

Angola, West Africa: Oil & Gas Production from Pre-Salt Carbonates to Post-Salt Clastics, from Onshore to Deep Offshore

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The oil and gas plays in Angola range from the pre-salt to the post-salt and include Tertiary-age clastic turbidite reservoirs, salt-rafted Cretaceous age Pinda carbonates, and pre-salt microbialitic carbonates similar to Brazil's giant Tupi oil discovery. These wide-ranging, high potential plays have led to a dramatic surge in Angola's oil production. A decade ago, Angola was producing approximately 750,000 barrels of oil per day and now production of almost 2.0 million barrels of oil per day has been achieved.

Angola is the second biggest oil producer in Africa after Nigeria which currently is producing about 2.2 million barrels oil per day. Due to Angola's highly favorable petroleum geology, within the next decade Angola is expected to replace Nigeria as Africa's top oil producer.

Historic Milestones

The first milestone in Angola's petroleum industry occurred in the late 1700's when the Portuguese colonialists discovered oil seeps and asphalt deposits at Libongos, about 60 km north of Luanda and shipped some of the oil to Lisbon and Rio de Janeiro to be used a caulking material to prevent water leakage into their ships. Libongos is located on the eastern edge of the Kwanza Basin within a half kilometer of outcrops of Pre-Cambrian granites.

The year 1915 marked the next important milestone for Angola when the Portuguese oil company, Companhia de Pesquisas Mineras de Angola, carried out the first drilling for oil in the valley of the Dande River, near the coastal village of Barra do Dande. The drill site was about 40 km northeast of Luanda. One of the wells, Dande-4 drilled in 1916 was tested at 6 bopd (barrels of oil per day) and was subsequently abandoned but it signified the first flow of oil in Angola. Drilling for oil in the onshore Kwanza Basin continued sporadically for the next forty years with no commercial success until 1955, when the Benfica-2 well just south of Luanda resulted in the first commercial discovery of oil in Angola. The oil was found in a salt-rafted block of Cretaceous-age Pinda carbonate. The field went on production in 1956, representing the beginning of oil production in Angola.

Angola's long-drawn-out civil war, which lasted from independence in 1975 until 2002 slowed down onshore exploration, so international companies focused on the offshore during that time. However, Angola's sedimentary basins are almost entirely offshore with only small extensions onshore. Consequently only a minor amount (10,000 bopd) of Angola's oil production is from the onshore.

The first offshore oil field in Angola, Malongo, was discovered in 1968 in the Angola province of Cabinda by the American company, Cabinda Gulf Oil Company. Chevron bought Gulf Oil in the early 1980's and the company is still operator of two blocks, now producing about 500,000 bopd.

In 1996 Angola was producing about 700,000 bopd when another historic event happened: the French oil company Elf Petroleum discovered the Girassol oil field on Block 17 in 1,300 meters of water about 140 kilometers off the coast of Angola. The discovery of Girassol stunned the oil industry since finding oil so far off the coast and in a new geological formation was totally unexpected. Additional drilling by Elf proved Girassol to be a giant-size oil field, with the oil bearing reservoir located in sandstones and conglomerates of Oligocene age (25 million years old) which were deposited as turbidites. This led to many more such discoveries in the Oligocene and Miocene (15 million years old) in the deep waters of Angola including by Chevron, Esso, Maersk, Total, BP, and the state oil company Sonangol. As a result, about 75% of Angola's production now comes from such reservoirs. Had Girassol and the follow-up fields not been discovered, Angola would have remained merely a modest oil-producing country with production of only about 500,000 barrels oil – now it is an important one.

Impact of Brazil

The discovery of the Tupi oil field in Brazil in 2007 was a historic event also for Angola. Tupi was drilled by Petrobras in the deepwater part of the Santos sedimentary basin – the water depth was 2,100 meters. The well was drilled about 5,200 meters below the sea floor. The total drill depth of the well was 7,300 meters; it had many mechanical problems and the final cost was \$240 million. But the costs were justified by the results. Tupi is estimated to hold over six billion barrels of recoverable oil reserves in the high pressured, high temperature environment beneath a massive (2 km) salt sheet. Tupi (now renamed Lula after Brazil's President Lula) was the first of the now famous pre-salt oil fields in Brazil.

The Tupi discovery proved that a working petroleum system exists beneath the salt layer of the Santos Basin. The oil source rocks are the organically rich lake shales, the reservoirs are lacustrine beach sands and porous limestones and dolomites known as microbialites, and the seal above the reservoirs which keeps the oil entrapped is the thick, impervious salt layer. Since the discovery of Tupi, many more pre-salt oil and gas fields have been found in the Santos Basin as well as in the more northern Campos Basin. Oil industry analysts such as Wood Mackenzie and IHS have estimated that the oil reserves in Brazil's pre-salt reservoirs could amount to some 20 to 30 billion barrels of recoverable oil. ANP which is Brazil's government oil industry regulatory agency has been quoted that the reserves to be up to 50 billion barrels. The impact of the pre-salt discoveries on Brazil is dramatic: Brazil's oil production is now at a record 2.2 million barrels of oil per day of which already about 350,000 barrels of oil per day is from the pre-salt. Petrobras believes that output from the pre-salt reserves will grow and bring Brazil's per-day oil output to at least 4 million barrels, nearly double current production.

