Abstract

In 2015 Angola will have experienced a century of oil exploration and production. A variety of 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 bopd (barrels of oil per day) and now production of almost 2.0 million bopd has been achieved. In the late 1700's 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 as a caulking material to prevent water leakage into their ships. First-ever drilling for oil was in 1915 about 40 km northeast of Luanda. Dande-4 drilled in 1916 was tested at 6 bopd and was subsequently abandoned but it signified the first flow of oil in Angola. In 1956 the Benfica oil field, near Luanda, went on production representing the beginning of oil production in Angola. The first offshore oil field in Angola, Malongo, was discovered in 1968 in the Angola province of Cabinda by the American company, Gulf Oil. In 1996 Elf Petroleum discovered the Girassol oil field on Block 17 in 1,300 meters of water about 140 kilometers off the coast of Angola. Additional drilling by Elf proved Girassol to be a giant-size oil field, with the oil bearing reservoir located in clastics of Oligocene age which were deposited as turbidites. This led to many more such discoveries. As a result, about 75% of Angola's current production now comes from such reservoirs. In 2011, 11 deepwater to ultra-deepwater pre-salt blocks in the Kwanza and Benguela Basins were awarded by Sonangol to a number of operators. Since that time, very encouraging pre-salt oil discoveries have been drilled by Maersk and Cobalt. In July, 2013 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. The first shipment of LNG was to a Petrobras LNG deliquification plant in Rio de Janeiro and thereafter 4 shipments of LNG from Angola were delivered to customers in Asia.
Selected References


Koning, T., 2013, Solving the Mystery of Angolan Oil: AAPG Explorer Magazine, v.34/4, p. 32-34.


The Angola Oil Industry – A Century of Progress in Exploration and Production

Presentation to the American Association of Petroleum Geologists
International Conference & Exhibition
September 14 - 17, 2014
Istanbul, Turkey

Tako Koning, Senior Petroleum Geologist
Gaffney, Cline & Associates
Luanda - Angola
Disclaimer Statement

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Sources of Information

This presentation is based entirely on public domain published information, including:

▪ Sonangol *Universo* magazines.

▪ Oil company magazines, e.g. BP *Calemas*, Chevron *CABGOC* magazines.

▪ SPE *Journal of Petroleum Technology*, AAPG *Explorer*, Upstream, World Oil, Offshore Engineer, BP Annual Oil & Gas Production Reviews, USA EIA reports.

▪ T. Koning presentations about Angola to AAPG, SPE, CSPG, GSL & PESGB.
Presentation Outline

▪ Angola in West Africa & Global Context
▪ Geology
▪ Conventional Oil Fields
▪ LNG Project
▪ Pre-Salt Oil Play
▪ Angola’s Oil Future
Angola’s Oil Production
1956 - 2014

ANGOLA OIL PRODUCTION BY YEAR (Barrels Oil Per Day)

- Deep Water (>500 feet/150 meters water depth)
- Shallow Water (0-500 feet/150 meters water depth)
- Onshore (Kwanza Basin and Soyo Area)

Sources: Sonangol Universo magazines, Website - Angola Finance Ministry, 2013 BP World Energy Review
Oil Producing Countries on West Coast of Africa

Source: Deloitte Petroview
## West Africa Oil Production – Current Production in BOPD (Barrels Oil Per Day)

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (BOPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria</td>
<td>2,200,000</td>
</tr>
<tr>
<td>Angola</td>
<td>1,650,000</td>
</tr>
<tr>
<td>Congo Brazzaville</td>
<td>340,000</td>
</tr>
<tr>
<td>Equatorial Guinea</td>
<td>320,000</td>
</tr>
<tr>
<td>Gabon</td>
<td>240,000</td>
</tr>
<tr>
<td>Ghana</td>
<td>110,000</td>
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<tr>
<td>Chad</td>
<td>100,000</td>
</tr>
<tr>
<td>Cameroon</td>
<td>75,000</td>
</tr>
<tr>
<td>Ivory Coast</td>
<td>30,000</td>
</tr>
<tr>
<td>Congo DRC</td>
<td>25,000</td>
</tr>
<tr>
<td>Mauritania</td>
<td>2,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5,092,000</strong></td>
</tr>
</tbody>
</table>

From: Oil & Gas Journal, SPE Journal of Petroleum Technology, Upstream
GLOBAL OIL PRODUCTION

Next 2 slides summarize
Global Oil Production – Top 20
Global Oil Production – Top 20

