Oil Discoveries in the East African Rift

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East African Rift System (EARS) Tectonic Elements

- Linked intra continental rift
- Extends 3,500 km across eastern Africa and is in the order of 50 km to 150 km wide
- The EARS can be separated into two dominant trends
  - Eastern Branch: Afar – North Tanzanian Divergence, initiated early Miocene (20 Ma) is more volcanic
  - Western Branch: Albertine Rift – Malawi Rift, initiated late Miocene (10 Ma) contains lakes

Source: Chorowicz 2005
The Formation of the EARS

- Elevated heat flow from the asthenosphere generates a thermal bulge (domes) leading to earthquakes, volcanic eruptions (flood basalts)

- This upwelling results in divergence of the plate boundaries, resulting in faults and fractures, rifts form and are filled with sediments

- Heat and burial matures organic rich source rocks, which expel hydrocarbons
Oil Discoveries EARS

Source: Petroview
Albert Rift Basin – Topography

Data Source: NASA and Petroview

Asymmetric Rift
Continued extension generates active faults and topography

Rwenzori / Mountains of the Moon
Albert Rift Basin – Tectonic Elements & Structural Style

- **TONYA FAULT**
- **NORTH TORO BUNYORO FAULT**
- **PAKWACH BASIN**
- **BUNIA BORDER FAULT**
- **RHINO-CAMP BASIN**

Source: Petroleum Exploration and Production Department, 2012 Interpretation

**Regional Seismic Line Through Albert Basin**

Source: Heritage Oil

**Southern Lake Albert Basin**

Source: Petroleum Exploration and Production Department, 2012 Interpretation
Lake Albert Hydrocarbon Potential Identified in 1920’s

- Alluvial Fan
- Low Sinuosity Channels
- Rift Scarp
- Delta
- Incised Channel
- Kibiro Oil Seep
- Butiaba
- Oil Seeps
- SAR slicks

Map showing locations such as Kibuku Oil Seep, Semliki, Uganda, DRC, and the Semliki Delta.
Stratigraphy – Waki B1 1938

- Waki B1 drilled in 1938 by Anglo European Investment Company of South Africa

- Late Miocene to Recent
  - Miocene and Pliocene bituminous shales and sandstones
  - 6-7% TOC in shales below 750 m, extractable oil
  - Pleistocene Conglomerates sandstones and shales
  - Holocene lakebed deposits

- Additional stratigraphic wells were drilled based on oil seeps

Source: Karp et al. 2012
Exploration History - Modern Efforts to First Discovery

- 1983 – Acquisition of Aeromagnetic data over the entire Albertine Graben
- 2002-2004 – Heritage Oil drilled Turaco 1, 2 and 3 in the Semliki Basin, dry holes
- 2003-2004 – Acquisition of seismic data over Lake Albert
- January 2006 – First oil discovery, Mputa-1, closely followed by Waraga-1
Kingfisher Discovery – October 2006, Flow Tested 13,000 bopd, ~ 200 Million Barrel Field

Three way dip closure against bounding fault

Source: Tullow
Albert Basin Burial Depth

Rapid burial and late hydrocarbon maturation

Mature and still active
Lake Albert Bathymetry Mimics Depth to Source Kitchen

- Currently active source kitchen
- Expulsion of hydrocarbons into reservoir quality rock
- Tectonostatigraphic evolution allows play elements to be present

Source: Tullow
Albert Rift Basin Summary

- Known hydrocarbon potential dating back to the 1920’s, active source kitchen identified from seeps and also sleeks identified from SAR

- Waki B1 drilled in 1938 proved that the play elements exist within the basin (reservoir, organic rich source and seal)

- The evolution of the rift basin itself provides the trapping mechanism, structural traps, stratigraphic traps are also viable concepts

- Muputa, Waraga and Kingfisher proved the hydrocarbon potential of the basin, generating significant flow rates on test

- Aggressive exploration and appraisal has resulted in resources in the region of a billion barrels of oil equivalent
South Lokichar Basin

- The South Lokichar Basin forms part of the Eastern Branch of the EARS
- Lies to the southwest of Lake Turkana

Data Source: NASA
South Lokichar Basin – Half Graben

Shell 1992

Entering oil window, local geothermal gradient?

Source: AOC
Drilled in 1992 to test a fault closed structural trap on the rift shoulder

Mature source rocks in the deeper section (TOC 1-3%)

High quality reservoir sands encountered, although some sands are affected by post burial diagnosis

Hydrocarbons were discovered in thin bedded sands within the Lockhorne Shale, questioning trap integrity
Schematic Section, South Lokichar Basin, Main Reservoir Types

Source: AOC

Primary Reservoirs
Secondary/Prospective Reservoirs

Enhanced Recovery Potential:

1. Fracture and/or Acid Stimulation
2. Horizontal Drilling
High Quality Auwerwer Reservoir

Auwerwer Core Data

- Twiga
- Ekales
- Ngamia
- Etuko

Ekales Core Plug
Porosity 23.6% & Perm 13.2 Darcies

- Porosity 15% to 30%
- Permeability 50 mD to multi Darcy
- Waxy sweet crude 25 – 38 deg API

Source: AOC
Ngamia & Amosing Discoveries

Ngamia Discovery & Ngamia West (Emong) Prospect
Best-Estimate Gross Resources:
Contingent (2C): 180 MMBO
Prospective: 281 MMBO, (COS: 64%)

Depth Structure Map: Base Auverner
COS: Geologic Chance of Success (%)

Amosing
Best-Estimate Gross Prospective Resources: 172 MMBO, (COS: 34%)

Source: AOC
Lokichar Basin Exploration & Appraisal – through 2014

2014 Wells:
• Amosing - (√) Discovery
• Ewoi - (√) Discovery
• Emong - (√) Sub-commercial
• Ekunyuk - (√) Sub-commercial
• Etuko Test - (√) Complete
• Twiga Appraisal (drilling)
• Ngamia Appraisal (drilling)
• Etom
• Ekosowan
• Agete Appraisal
• Amosing Appraisal

Seismic:
• Ngamia-Twiga 3D (550 sqkm)
**South Lokichar Summary**

- Loperot-1 was drilled in 1992 by Shell, proved the presence of hydrocarbons in the South Lokichar Basin, small resource base, thin sands within the Lokhone Shale

- Ngamia-1 was drilled by Tullow in 2012 in a fault terrace juxtaposed against the main bounding fault on the western side of the basin, encountered high quality Auwerwer sands
  - Waxy crude 25 – 35 deg API
  - Five DST’s flowed oil ~ 3,200 bopd

- Twiga, Etuko, Amosing and Ageta confirm the potential of the basin
Thoughts & Summary

- The Albert Rift Basin and the South Lokichar Basin prove the oil potential of the EARS
  - Can these models be transferred along the greater EARS?

- Sediment influx along the rift will be controlled by accommodation space, environment of deposition (fluvial/alluvial) and provenance of erosion, reservoir quality

- Maturation and expulsion of hydrocarbons will be controlled by depth of burial and local geothermal gradients considering upwelling asthenosphere and volcanism

- Inversion must be considered (observed in the Rhino Camp Basin) as this has the ability to turn off source rock maturation and generate trap breach (loss of hydrocarbon)

- Export routes 1000 km plus, refining (wax removal), cash flow?
Rwenzori Mountains - “Mountains of the Moon”

Source: http://ecsforum1.wordpress.com/2013/04/02/africas-physical-features/