A Tectono-Stratigraphic Development of the Albertine Graben of Uganda, Western Arm of East African Rift System Based on Sedimentary Exposures, Seismic and Well Data*

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Abstract

The Albertine Graben is a Tertiary rift system with a complex evolution history. Though it is essentially an extensional province, there is undeniable evidence of compressional tectonics. The graben comprises a number of structural and topographic basins, lying in a general northeasterly (NE) trend in en echelon pattern. The basins have varying ages, “younging” both to the north and south. Therefore, correlation of the different stratigraphic units from one basin to the next has been a complex task. Since Miocene, when rifting was initiated in the Albertine Graben, there have been several tectonic episodes that have shaped the geometry of the basins. The observed structural styles from seismic data, is due to a combination of (1) pre-rift basement fabric and (2) secondary modification as a result of extensional and strike-slip tectonics that has been active since Miocene. The Albertine Graben forms the northernmost termination of the western arm of the East African Rift System. Since Miocene, thick sediments, up to 6 km in some basins, have accumulated. The fault systems that comprise this rift are highly segmented, separated by relay ramps and accommodation zones which sometimes are basement highs. The graben can be divided into three structural domains, based on structural geometry and trend; namely; the southern, central, and northern domains. The structural elements in the southern domain trend in a NNE–SSW direction, structural elements in the central domain change to a NE–SW direction, while the structural elements in the northern domain return to a NNE–SSW trend. Different stratigraphic schemes have been developed by oil companies and researchers that have operated in Uganda. These schemes have largely been uncoordinated and give varying ages to the same sedimentary packages. The petroleum Exploration and Production Department in the Ministry of Energy and Mineral Development of the Uganda Government is coordinating a study to harmonize the different stratigraphic schemes. This article discusses the work that has been done to harmonize the different stratigraphic schemes using sedimentary exposures, seismic, and well data that have been acquired in the Albertine Graben.

Selected References


A TECTONO-STRATIGRAPHIC DEVELOPMENT OF THE ALBERTINE GRABEN OF UGANDA, EAST AFRICAN RIFT SYSTEM

PRESENTED AT THE AAPG ANNUAL CONVENTION AND EXHIBITION, 2015 DENVER, COLORADO - USA

BY:

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1. Introduction
2. Tectonic setting of the Albertine Graben
3. The Stratigraphic Commission
4. Stratigraphy Study results
5. Challenges
6. Further work
INTRODUCTION

- The Albertine Graben is now a proven petroleum province.

- Different stratigraphic schemes by different researchers in the Albertine Graben - Uganda:

- Government established a Stratigraphic commission + collaboration with industry.

- Develop a coherent stratigraphic framework of the Albertine Graben.

- Establish and correlate reservoir intervals.
INTRODUCTION

THE AFRICAN RIFT SYSTEMS

Continent under break up

- The Central African Rift System
- The Red Sea, Gulf of Suez Rift
- The East African Rift System
  - Four branches:
    - Eastern
    - Western
    - Southern
    - South Western
East Africa Rift System

- East Africa Rift System consists of a string of Miocene age rift basins that cut through East Africa.
- All Rift basins are non-marine
- Early rifting created under-filled basins with ideal conditions for deposition of thick source rocks
The Albertine Graben forms the northern most part of the Western arm of the East African Rift System.

Formed by en-echelon extensional fault systems on either side.

From available data, rifting initiated during Early Miocene and is still tectonically active.
Structural Setting

- Three structural domains interpreted in the Albertine Graben namely; Northern, Central and Southern domains based on structural trends and fault geometry.
- The fault system in the Southern and Northern domains trend in an almost N-S direction that changes to a SW-NE direction in the Central domain.
- The Central domain is an almost full graben structure while the southern and northern domains are typically half grabens.
- Two accommodation zones separate the three structural domains; The Rwenzori and the Nile Delta accommodation zones.
Study Methodology

- Objective is to establish a coherent stratigraphic scheme of the Albertine Graben
Outcrop Study

- Area of sediment exposures in less than 10% of the Albertine Graben.
- Sedimentary Exposures provide an idea of deposition, lateral variation of facies, and an indication of structural setting.
- Access to fossil record in the sediments documents age but also evolution of the basin.
Structure from Seismic

- Seismic stratigraphy
- Reconstruction of the structural history
- Confirmation of thickness and distribution of different formations
- At least two phases of rifting can be interpreted
Structure from Seismic

- Overall extension
- Folding in upper section
- Mild Inversion or fault propagation folding?
- Plio-Pleistocene inversion interpreted in the Rukwa Rift
Subsurface data interpretation

- Determination of facies associations & depositional Environment from core.
- Break down of logs - facies associations & depositional environment.
- Determination of thickness and distribution of different formations.
- Correlation using sequence stratigraphic techniques (*cautiously*)
Outcrop to Subsurface Correlation

- Definition of 1st order (broad stratigraphic) packages
- Correlation between well data and outcrop
- Outcrop Gamma ray
PROJECT RESULTS
Completed Work

