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.

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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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PRESENTATION OUTLINE

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

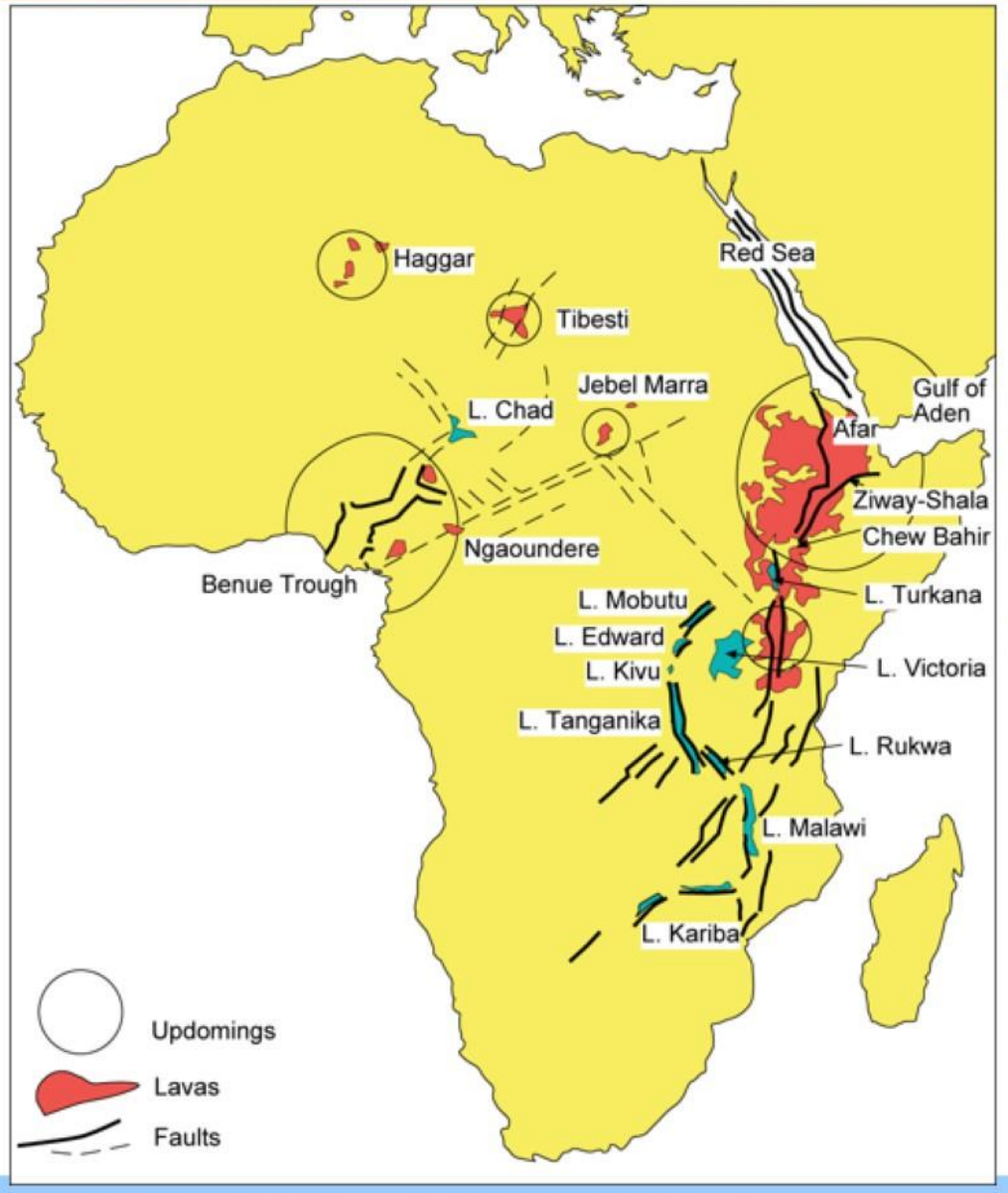
INTRODUCTION

- The Albertine Graben is now a proven petroleum province
- Different stratigraphic schemes by different researchers in the Albertine Graben - Uganda

  Gautier, 1970; Pickford et al. 1993; Senut & Pickford 1994; Van Damme & Pickford, 1993, 1995, 2003, 2010 & Petroleum Exploration and Production Department, 1996, 2001, 2007, 2009.

