântico Sul Shipyard (EAS) at the port of Suape in Pernambuco in partnership with Samsung Heavy Industries of Korea, a world leader in producing deep-water rigs. Costs at Brazilian shipyards are nearly double those in Korea, which benefits from economies of scale and better organization and skills. These Brazilian shipyards are lucky to have firm government contracts at high prices while tanker rental rates are collapsing in a slowing world economy.

Petrobras sought bids from Brazilian shipyards for 28 rigs to be delivered by 2017, but accepted only one offer for seven drill ships at a total cost of \$4.65 billion from Atlântico Sul. It rejected the other bids as being more than 20% over international prices. Petrobras expects to take delivery in 2011 of nine rented rigs, four of them capable of drilling in water depths of 3,000 meters. It also is taking a 10% stake in a new holding company, SETE Brasil, to buy rigs for leasing to Petrobras, with capital provided by government pension funds and foreign institutional investors as a way of keeping the rigs off Petrobras's

balance sheet. Almir Barbassa, the Petrobras finance director, said that "some \$20 billion" will be needed for these deals, of which 20%-30% would be shareholder capital and the rest borrowed. Most industry participants doubt the capacity of Brazilian shipyards to build the drillships at a cost of \$664 million each, the winning bid. These shipyard projects are 100% funded by the government.

The Atlântico Sul Shipyard forms parts of the new industrial complex at the deep-water port of Suape in the old sugar-growing region of Pernambuco in the Northeast. There digitalized machines automatically cut and shape steel plates that are carried by giant cranes, with hauling capacity of 1,500 tons, for assembly at the dry-dock. EAS is a joint venture between the Brazilian construction companies Camargo Correa and Queiroz Galvão with Samsung Heavy Industries of Korea. EAS has orders from Petrobras, worth several billion dollars, for 20 supertankers and seven deep-water drillships. World leader in producing these drillships, Samsung designed the new shipyard and sent 26 of its technicians to Pernambuco to train EAS employees in different specialties. EAS sent 22 Brazilians to spend a total of 75 days to learn production methods at Samsung's shipyard in Korea. Productivity still is low, with 160 man-hours needed to produce a ton of fabricated steel, against 22 hours in Korea. Highly disciplined, with sophisticated methods of serial assembly, the Korean shipyard delivers 60 tankers and drillships per year. Still a beginner, its Brazilian offshoot only will deliver one tanker and one platform frame in 2011. EAS has been financed since 2007 by government loans totaling R\$5.7 billion (roughly US\$ 3 billion).

"We built the shipyard and the first ship simultaneously," said a production manager. "We need to climb the learning curve. We won't compete with the Koreans. We just will do the basic work. We are limited

by the lack of experienced engineers. You may be able to train a welder in a year, but an engineer becomes really useful only after five years. When the big government projects ended in the 1980s and 1990s, many unemployed engineers wound up driving taxis. These guys don't return to the profession." To meet quality standards, EAS recruited Brazilian technicians of Japanese descent, known as *dekasseguis*, who had worked on production jobs in Japan.

Progress is slow

For now, progress is slow, with the welder playing a critical role. "A ship is made of steel plates," said Paulo Kempers, an engineer who went to Korea to train. "Steel plates generate most of the cost of a ship, with welds accounting for 2.5% of its weight. Without good welding, the ship's structure is weakened, unable to withstand rough seas." Anchored at the pier is the yard's first supertanker *João Cândido*, named for the hero of a revolt in 1910 of black sailors in the Brazilian navy against corporal

punishment, that was waiting for repairs because workers rushed to finish it in time for Lula to speak at its launch last year. At the ceremony, Gabrielli announced that the *João Cândido* was opening "a new cycle" of the Brazilian shipbuilding industry. Earlier this year several top managers of EAS were fired.