When the conjugate margins of Angola and Brazil are juxtaposed or reconstructed to the time of the initial opening of the south Atlantic, about 140 million years ago in the early Cretaceous, this clearly shows that the Santos and Campos Basins were located adjacent to Angola's Benguela and Kwanza Basins. Accordingly, the success in the pre-salt of Brazil could be repeated in Angola's deepwater areas where drilling in the pre-salt has negligible before 2011.

More History is Made

As a result of investigating the southern Atlantic conjugate margins, a historic event for the Angola oil industry occurred in December, 2011 when eleven deepwater to ultra-deepwater blocks in the Kwanza and Benguela Basins were awarded by Sonangol to a number of operators including BP, Cobalt, Repsol, Total, Eni, ConocoPhillips and Statoil. Non-operators with working interests included

Sonangol and China-Sonangol. Statoil obtained the lion's share of these blocks with two operated blocks and non-operated working interests in three other blocks.

In January, 2012, Maersk announced that the Azul-1 well in deepwater Block 23 was the first well to penetrate pre-salt objectives in the Angolan deepwater. The well was drilled in a water depth of 920 meters and reached a total depth of 5,330 meters. The press release stated that "the preliminary interpretation of the data indicated a potential flow capacity of greater than 3,000 BOPD. We are encouraged by the results of our first pre-salt exploration well in this region, which was also the first ever deep water well targeting pre-salt reservoirs in the Kwanza Basin".

Shortly afterwards in February, 2012, Cobalt International Energy (CIE) announced the results of its Cameia-1 well, drilled in 1,680 meters of water in deepwater Block 21, again targeting the pre-salt section. Cobalt reported that the well confirmed the presence of 360 meters of gross continuous oil column with over a 75% net-to-gross pay estimate. No gas-oil or oil- water contact was evident on the wireline logs. An extended DST (drill stem test) was performed on Cameia-1 which flowed at a sustained rate of 5,010 bopd of 44 degrees API oil and 14.3 million cubic feet per day of associated gas thus approximately a total of 7,400 boepd with limited drawdown. Cobalt also stated that the well has the potential to produce in excess of 20,000 bopd.

The Future

Based on my 40 years of experience in the oil industry, I expect that the Angola oil industry will remain vital for many more years. Already, two-thirds of Angola's oil production is from the deepwater and, unquestionably, more Oligocene and Miocene oil discoveries will be made in the ultra-deepwater areas seawards off Blocks 31, 32 and 33. Based on the drill results of Maersk's and Cobalt's wells, the pre-salt play suddenly looks very promising.

Could the dramatic increase in production seen in Brazil as a result of the discovery of the pre-salt happen to Angola? Based on the recent successes by Maersk and Cobalt, it is possible, although much more drilling is needed. Indeed, could Brazil's pre-salt plays be "duplicated" elsewhere in West Africa? In 2012 and 2013, in the deepwaters of Namibia, five exploration wells were drilled unsuccessfully by operators including Petrobras, BP, and HRT Oil & Gas in the hopes that the pre-salt play extended there. On the other hand, in 2013, Total as operator and Cobalt as minority partner drilled in deepwater Gabon the Diamante-1 exploration well which was drilled as the first-ever well targeting a deepwater prospect. Encouragingly, this well drilled in 1,729 meters of water to a depth of 5,584 meters encountered 50 – 55 meters of gas and condensate. The well was temporarily abandoned pending further analysis of the data.

Another milestone in Angola's petroleum industry happened in July, 2013 when the LNG plant at Soyo, in northern Angola commenced production at 5.2 million tonnes per year. On an energy-equivalent basis, this amounts to about 200,000 barrels of oil per day. A strong demand exists for Angola's natural gas due to the increasing consumption of LNG in Asia and also as Europe seeks to diversify its sources of LNG. In addition, as gas becomes increasingly the preferred fuel of the future, there will be much focus in Angola on its minimally explored gas potential.

Concluding Comments

The oil industries of Angola and Canada have much in common. For both countries, the oil industry provides the government with much needed revenue via royalties and taxes. Indeed, Angola is very much a "petro-economy" where the oil industry provides 95% of the country's foreign exchange. For geoscientists, both countries are very interesting and challenging work-wise since oil industry

professionals can work on an enormous variety of plays from onshore to offshore. In Angola the age of the reservoirs range from Cretaceous to Tertiary whereas in Canada the reservoirs are as old as Devonian and as young as Tertiary. With both countries, the oil industry is long-term, not short-term; the industry in both countries is not anywhere close to being “played out”. Both countries have much unexplored geological potential and the use of technology such as horizontal drilling, hydraulic fracturing, 3D & 4D seismic, and secondary recovery will ensure long term, bright futures in the oil industry for both countries.