- Government established a Stratigraphic commission + collaboration with industry
- Develop a coherent stratigraphic framework of the Albertine Graben.
- Establish and correlate reservoir intervals

INTRODUCTION

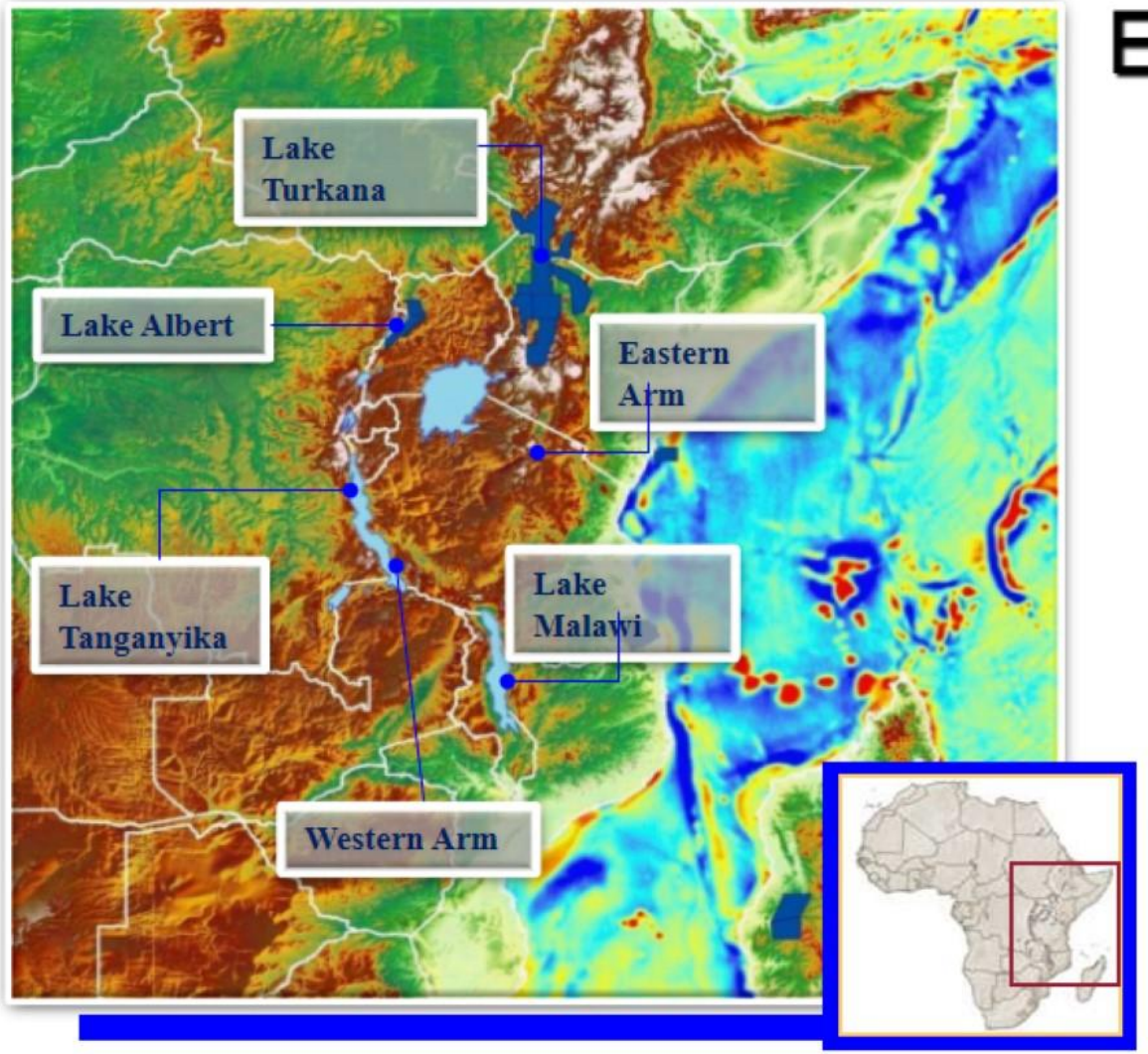


THE AFRICAN RIFT SYSTEMS

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

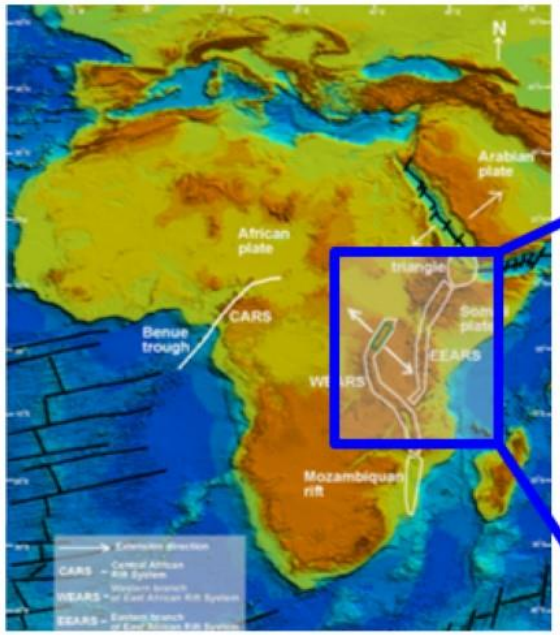
TECTONIC SETTING OF THE ALBERTINE GRABEN