Little by little, EAS is training welders, among them several women who before were dependent on the government's *Bolsa Família* program of financial aid to poor families. Ione de Oliveira, 30, finished secondary school and worked as a kitchen helper at a tourist hotel, aided by *Bolsa Família*, before becoming among the 400 candidates selected from 5,000 taking a test in 2007, then taking remedial courses in Portuguese and math before studying the theory of welding. "At first, I made many mistakes and could not see the defects," said Ione, who now works as a team leader. "It's not enough for a weld to look good. It must be good inside. So we test it with X-ray, ultrasound and for magnetic particles."

According to the Booz study, Brazilian suppliers claim that their competitiveness is undermined by high taxes and interest rates, lack of technicians, poor infrastructure and scarcity of long-term credit. They do little product research, export little and remain dependent on Petrobras. Their factories generally work on one shift, leaving them excess capacity that could be exploited if they were to become competitive. It will be hard for them to compete soon in high-tech activities such as seismic surveys, drilling equipment and services, manufacturing turbo-generators and automation measurement and control. Overall, Brazil's costs are 55% higher than world market prices for comparable equipment, and much higher in some cases, without being able to offer critical high-tech supplies. With a desperate shortage of qualified professionals, Brazilian engineering firms use up to six times as many man-hours as foreign firms for similar projects. Some types of valves cost four times more than imports.

6. Human resources

Since its creation six decades ago, Petrobras developed from rudimentary beginnings to become a robust knowledge system. But Petrobras is not Brazil. While Petrobras invested heavily in the development of a world-class technical staff, Brazil's political class refused and still refuses to engage in the effort needed to give most Brazilians the opportunity for a decent public education. Many in the industry believe that the lack of skilled manpower is the biggest obstacle to the development of the huge oil discoveries in the South Atlantic.

Petrobras sent hundreds of its most promising geologists and

engineers abroad for advanced study, generating the knowledge system that led to the deep-water discoveries of recent years. Meanwhile, basic education for most Brazilians was allowed to languish in failure, negligence, perverse incentives and political manipulation for the short-term benefit of mayors and governors. In an overheated economy, now famous as a consumer market and as a cornucopia of natural resources, the urgent need to find skilled workers is driving creation of ambitious government programs to build human capacity to overcome the failures of basic education.

The Petrobras technical staff is said to be severely overstretched

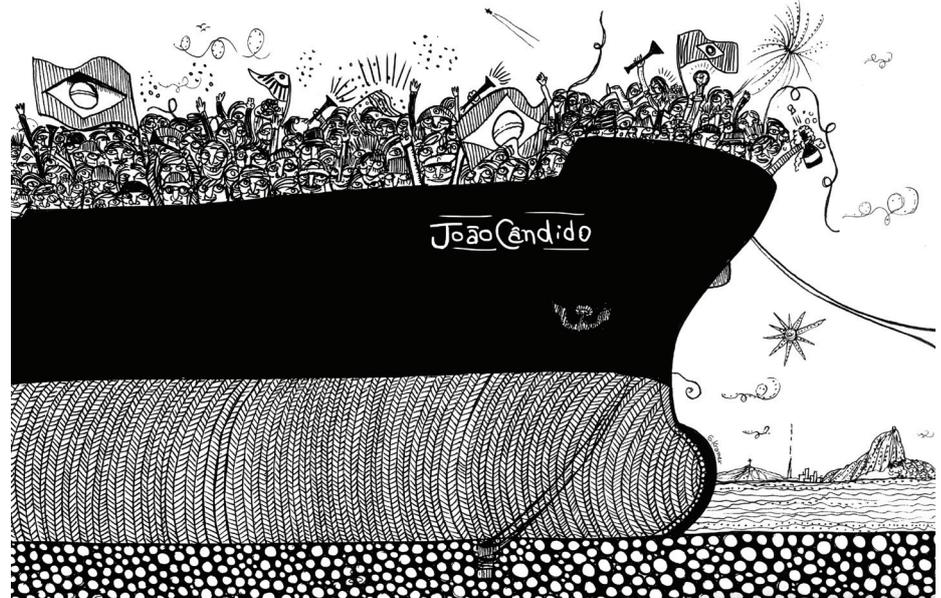
as it struggles, often heroically, to manage so many large and complex projects. "There is only so much a company can do with a finite amount of critical resources such as equipment, professionals and suppliers," one industry economist observed. "Obviously there is a point beyond which the risks outweigh the benefits." One reason given privately for creating a new "strategic reserve" for the presalt discoveries was to contain the exodus of senior Petrobras technicians to join private oil companies at higher salaries. These include foreign firms operating in Brazil – Shell, Chevron, Statoil and BP – as well as new Brazilian companies – OGX,