- Semliki Basin – Southern Lake Albert
- Kaiso Tonya Area – Mid Lake Albert
- Butiaba-Wanseko Area – Northern Lake Albert

Work in Progress

- Lake Edward - George Basins
- Rhino Camp Basin and
<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Thickness (m)</th>
<th>Strat-column</th>
<th>Major depositional environments</th>
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<tbody>
<tr>
<td>Pleistocene</td>
<td>Nyabusosi</td>
<td>600-700</td>
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<td>Fluctuating coastal to shallow lacustrine</td>
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<tr>
<td>Late Pliocene</td>
<td>Nyakabingo</td>
<td>150-200</td>
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<td>Repeated prodeltaic to delta front progradations</td>
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<td>Mid-Late Pliocene</td>
<td>Nyaburogo</td>
<td>400-500</td>
<td></td>
<td>Delta plain to delta front</td>
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<tr>
<td>Late Miocene - Early Pliocene</td>
<td>Oluka</td>
<td>300-400</td>
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<td>Lacustrine passing up into delta plain with minor fluvial intercalations</td>
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<tr>
<td>Late Miocene</td>
<td>Kakara</td>
<td>500-600</td>
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<td>Mainly Deltaic with influence of channels</td>
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<tr>
<td>Mid/Late Miocene</td>
<td>Kasande</td>
<td>50-120</td>
<td></td>
<td>Lacustrine</td>
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<tr>
<td>Early-Middle Miocene</td>
<td>Kisegi</td>
<td>&gt;300</td>
<td></td>
<td>Stacked/amalgamated fluvial sandstones in semi-arid conditions</td>
</tr>
</tbody>
</table>
Significant events in Semliki evolution

Interpreted from outcrop data

Top ironstones mid-Nyabusosi
Thick ironstone nr top Nyakabingo - break

Mass extinction/tectonism ca 4.5 Ma

Major Oluka transgression
Thick ironstone top Kakara – major break?

Ironstone onset base Kakara Fm

Major "Kasande" rifting & "transgression" just before climate change?
Semiarid/arid Kisegi fluvials

From Pickford et al 1994
<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Thickness (m)</th>
<th>Strat column</th>
<th>Depositional environment</th>
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<td>Kaiso Village</td>
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<td>Channel deposits</td>
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<td>Mid-Late Pliocene</td>
<td>Warwire</td>
<td>150-300</td>
<td>Deltaic-Marginal Lacustrine</td>
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<tr>
<td>Early Pliocene</td>
<td>Nyaweiga</td>
<td>100-200</td>
<td>Lacustrine</td>
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<td>Late Miocene</td>
<td>Nkondo</td>
<td>150-400</td>
<td>Stacked/amalgamated fluvial channel sands</td>
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</tbody>
</table>
Significant Events in Kaiso-Tonya evolution

Partial outcrops earlier miscorrelated

Major faulting

Nyaweiga lacustrine incursion

Major reservoir interval!

Not exposed

Probable base Nkondo Fm well

From Pickford
### NORTHERN LAKE ALBERT BASIN
BUTIABA- WANSEKO & PAKWACH AREA

<table>
<thead>
<tr>
<th>Age</th>
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<th>Strat Column</th>
<th>Depositional Environment</th>
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<td>Predominantly fluvial (young) channel sands</td>
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<tr>
<td>Late Pliocene</td>
<td>Pacego</td>
<td>30-100</td>
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<td>Lacustrine</td>
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<td>Mid-Late Pliocene</td>
<td>Paara</td>
<td>50-200</td>
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<td>Deltaic with occasional fluvial influence</td>
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<tr>
<td>Mid-Late Pliocene</td>
<td>Nyamsika</td>
<td>15-80</td>
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<td>isolated fluvial channel complex</td>
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<tr>
<td>Mid-Late Pliocene</td>
<td>Wangkwar</td>
<td>100-200</td>
<td></td>
<td>Stacked/amalgamated fluvial channel complex</td>
</tr>
</tbody>
</table>

Tangl Fmn
Paara formation
Nyamsika formation
Wangkwar Fmn
Cap Rock – Kasande, Nyaweiga and Pacego
- Source Rock – Kasande Formation
- Reservoir Rock – Kisegi, Kakara and Warwire
CHALLENGES

- Lack of absolute age data
- Correlation of surface to subsurface formations
- Scanty well data to define subsurface especially in Rhino camp and Lakes Edward-George basins.
Finalize and link the Stratigraphy of Lakes Edward-George basin with Central part of Albertine Graben. Initial work has indicated that the basin has young stratigraphy than Central Albertine Graben, probably oldest strata is late Miocene.

E-W Cross Section (BB') with faults dipping to the East on the western side of the basin, whereas a western dip is seen on the Eastern side.
FURTHER WORK - Rhino camp Basin

- Finalize and link the Stratigraphy of the northern part of Albertine Graben (Rhino camp basin) with the Central part of Albertine Graben

- Absolute Age Dating

- Further work to define smaller (2\textsuperscript{nd} to 4\textsuperscript{th} order) reservoir packages