Jubilee field: A century of preparation

- Ghana, the Gold Coast, is famous for its gold but oil exploration dates back to the end of the 19th Century
- Ghana has two Cretaceous sedimentary basins (Tano and Keta) and two Paleozoic Basins (Saltpond and Voltaian) which have all been explored to some extent

<table>
<thead>
<tr>
<th>Basin</th>
<th>Age of Sediments</th>
<th>Wells Drilled to date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tano</td>
<td>Cretaceous</td>
<td>62 includes appraisal wells and shallow onshore boreholes</td>
</tr>
<tr>
<td>Keta</td>
<td>Cretaceous</td>
<td>10</td>
</tr>
<tr>
<td>Saltpond</td>
<td>Paleozoics</td>
<td>20 includes appraisal wells</td>
</tr>
<tr>
<td>Voltaian</td>
<td>Paleozoics</td>
<td>1</td>
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</tbody>
</table>

Geological Map of Ghana

- Tano Basin
- Saltpond Basin
- Keta Basin
- Oil Seep
- Cape Three Points

Limited success through early frontier exploration – oil shows
- 1896 - 1903 West African Oil and Fuel Co. Ltd
- 1909 - 1913 Societe Francaise de Petrole, now Elf/Total
- 1923 – 1925 African and Eastern Trading Corp
- 1956 – 1957 Gulf Oil Co

1957 Independence from UK – then first oil and gas field discoveries
- 1970 - Signal Oil discovered Saltpond Field offshore within Devonian.
  - Estimated oil in place 45 million barrels, on stream 1978
- 1970 - Volta Petroleum find oil in Volta Tano-1X, in first offshore Tano well
- 1973 - Zapata discovers first offshore gas with Cape Three Points-1X
- 1978 -1980 Phillips discover oil & gas in North and South Tano
- 1985 - PetroCanada International Assistance Corp (PCIAC)

GNPC established as statutory body with E&P responsibilities in 1985

- 1985 - Law establishes legal and fiscal framework for E&P activities
- 1986 - Diamond Shamrock drill onshore
- 1987 - Government of Japan through JICA and JNOC acquire seismic over Saltpond
- 1988 - 1989 Arco TP-1 well is first to test a stratigraphic play. Encounters oil shows in an Upper Cretaceous turbidites
- 1989 - 1994 GNPC acquires 3D seismic over South Tano discovery
  - appraisal wells on South Tano drilled, one drillship and three rigs purchased
- 1990 - Amoco drill offshore
- 1999 - Hunt Oil drilled West Cape Three Points-2 well near South Dixcove-1X.
  - Encountered 14ft of light oil in Upper Cretaceous
- 2002 - Dana encounters light oil down-dip of TP-1 in Upper Cretaceous reservoir

Exploration focus shifts towards deepwater stratigraphic traps

- 2004 - Kosmos Energy acquired Deep Water Cape Three Points block
- 2006 Tullow Oil signed package of Deep and Shallow Water Tano blocks:
  - Shallow Water Tano low materiality - farmed down to 31.5%
  - Deepwater Tano signed 49.95% with major partners Kosmos & Anadarko
  - Pre-agreed trade with Kosmos and Anadarko for 22.9% in West Cape Three Points
- 2007 - Mahogany-1 discovers Jubilee Oil Field
- 2007 - Hyedua-1 follow-up confirms Jubilee as a world class sweet oil field
- Major breakthrough after a ‘Century of Preparation’!
Regional geology
Regional tectonic setting

Tano Basin, West African Transform Margin
- Between Romanche & St Paul transform faults
- Mainly extensional structural style

What is a Transform Margin?
- Differential movement in spreading oceanic crust
- Accommodated by slip on transform faults
- Transform faults meet the continents at transform margins

Impact for oil potential?
- Transform margins are often associated with restricted oceanic circulation
- Anoxic conditions preserve organic material
- Organic material, if buried sufficiently, generates hydrocarbons
Plate-tectonic evolution: early Aptian – 122 Ma

Early Aptian 122 Ma

- North and South Atlantic were opening
- West African Transform Margin not yet part of an open ocean, but due to plate movement significant topography was developing
- West African Transform Margin similar to present day East African Rift Basins, with rift lakes
- Lakes were an important environment for deposition of organic matter which, following later burial, generated hydrocarbons
Plate-tectonic evolution: early Albian – 108Ma

Early Albian – 108 Ma
- South America & Africa become fully separated
- Last point of contact in western Cote d’Ivoire
- Tano Basin part of an extensional Rift Basin system which received substantial clastic sediment input from the African continent