HRT and Queiroz Galvão E&P – that are heavily staffed by former Petrobras executives. Petrobras has no quarantine policy for departing executives with access to confidential information. While top Brazilian executives in the private sector command salaries higher than those prevailing in the United States or Europe, Petrobras recruits its career officers by competitive examination. They rise to manage resources and assets far out of proportion to their earnings. In the private sector Paulo Mendonça, former Petrobras executive manager for exploration, earned \$12 million as president of OGX in 2010, about 17 times more than the president of Petrobras. Marcio Mello, a former Petrobras geologist, earned about \$4.5 million as head of HRT, a new company created in 2008.

The Petrobras University

Petrobras urgently seeks to develop new skills. The Petrobras University in Rio and Salvador trains and retrains 70,000 employees yearly. PROMINP (Program for Mobilization of National Industry) attempts to train workers for Petrobras's suppliers. The government makes bombastic announcements of new emergency programs: PRONATEC (National Program for Access to Technical Education and Jobs) aimed at offering eight million places by 2014 in 800 technical schools and federal institutes; E-Tec (Open Technical School) to provide distance instruction for 263,000 students by 2014; the Foreign Study Program for 100,000 scholarships at universities abroad by 2014, the year of the next presidential election. These announcements overlook the lack of qualified instructors for existing technical education programs, which has left 20,000 students without classes in federal institutes.

PROMINP, launched in 2003, attempts to train 247,000 people



by 2013 for suppliers of Petrobras, including welders, mechanical engineers, operators of cranes, tractors and machine-tools, engineers specialized in piping and in 3-D and computer-aided design, in all more than 800 occupations.

José Renato de Almeida, a Petrobras veteran who directs PROMINP, says: "It was hard to fill 78,000 places in the courses because of the low level of schooling of the candidates. Most needed remedial courses in Portuguese and arithmetic so they could read printed manuals and make simple calculations before beginning training for work. We lack instructors and properly equipped workshops. Many pupils quit the course and their monthly stipend of R\$300. President Lula went to Pernambuco to hand out diplomas, but the graduates still lacked the skills to begin work. Businessmen refuse to invest in training our graduates for fear that would quit later, seduced by better pay offered by other employers."

With a budget of R\$228 million (US\$142 million), PROMINP concentrates its efforts on the "System S" training centers operated by business associations: Senai, Senac, Senap, etc. The National Confederation of Industry (CNI)

doubted the results of training offered by System S and ordered an outside study of these programs. "The surging demand for trained workers far exceeds the training capacity of Senai," said one researcher. At the Atlântico Sul Shipyard in Pernambuco, 3,000 ex-cane cutters were trained as welders by Senai in the nearby city of Cabo, but nearly all were rejected by the shipyard.

In the presalt boom, Petrobras is building two new office towers in Rio de Janeiro, where its employees are spread among 12 different buildings, and another tower in the port of Santos to house new staff and functions related to the new discoveries.

But there is a demographic breach separating generations of Petrobras employees, common to the global oil industry as older technicians retire. According to Gabrielli, "40% of our staff has been with us for less than nine years and another 60% is with us more than 19 years and approaches retirement. The 10-year gap between these two generations of employees was caused by the downsizing that took place throughout the world oil industry because of the low international prices of the 1980s and 1990s." Many technicians retired early, some because they worked at

high-risk jobs and others because they took buyouts, many of them only 45 or 50 years old. Said one human resources director: "We retired our knowledge base and then we hired consultants."