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Production (BOPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Russia</td>
<td>10,400,000</td>
</tr>
<tr>
<td>2.</td>
<td>Saudi Arabia</td>
<td>9,500,000</td>
</tr>
<tr>
<td>3.</td>
<td>USA</td>
<td>8,400,000</td>
</tr>
<tr>
<td>4.</td>
<td>China</td>
<td>4,200,000</td>
</tr>
<tr>
<td>5.</td>
<td>Canada</td>
<td>3,400,000</td>
</tr>
<tr>
<td>6.</td>
<td>Iran</td>
<td>3,200,000</td>
</tr>
<tr>
<td>7.</td>
<td>Kuwait</td>
<td>2,600,000</td>
</tr>
<tr>
<td>8.</td>
<td>Mexico</td>
<td>2,500,000</td>
</tr>
<tr>
<td>9.</td>
<td>Iraq</td>
<td>2,400,000</td>
</tr>
<tr>
<td>10.</td>
<td>U.A.E.</td>
<td>2,400,000</td>
</tr>
</tbody>
</table>
# Global Oil Production – Top 20

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Production (BOPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>Nigeria</td>
<td>2,200,000</td>
</tr>
<tr>
<td>12.</td>
<td>Brazil</td>
<td>2,100,000</td>
</tr>
<tr>
<td>13.</td>
<td>Venezuela</td>
<td>2,100,000</td>
</tr>
<tr>
<td>14.</td>
<td>Angola</td>
<td>1,650,000</td>
</tr>
<tr>
<td>15.</td>
<td>Norway</td>
<td>1,600,000</td>
</tr>
<tr>
<td>16.</td>
<td>Kazakhstan</td>
<td>1,600,000</td>
</tr>
<tr>
<td>17.</td>
<td>Algeria</td>
<td>1,200,000</td>
</tr>
<tr>
<td>18.</td>
<td>Qatar</td>
<td>1,200,000</td>
</tr>
<tr>
<td>19.</td>
<td>Colombia</td>
<td>1,000,000</td>
</tr>
<tr>
<td>20.</td>
<td>U.K.</td>
<td>1,000,000</td>
</tr>
</tbody>
</table>
Angola’s Oil History – the Past

Source: T. Koning, AAPG Explorer magazine, April 2013
Angola’s Oil History – the Past
The Libongos Oil Seeps – Pre-Salt Oil

Libongos oil seeps. Here oil has migrated into Pinda-equivalent porous carbonates. This oil has been analyzed by Norsk Hydro and Chevron to be pre-salt oil. The oil-filled Pinda has been eroded exposing it at the surface and creating these oil seeps. Recent (2011 & 2012) pre-salt discoveries in the deepwater Kwanza Basin by Maersk Oil (Azul-1) and Cobalt International Exploration (Cameia-1) has focused attention on these oil seeps since they provide an important data point on the pre-salt of the Kwanza Basin.
Angola’s Oil History – the Past

The Libongo Oil Seeps – *Pre-Salt Oil*
Angola’s Oil History – the Past
The Libongos Oil Seeps – *Pre-Salt Oil*
Angola’s Oil History – Dande-4 Drilled in 1916, Tested 6 BOPD – *Pre-salt Oil*
We begin with an introduction to the basic types of oil and gas fields
Geology

Depositional Processes Respond to Sea Level Changes
Geology – Lower Congo Basin, Esso Block 15, Slope Channel System in Oligocene-Miocene Malembo formation

From: Porter et al, Exxon, 2006, AAPG Memoir 88
Major Oil & Gas Fields Continue to be Discovered in Angola in Past Five Years

- ENI has drilled 8 oil discovery wells on Block 15/06 (9 wells, 8 discoveries)
- MAERSK has drilled 3 oil discovery on Block 16
- TOTAL has drilled 3 oil discoveries on Block 17/06 (3 wells, 3 discoveries)
- PETROBRAS has drilled 1 oil discovery on Block 18/06
- PLUSPETROL has drilled 1 oil discovery on Cabinda South Block
The Golden Triangle for Deepwater Oil & Gas Exploration: The Gulf of Mexico – Brazil & West Africa

Source: T. Koning, SPWLA Angola Forum, 2010
“Hardly anywhere in the world measures up to the recent exploration significance of Angola”

Source: Oil + Gas Journal, May 23, 2005

This quotation still applies to today, according to this presenter.
Lower Congo Sedimentary Basin - Key Points