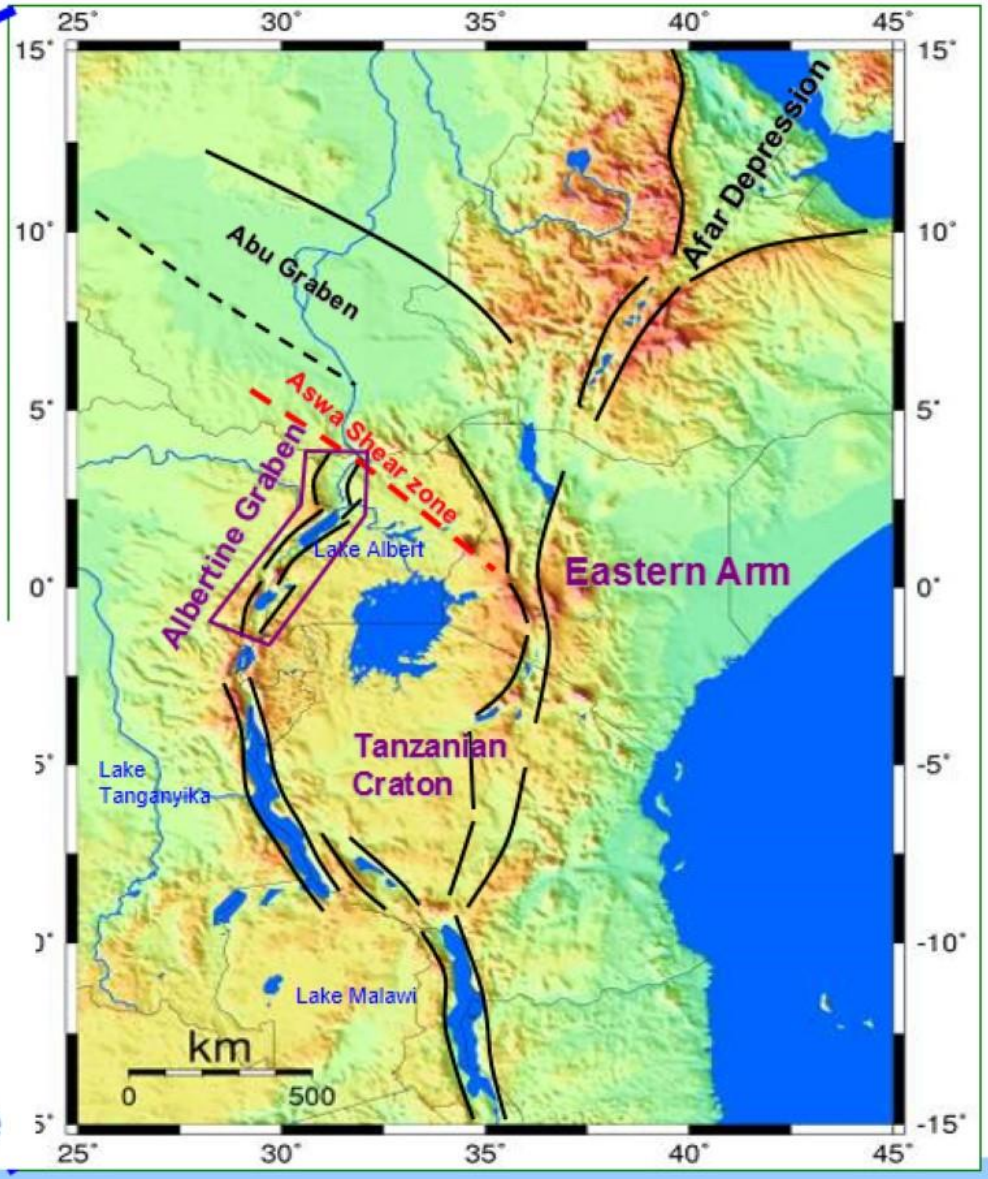


East Africa Rift System

- 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

TECTONIC SETTING OF THE ALBERTINE GRABEN



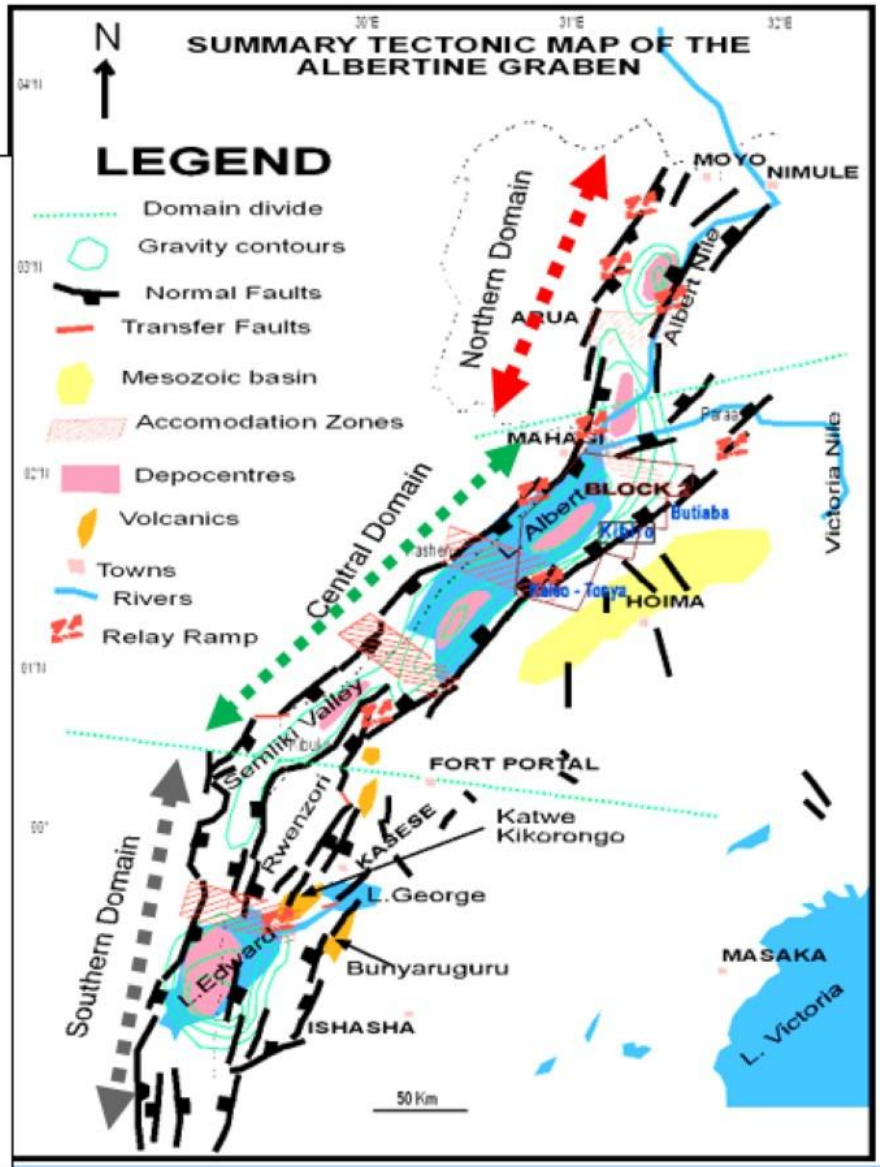


- The Albertine Graben forms the northern most part of the Western arm of the East African Rift System
- Formed by en-echelon extensional fault systems on either side
- From available data, rifting initiated during Early Miocene and is still tectonically active

TECTONIC SETTING OF THE ALBERTINE GRABEN

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.