Middle Albian
- Significant uplift and erosion occurred
- Topography influenced Tano Basin deposition
- South Tano High was instrumental in the creation of the Jubilee field
Paleo-reconstruction: Cenomanian – Turonian – 93Ma

Cenomanian-Turonian - 93 Ma
- South America and Africa completely separated
- Onset of “drift” and oceanic crust

West African Transform Margin
- Rapid drowning the West African Transform Margin created ideal conditions for deposition of thick rich source rock in Cenomanian
- Creation of a deep basin, with significant river systems onshore, led to deposition of large turbidite fan/channel complexes in deep water
- Jubilee is amongst the oldest of several fans
- Continued extension and subsidence resulted in deposition of thick shale which seals Jubilee and the other prospects in the margin
- Turbidite fans form Stratigraphic Traps for oil
What are turbidity flows and turbidite fans?

- A turbidity flow is a current of rapidly moving sand-laden water moving down a slope, underwater. The current moves because it has a higher density than the water through which it flows.

- A turbidite fan, such as at Jubilee, is a ‘bird’s foot’ shaped deposit of sand dumped on the seabed by a turbidity flow.
Regional geology - conclusions

- Exceptionally favourable coincidence of regional geological factors
- Rich source rocks deposited and matured for oil
- Tectonics and structural geology establish framework for focusing charge
- World class turbidite reservoirs deposited in giant stratigraphic traps
- Highly effective seals preserve oil and gas for discovery and development
Exploration focus – Tano Basin
Regional geology to prospectivity

West African Transform Margin geology

- Source rock buried sufficiently to generate oil
- Turbidite fan / channel systems create migration route and highly productive reservoir

Prospectivity

- South Tano High creates focus of migration, concentrating oil generated in a large kitchen
- Jubilee fan drapes over high, on top of source rock and focuses charge up-dip
- Structure of South Tano High influenced deposition of Jubilee fan
- Thinner areas on the flanks, where the sands may not have been deposited, help form a trap
Geological model incorporating well data constrains prospect risks

- Source rock – Cenomanian source modelled to be mature but unproven as previous wells likely accessed charge from older source rocks

- Migration route – sands interpreted from seismic and identified in offset wells. Interpreted to be low risk

- Reservoir – interpreted from seismic. Offset wells relatively poor quality but 3D seismic and facies analysis suggests Jubilee sands better developed

- Trap – A stratigraphic trap was postulated at Jubilee but was very high risk. A very thin sand can result in leakage of oil over geologic time
Reducing the risk to acceptable levels for investment

Risk reduction through Seismic Analysis

- 3D Seismic interpretation, facies, attribute and Amplitude Variation with Offset (AVO) analysis are essential in de-risking a stratigraphic prospect

- Amplitude Variation with Offset (AVO) techniques widespread in the industry

- Uncalibrated AVO, where the seismic response is poorly understood due to lack of nearby well control, is a dangerous tool and can lead to very expensive mistakes

- Tullow’s extensive database and experience in West Africa provide the key to unlocking this complicated seismic attribute and reducing the risk on stratigraphic traps such as Jubilee

- This analysis assists with optimally locating exploration and appraisal wells

- Following synthesis of this approach, a prudent investment decision was taken
The ongoing campaign – expansion and repetition

Building on Tullow strengths

- Core Play – Stratigraphic Trap, a Tullow strength in West Africa
- Core Area – Material acreage position in West African Transform Margin

Campaign area identified, then expand acreage position

- Secure high-grade acreage
- Acquire 3D data to evaluate a set of prospects
- Secure rig capacity for drilling campaign

Deepwater Ghana

- Following success of Mahogany-1 in 2007, capital allocated to accelerate campaign
- Hyedua-1 well drilled and High Resolution 3D/4D survey acquired
- Turonian Jubilee analogues to be drilled – Tweneboa, Ntomme, Owo, Teak
- Campanian Odum analogues to be drilled – Tweneboa, Onyina, Walnut
Atlantic Twins

- Regional understanding extends across Atlantic
- Source rocks and reservoirs common to both sides
- Recognising that twin basins are seldom symmetrical
- South American acreage under review
- Applying African plays in South America and vice versa
- High-grading acreage opportunities
- Pursuing various farm-in opportunities
Exploration focus - conclusions

- Core capability identifies high impact potential of major new stratigraphic play in Tano Basin
- In-house seismic technology skills reduced risks to acceptable levels
- South Tano High and Jubilee fan create ideal hydrocarbon trap conditions
- Data gathered at Jubilee supports analogue opportunities in basin
- Expertise in region transferable to adjacent countries and across Atlantic
- Significant upside potential remaining