- Basin covers 115,000 sq km from shoreline to water depths of 3500 meters
- Since the discovery of Girassol in 1996, exploration has focused on the deepwater turbidite sands associated with the ancestral Congo River
- Excellent seismic imaging has led to the high rates of exploration success (85%)
Angola Oil Concessions
Oil Companies Present in Angola: Operators of Blocks

- Chevron American
- Esso American
- Vaalco American
- Cobalt American
- ConocoPhilips American
- Total French
- BP British
- ENI Italian
- Repsol Spanish
- Petrobras Brazilian
- Pluspetrol Argentinean
- Statoil Norwegian
- Maersk Danish
- Sonangol P&P Angolan (state oil company)
Oil Companies Present in Angola: Non-operators

- Naftagas
- Partex
- Odebrecht
- Teikokou
- Sinopec
- ACR
- Force
- Partex
- Prodoil
- SOCO
- Svenska
- Falcon
- China
- Somoil
- Interoil
- Initial Oil
- Marathon
- Ajoco
- Petrogal
- Sonangol
- Grupo Gema
- Galp Enegia
- Etc etc
### Current Angola Oil Production – By Operator in Bopd - Data from Minfin Website

<table>
<thead>
<tr>
<th>Operator</th>
<th>Production (BOPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>600,000</td>
</tr>
<tr>
<td>ESSO</td>
<td>350,000</td>
</tr>
<tr>
<td>CHEVRON</td>
<td>340,000</td>
</tr>
<tr>
<td>BP</td>
<td>300,000</td>
</tr>
<tr>
<td>SONANGOL P&amp;P</td>
<td>55,000</td>
</tr>
<tr>
<td>SOMOIL</td>
<td>5,000</td>
</tr>
</tbody>
</table>

Note: Approx 3/4’s of the oil production is from deep water fields, 1/4 of the oil production is from shallow water fields & onshore.
Stratigraphic Column

Source: Schlumberger, 1992 - WEC (Well Evaluation Conference)
Post-Salt Oil Fields

- LOMBO EAST as an example of a post-salt Pinda carbonate oil field
The Lombo East Oil Field

- Lombo East is a Typical Pinda Carbonate (Dolomite & Limestone) Oilfield
  
- OOIP 310 MMSTB
  
- Recovery Factor 47%
  
- Cumulative Production 140 MMBLS
  
- Peak Production 33,000 BOPD from 9 wells (3,500 BOPD/Well)
Figure 5 - Regional geological cross-section through the Southern Fields Area, Block 2.
PINDA RESERVOIRS

PINDA CARBONATE RESERVOIRS EXHIBIT A WIDE VARIETY OF TEXTURES, PORE TYPES, AND PORE SIZES. MOLDIC AND INTERCRYSTALLINE PORES ARE PREDOMINANT. THE AVERAGE POROSITY OF THESE RESERVOIRS IS 12 PERCENT.
Review of Angola’s Deep Water Oil Fields

- Chevron Block 14
- Esso Block 15
- Total Block 17
- BP Block 18
Deepwater Discovery

Source: TransOcean website, 2009
Deepwater Turbidite Deposits

▪ Turbidites are sands and gravels which flowed in subsea rivers from land seawards & downwards to the sea floor

▪ 3/4’s of Angola’s oil production is now from the deepwater and comes from turbidite sand and gravel deposits
Tertiary Oil-bearing “Fan”

TERTIARY TURBIDITES OIL FIELDS APPROX. 15 BILLION BARRELS RECOVERABLE REPORTED

CHEVRON Deepwater Block 14

- CHEVRON is operator with partners Sonangol, Total, Agip, Petrogal

- Kuito Field – First Tertiary deepwater field on production, discovered in 1997 and fast-tracked onto production in 1999
Offshore Angola

Source: Chevron Angola corporate magazine, 2012
Seismic View of the Kuito Field
CHEVRON Deepwater Block 14 Kuito Oil Field

Figure 6. Seismic line through Kuito field. Line is oriented across depositional axis of channel. Note differential compaction and stacking of amplitude packages that indicate sandy turbidite channel systems.