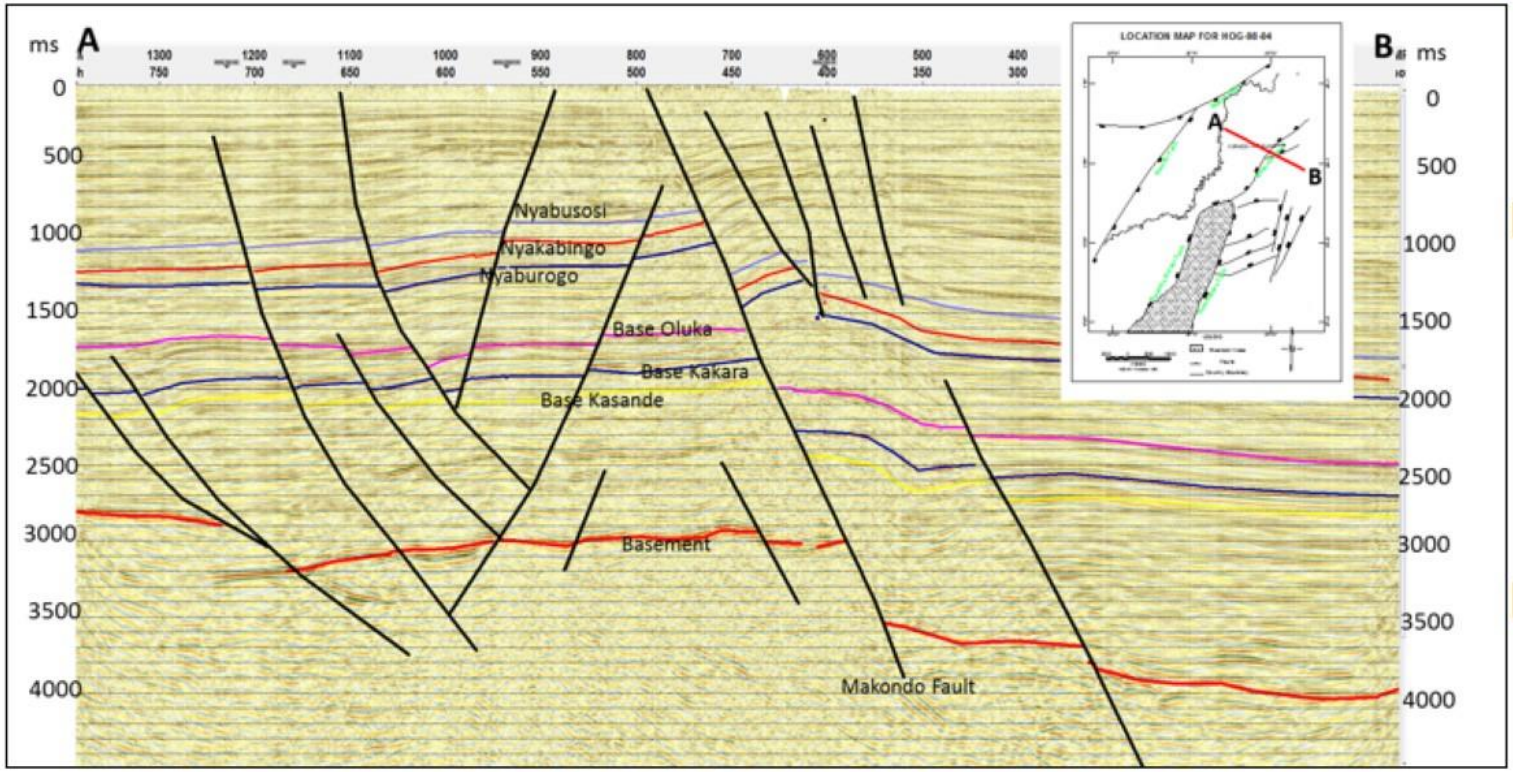
Study Methodology

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

Outcrop Study

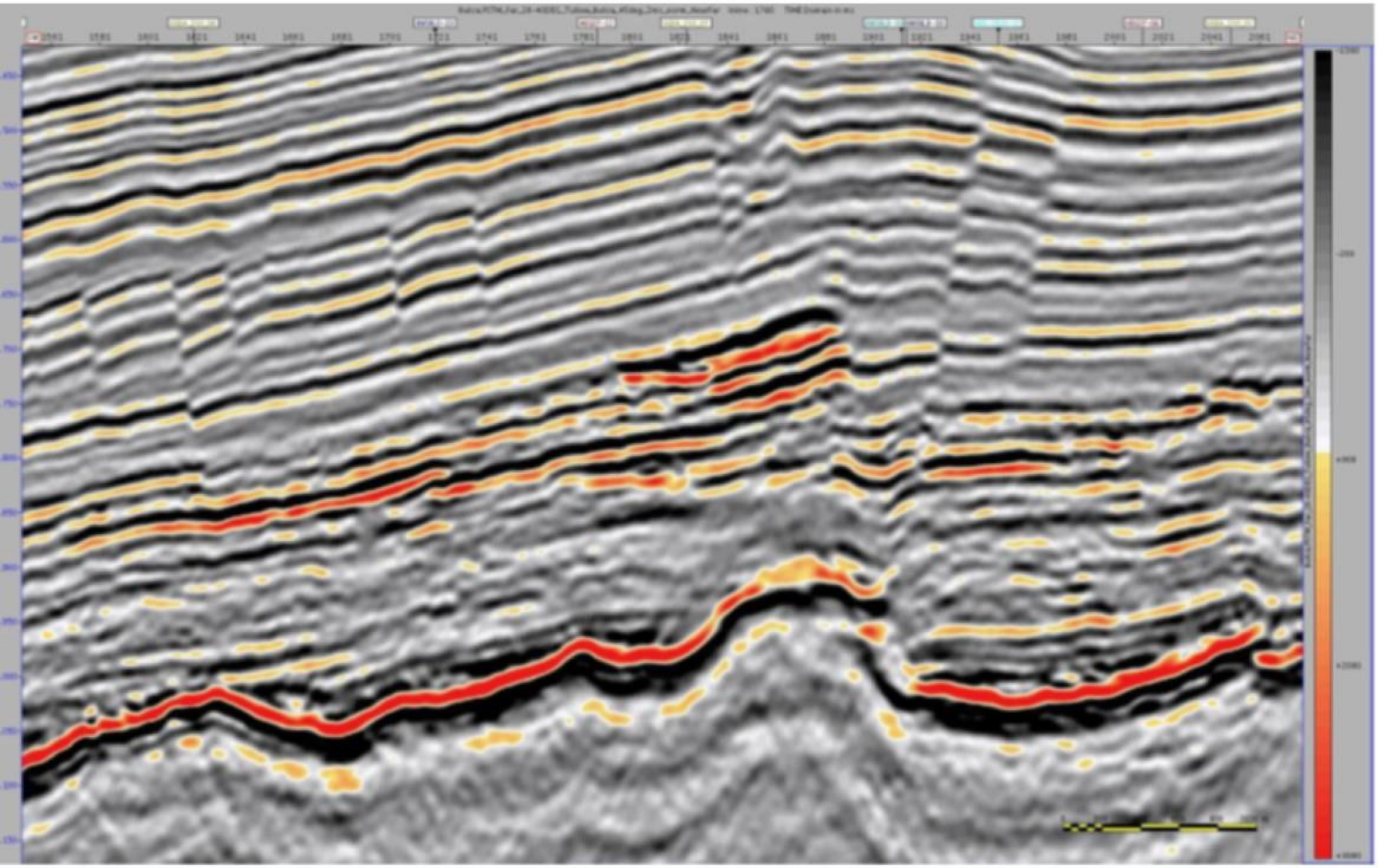
- Area of sediment exposures in less than 10% of the Albertine Graben.
- Sedimentary Exposures provide an idea of deposition, lateral variation of facies, and an indication of structural setting.
- Access to fossil record in the sediments documents age but also evolution of the basin.