This change in the personnel structure provokes bitter controversy over outsourcing. Petrobras says it uses 291,000 people not directly on its payroll, against 80,000 regular employees, of whom 29,000 were hired since 2001. Petrobras says it intends to hire 6,000 more employees by 2013. As widely practiced in the private sector, outsourcing enables Petrobras to gain flexibility while limiting the generous fringe benefits obtained by its regular staff. Government attorneys complain that Bureau Veritas, a foreign company that does inspections and certifications in 140 countries, hired a retired Petrobras engineer to select and train outsourced engineers to scrutinize operations on platforms and specialized vessels that, for example, lay pipe at sea and use robots to inspect subsea equipment. The controversy over outsourcing

involves disputes over local content rules in supplying equipment ordered by Petrobras for exploration and production in deep waters.

Outsourcing of services

On these practices, Professor Tyler Priest of the University of Houston, an oil industry historian, observed: "Outsourcing of services in the offshore industry is the standard way of doing business, and has been since the beginning of the industry in the 1940s and 1950s. Over time, operators outsourced more and more. For example, operators initially ran their own seismic crews, but eventually outsourced all seismic acquisition. Beginning in the 1990s, operators began to outsource more and more of their R&D, most of which had traditionally been done in house. Just about everything these days is outsourced to specialized companies: seismic acquisition, drilling, fabrication, transportation, installation, well services, subsea engineering, catering, you name it. Operators keep things that give them a competitive advantage (i.e. seismic

interpretation) or are necessary for managing risk (i.e. well design and engineering) in house. If anything, it looks like Petrobras outsources much less than other major companies."

Until Brazilians commit themselves to a coherent and long-term effort to improve the quality of public education, they will find themselves with the lesser share of value added in the equipment and services needed for developing deep-water oil and other complex industrial projects. For example, the Norwegian company Subsea 7 won a \$1 billion order from Petrobras to supply four 9,900-ton buoys to be installed 250 meters beneath the ocean surface in the Lula and Guar fields, in addition to 27 catenary risers with a total length of 3.9 kms. to connect the platforms with subsea wells. The multinational FMC won another contract for \$130 million to supply systems for separation of oil and gas on the seabed, operated by robots. Although these systems will be assembled in Brazil, owing to local content rules, most of their value added will be created abroad.

7. The grandiose seduction

Petrobras's \$225 billion investment program for 2011-15, the world's largest in the oil industry today, was curtailed to curb overheating of Brazil's economy and to prevent these investments from overreaching the state-controlled oil company's financial and operational capacity. Luciano Coutinho, president of the National Bank for Economic and Social Development (BNDES) and a member of the Petrobras board, said the company "should seek more realistic goals."

Gabrielli said Petrobras is engaged in 688 projects costing more than US\$25 million each and 3,000 projects costing less than that. These

projects include four new refineries, buying and leasing of deep-water drilling and production installations, gas pipelines, supertankers, petrochemicals, electricity generation and facilities for producing and transporting ethanol and biodiesel. Gabrielli said that Petrobras wants to become Brazil's biggest producer of sugar-based ethanol by 2015, while building a new ethanol pipeline. While Petrobras has built no new oil refinery since 1980 and now imports large volumes of refined products, the decision to build three new refineries in the Northeast, far from the main markets, has been criticized as a concession to Lula's political backers.

Petrobras argues that, without the new refineries, imports of liquid products would rise from 5% of total demand in 2010 to 40% by 2020. The projected cost per barrel of capacity in these new refineries ranges from \$33,000 to \$52,000, roughly double the cost of new refineries elsewhere in the world. "The reality is that Petrobras is swamped by projects," said a company veteran who played a key role in developing the giant offshore fields of the Campos Basin. "The capacity of Petrobras to manage all these projects has been overwhelmed for some time now."