Source: Chevron & Sonangol, AAPG Memoir, Giant Oil Fields, 2002
Figure 6. Seismic line through Kuito field. Line is oriented across depositional axis of channel. Note differential compaction and stacking of amplitude packages that indicate sandy turbidite channel systems.
ESSO Deepwater Block 15 Kizomba Field
ESSO Deepwater Block 15, Kizomba Oil Field

Source: Esso, AAPG Memoir 88, 2006
ESSO Deepwater Block 15 Kizomba “A” FPSO

Source: Esso corporate magazine, 2007
**ELF exploration angola**

3 grands ensembles

**ROSA-LIRIO-CRAVO-ORQUIDEA,...**
- Recensement des réserves et développements possibles à l'étude

---

**GIRASSOL**
- Réserves 1ère phase projet: 725 Mmbbl
- Décision de développer: 08/07/98
- Mise en production: mi 2001

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**TULIPA**
- Zone prouvée à apprécier

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**DALIA**
- Réserves: 860 Mmbbl
- Décision de développer: début 2001
- Mise en production: début 2004

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Source: Elf Petroleum corporate magazine, 1999
Figure 5. Average-amplitude displays in three intervals showing a simple, but highly sinuous channel form with at least one possible neck-cutoff loop.  
(A) Deepest interval just below the H horizon, that is, 0 to +20 ms. (B) The first interval just above horizon H, that is, 0 to −20 ms. (C) The second interval above horizon H, that is, −20 to −40 ms. The width of the high-amplitude facies increases from the lower to upper intervals. Lines 1, 2, 3, 4, 5, and 6 are seismic sections shown in Figures 8–15.
Figure 17. Amplitude display of a composite interval (combining all four intervals shown in Figure 3) of complex sinuous-channel systems. Two sinuous channel complexes—complex A and complex B—both originating from a single parent channel, are shown. The parent channel first took the course of complex A and then avulsed to complex B. Features that resemble cutoffs are present in complex A. The sinuous loop that shows the seismic line (Figure 3) location is the focus of our article and is our complex sinuous channel example 1 in the text. The sinuous loop consists of crescent-shaped high-amplitude seismic facies 2, 2A, 2B, 2C, and 1 (1A, 1B), interpreted to be migratory channel courses (see Figure 18A).
Girassol Moves West
TOTAL Deepwater Block 17, Girassol Oil Field

Source: Total corporate magazine, 2011
TOTAL Deepwater Block 17, Dalia Oil Field

Scheme, designed to produce 240,000 barrels per day, logistical as well as an economic challenge, requiring to push a number of technologies to their very limits.

Source: Total corporate magazine, 2011
BP Block 18 Deepwater Block:

- Block operator is BP (50%); partner is Sonangol Sinopec (50%)

- Area of block is 4,900 sq km

- On production in 2008, has produced up to 220,000 BOPD

Information source: GeoLuanda Conference, 2000 & SEG & other publications
A 3-D perspective view of a subsurface structure map, undeveloped offshore West Africa reservoir, draped with a 2-D spectral decomposition image. The reservoir is a sandy turbidite filling an erosional valley at a depth of about 3,100 meters. The draped image also conveys a 3-D perspective by showing three different slices through the reservoir section with different color bars (red, green and blue). Understanding the vertical stacking patterns of flow units is important for determining optimum drainage.
BP Blk 18, Greater Plutonio
BP Block 31 PSVM
Angola LNG Project

- $10.0 billion project constructed at Soyo, northern Angola
- Purpose is to monetize gas currently being flared
- Partners are Sonangol, Chevron, BP, Total and ENI
- Started production in July, 2013, goal is 5.2 million tons per year LNG mainly for USA markets, also 125 MMSCFG/D for industrial development in Soyo
The Angola LNG Project will gather associated gas from FPSO’s located in Blocks 15 (operated by ExxonMobil), 17 (operated by Total) and 18 (operated by BP) in water depths of up to 1500 meters and from Blocks 0 and 14 (operated by ChevronTexaco).

Angola LNG will also develop previously discovered non-associated, shallow water, gas fields in Blocks 1 and 2 as required to supplement the gas produced in association with oil.

Gas production from these Blocks will be transported by high pressure pipelines to the LNG plant onshore for conditioning and extraction of NGL’s before liquefaction to LNG.
Angola LNG Project

Source: Angola LNG corporate magazine, 2013
Angola LNG Project

Source: Angola LNG corporate magazine, 2013
Angola LNG Project

- **SIGNIFICANT ECONOMIC IMPACT!**

- 5.2 MMTonnes/year LNG is energy equivalent to 200,000 barrels of oil per day

- Angola currently producing 1,650,000 barrels of oil per day but with LNG it will be total of 1,850,000 barrels of oil equivalent per day (BOEPD)
Angola LNG Project

▪ A “win-win” mega-project

▪ Commercializes natural gas which previously was flared off

▪ Creates significant job opportunities for Angolans

▪ Creates secondary industries in the Soyo area such as possible fertilizer plants, petrochemicals
PRE-SALT!!!