The scale and complexity of efforts to finance Petrobras investments

have attracted new scrutiny. Of the \$70 billion raised on stock markets last September, \$45 billion was government money. Its sovereign wealth fund and the BNDES bought \$16 billion in Petrobras stock, increasing the government's voting shares from 58% to 64%. As part of this circular transaction, the finance ministry borrowed R\$30 billion [\$18 billion] to lend to BNDES so BNDES could buy Petrobras stock. Petrobras returned the \$45 billion to the Treasury to pay for rights to explore and produce up to 5 billion barrels of oil and gas from potential reserves in seven presalt fields of the Santos Basin. The expected gains from these rights were based only on seismic surveys and on a single well drilled in Franco, seen as the largest of these fields.

The R\$74 billion (\$45 billion) payment by Petrobras to the Treasury formed part of complex maneuvers to balance fiscal accounts, while critics argued that Petrobras overpaid for these new deep-water prospects. Even so, the stock flotation gave Petrobras a net inflow of funds of roughly \$25 billion, a historical record for world capital markets.

The investment projects are so varied and ambitious that Petrobras will have to raise more capital within a few years, including \$36-\$60 billion in new borrowing and \$14 billion from sales of assets. In the months before the financial crisis of August 2011, Petrobras was unable to profit from world price increases because domestic gasoline and diesel prices were frozen by the government in its efforts to control inflation, limiting the free cash flow available for its investment program.

Petrobras and its suppliers continue to depend on loans from the BNDES at subsidized rates to sustain their investment programs, absorbing a large share of the huge increase of Treasury lending to the BNDES, rising from R\$8 billion outstanding in 2007 to R\$296 billion

in 2011, including a R\$55 billion loan announced for this year. Since 2006 loans disbursed by BNDES have grown by 38% annually. The volume of its loans in 2010 to Brazilian firms was three times greater than all World Bank lending to more than 100 countries. BNDES claims now account for 23% of all corporate debt in Brazil as its lending capacity approaches saturation in a credit expansion that threatens to revive chronic inflation. In August 2011, plans were announced for the BNDES to lend another R\$500 billion (US\$320 billion) by 2014 to support an accelerated development program, *Brasil Maior* (Greater Brazil).

Petrobras may have been given a poisoned chalice by nationalists under its statutory obligation to become the operator, with a 30% minimum stake, in the giant presalt prospects in the "strategic" areas of the Santos and Campos basins. The chief nationalist was President Dilma Rousseff, who chaired the Petrobras governing board until last year. Given the state company's strained financial and technical commitments, Petrobras may find it difficult to develop some of the seven giant prospects ceded by the government, together estimated officially to contain the equivalent of 5 billion barrels of oil, for which it paid \$45 billion to the federal treasury after last September's circular stock flotation. Under the 2011-15 plan, Petrobras is to expand presalt investments by \$20 billion to \$53 billion, of which \$12 billion will be spent on the seven deep-water prospects. While Petrobras predicts that it will produce 150,000 BDOE in 2015 from Franco, the biggest of these prospects, independent analysts say a more realistic target would be 2019.

Two years after Lula's government proposed to Congress a new legal regime for the "strategic" deep-water areas not already leased, outstanding issues remain in legislative gridlock.

Furious Congressional debate on the new institutional regime focused almost entirely on distribution of royalties among states and municipalities, neglecting the governance and technical issues posed by deep-water exploration and production. Distribution of revenues in one of the world's most decentralized federations has provoked bitter controversy throughout Brazil's two centuries of independence, with the poorer states of Amazônia and the Northeast wielding veto power over new legislation. The new production-sharing regime fortifies a politically-protected state capitalism with broad discretionary powers and little transparency. The reinforced Petrobras monopoly would reduce chances for spreading costs and risk among several companies. The complex coalitions of several political parties prevailing since 1985 distorts investment decisions, as with the three refineries being built in the Northeast.

The renewed world financial turbulence adds to the uncertainties faced by oil companies in developing complex projects in remote regions, increasing the importance of large-scale management capabilities. There are now over 200 exploration and production projects worldwide that have a budget in excess of \$1 billion, of which Brazil's presalt development is the biggest. Andrew Gould, former head of Schlumberger, warned before the crash that many of these projects "suffer significant cost overruns. Indeed, as a general rule 30% of such projects experience budget overruns of 50%." Cost inflation is common in offshore oil services and supplies. Many Petrobras contracts carry cost-plus clauses, while the \$225 billion investment program for 2011-15 does not contain inflation projections.

Under the new production-sharing regime for the "strategic" presalt areas, the issue of costs is likely to provoke intense controversy. Under production-sharing, compensation



for operators is divided between “cost oil,” enabling companies to recover expenses for exploration, development and production, and “profit oil,” which producers share with the government as prescribed in their contract. As costs escalate, the government share shrinks. Controversies arise that are endemic in production-sharing contracts. The controversies usually are settled in favor of the government, which acts as both contracting party and regulator.

The issue of costs undermines the illusion of unlimited resources inspired by the pre-salt discoveries. These myths hide other disturbing questions. Gabrielli says that Petrobras’s US\$225 billion investment program absorbs annually one-tenth of Brazil’s gross fixed capital formation in a nation with one of the lowest rates of public investment in Latin America. The National Petroleum Industrial Organization

(ONIP), a public/private umbrella association, says that capital spending for oil and gas in 2009-12 will total \$147 billion, or 60% of all Brazil’s industrial investment, leading business groups to fear a crowding out of capital spending in other areas of manufacturing.

Beyond euphoria

Does Brazil really need to invest in pre-salt development at this speed and scale? Will these accelerated investments create distortions of their own? Are these investments in oil more important to the future of Brazil than more investment in education, ports, airports, electricity generation and transmission, communications, basic sanitation and transport infrastructure? Then what are the priorities? What is the safest and most productive strategy?

The illusion of limitless resources on the horizon seduced Brazilian leaders into a premature triumphalism

while neglecting basic needs. This grandiose seduction is embodied in fiscal parasitism and megaprojects of doubtful value, badly conceived and executed without serious calculations of cost, that will drain resources from the economy for decades to come. The political class tends to forget how hard it was to consolidate democracy and end chronic inflation and how easy it is to plant the seeds of future instability. Brazil’s success will depend on its capacity to invest successfully in education and infrastructure to make its people more productive. These real achievements come not from winning lottery tickets but instead from dedicated effort to overcome need and limitation. The discovery of huge amounts of oil and gas beneath the deep waters of the South Atlantic bred dangerous illusions that basic limitations have been removed. The discoveries have raised the stakes of risk and reward for Petrobras and the Brazilian people. ■

How Petrobras works

José Sérgio Gabrielli de Azevedo

These are comments by the president of Petrobras on some issues raised at the conference on pre-salt development on August 16, 2011, organized by the newspaper O Estado de São Paulo and the Fernand Braudel Institute of World Economics

Agência Petrobras

How does Petrobras function as a conglomerate, involved in so many businesses?

Petrobras sells 380 products, including fertilizers, electricity, refinery products and natural gas. We export and sell to our own national distributor, BR, and other wholesalers. Petrobras has a fantastic team. We have 3,200 high-level managers and another 3,000 coordinators, plus some 2,000 senior consultants. Petrobras has a permanent staff of 77,000 that is expanding to reach 103,000 by 2015. We have a small governing board of six directors and the president. Our top-level team has more than 100 people. These are the ones who basically run Petrobras.

We made two extremely important changes in the company in recent years. We discarded the concept of business units, where we had stand-alone firms in different areas, important for defining knowing each one's responsibility, but you lose this when the company is growing fast. Our basic organization now is what we call operational units. We separate the responsibility for operating today's assets from those responsible for creating new assets. In all business areas we have management units responsible for new projects. Petrobras suffers from a phenomenon that is not unique in the industry but may be more serious: 52% of our workforce has spent less than nine years with the company, while 46% has more than 20 years' experience. There are few in-between. So our big challenge now is to mix these generations, so that the experience of our older employees is passed on to our new ones.