- BRAZIL

- ANGOLA
Impact of Brazil’s Recent Pre-Salt Mega-Oil Discoveries on Angola’s Oil & Gas Potential

- Major world class pre-salt (sub-salt) oil and gas discoveries have been made since 2007 in the deepwater of Brazil.

- Petrobras believe the pre-salt fields could be producing 2.0 MM BOPD by 2020 thereby doubling Brazil’s oil production to about 4 MM BOPD.

- Brazil and Angola were contiguous (joined up) in Cretaceous time.

- This play has been minimally evaluated in the deepwater of Angola.
Reconstruction of the South Atlantic Ocean Evolution

From: M.S. Albio, 1986 Ministry of Petroleum SADC paper
Pre-Drift Reconstruction of S. America-Africa (124 MYBP)
Geology – Brazil vis-à-vis Angola

ANGOLA PRE-SALT LICENCE AWARDS

@ Upstream Magazine
January 28, 2011

Angola 2011 Bid Round – Award of Pre-salt Blocks

- All blocks are located in the deepwater Kwanza Basin
- Bid round was described as “a historic event in Angola’s oil industry”
- Operators include BP, ENI, ConocoPhillips, Cobalt, Repsol, Total, Statoil
- Blocks were officially awarded in December, 2011
- Chevron, Exxon, Petrobras, Shell & Galp Energia were absent
Kwanza Basin – Deepwater Drilling Results – Wells which Flowed Oil & Gas from the Pre-Salt
Publically Announced Info on Pre-salt Drilling – Maersk – Azul-1

- January 14, 2012 MAERSK OIL announced that their first well on deepwater Block 23, AZUL-1 was “mini-tested” indicting a flow capacity of greater than 3,000 BOPD; Maersk viewed the results as “encouraging”
- Azul-1 was the first ever deep water well targeting pre-salt reservoirs in the Kwanza Basin
- Drilled in 920 meters water to a depth of 5,330 meters
Publically Announced Info on Pre-salt Drilling – Cobalt – Cameia-1

- February 9, 2012 COBALT announced that CAMEIA-1 drilled on Block 21 in 1,680 meters (5,500 feet) of water tested at 5,010 barrels of oil per day from pre-salt carbonates.
- 360 meters (1,180 feet) of gross pay of which 75% is net pay.
- No gas/oil or oil/water contacts encountered.
- Well has potential to produce at excess of 20,000 barrels of oil per day.
Publically Announced Info on Pre-salt Drilling – Cobalt – Lontra-1

- December 1, 2013 COBALT announced that LONTRA-1 was drilled on Block 20 to a depth of 4,195 meters
- 75 meters of net pay “in a very high quality reservoir section”
- Lontra-1 tested at 2,500 barrels per day of condensate and 39 MMcf/gpd; flow rates were restricted by the surface test facilities on the rig
- Press reports: 2.2 – 3.8 TCF gas or 900 MMBOE
Publically Announced Info on Pre-salt Drilling – Cobalt – Orca-1

- May 9, 2014 COBALT announced that ORCA-1 was drilled on Block 20 to a depth of 3,872 meters
- 76 meters of net pay “in excellent reservoir quality section”
- Orca-1 tested at 3,700 barrels pol per day of and 16.3 MMcfgpd; flow rates were restricted by the surface test facilities on the rig
- Cobalt reports a resource range of 400 to 700 million barrels of oil
The “Angola Advantage” – Oil & Gas Industry

- World class geology
- Benign operating environment (no ice bergs, hurricanes, high seas)
- Subsurface drilling is not difficult, e.g. no major over-pressuring problems, etc
- Contractual stability due to political stability (government has been led by MPLA since independence in 1975)
CONCLUSIONS

- Significant undiscovered oil and gas resources remain to be found in Angola in the deepwater and also in the minimally explored pre-salt oil play; if the pre-salt play is successful, Angola’s oil production could double.

- Many opportunities are available for companies willing to invest and be active for the long term.
Angola’s Oil Production 1956 - 2014

ANGOLA OIL PRODUCTION BY YEAR (Barrels Oil Per Day)

- Deep Water (>500 feet/150 meters water depth)
- Shallow Water (0-500 feet/150 meters water depth)
- Onshore (Kwanza Basin and Soyo Area)

Sources: Sonangol Universo magazines, Website - Angola Finance Ministry, 2013 BP World Energy Review
Obrigado!

Thank You!

www.gaffney-cline.com