Investments

We had \$224 billion for the 2010-14 plan and \$ 224.7 billion for 2011-15. The difference is not just \$700 million. There are structural differences. The first change is how much this is worth in Reais. Because our currency gained value, this means R\$389 billion instead of R\$419 billion, while in dollars it is nearly the same. Over the next five years, Petrobras will be investing R\$2,000 every second, 24 hours each day, seven days every week, 365 days a year. The



investment is gigantic. The second important difference is in the plan's structure. We will increase our investment in exploration and production (E&P) by \$8.7 billion, totaling \$117 billion. Of this, 65% will be invested in development of the discoveries, 17% in infrastructure and 18% in exploration. Of the \$23 billion for exploration, one-third will be in the presalt fields and two-thirds in other areas.

Risks

One thing is exploration risk. Another is development risk. Nobody says that the presalt discoveries carry no development risk, which involves the nature of the reservoir and porosity and permeability of the rocks. Exploration risk is measured by the success rate of discovery wells. In the presalt area, our exploration has a success rate of 87%, compared with a world average of 20% to 25% for the industry.

Refineries

They keep saying they we are rushing too fast in investing in refineries, which is not true. The Brazilian market is growing fast. Today we consume 2.2 million barrels daily (BD), with a refining capacity of 1.8 million BD. So we are importing diesel, naptha, jet fuel kerosene, gasoline and alcohol. Last year Brazil's GDP grew by 7% while gasoline demand grew by 19%. Looking toward 2020, we will consume more

than 3 million BD in refinery products. Today 5% of Brazilian demand is imported. If we fail to invest in refineries and the market demands 3.3 million BD, in 2020 we would be importing 40% of our needs. Do you think that a company with the market power of Petrobras will do nothing? Will it lose its role in one of the world's biggest markets? Today there are only four countries with markets of at least 3 million BD: United States, China, India and Japan. With a market of 3 million BD, why should Petrobras stand idle? We will invest in this market. We will invest \$4 billion in refining, half in four new refineries and the other half in upgrading existing refineries. We will reduce the sulfur in our diesel and gasoline, as the law requires.

North Sea

We have heard criticism that the presalt discoveries should be developed with the participation of several companies, as in the North Sea, instead of Petrobras acting as the sole operator. There is a basic difference between what happened in the North Sea and developments here. In the North Sea the learning and production curve rose from 1959 to 1999, when commercial and technical knowledge about deep waters was very limited. No company dominated deep waters. This is why there were many operators in the North Sea. So the ancient fishing ports of Aberdeen in Scotland and Stavanger in Norway were transformed to build platforms. What is happening now? Now Petrobras is a company that grew by 10% annually over the past 30 years.

Petrobras migrated from drilling on land to shallow waters, at a time when drilling in from 70 to 160 meters was the big challenge. In 1980 we had to import platforms for drilling in 100 meters. Petrobras then migrated from shallow waters to deep waters. Today we operate 45 production units

in deep waters, which is more than the second, third and fourth-ranking companies, taken together. So Petrobras is by far the world's biggest operator in deep waters. Petrobras is the company with the highest success rate in the world for deep-water drilling. It is the company with the best knowledge of Brazil's presalt geology. What happens is that at first you discover large reservoirs. Development of production begins and it grows fast. Production reaches a peak and then begins to decline. This is inevitable. You very rarely can find more large reservoirs in these areas. So you must migrate to another basin. We had the good fortune that, with the Campos Basin maturing after producing since 1978, we found something even bigger in the Santos Basin along our coast.

We can say that God is Brazilian, but God only helps those who work hard and wake up early. God helped Brazil and Petrobras, but the fact remains that, when the Campos Basin was maturing, we found a newer, bigger frontier with trained technicians who knew the equipment and with the infrastructure in place, things that were not possible in the first 10 years of the North Sea. So we can say that being sole operator for the presalt discoveries is challenging but not impossible. We will do this better than having 10 operators fighting over access to ports, vessels and equipment.

Political interference

Does anyone think that Exxon, BP, Total, Repsol, Shell and Sinopec do not have to deal with political interference? Does anyone think that any big oil company is impervious to political influence? Is there not political interference in the hierarchies, strategies and big decisions? This is the nature of the oil business.