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

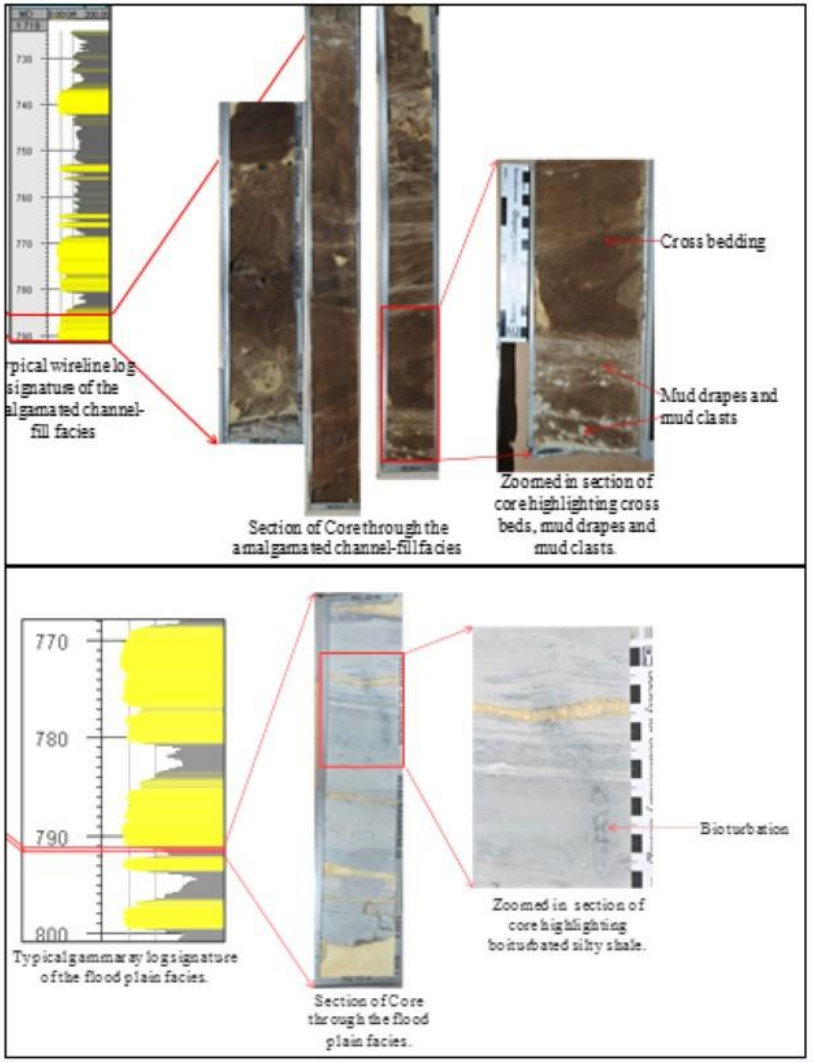
Structure from Seismic



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

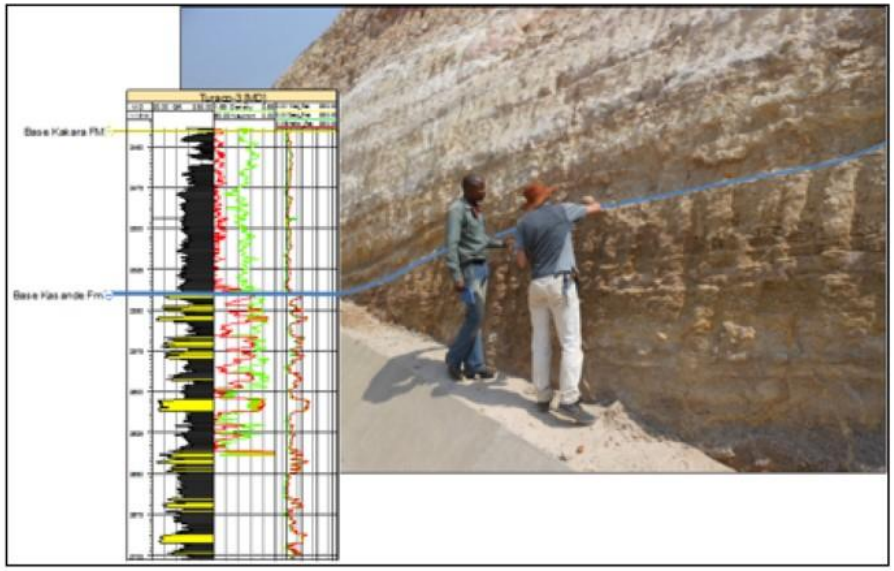
Subsurface data interpretation

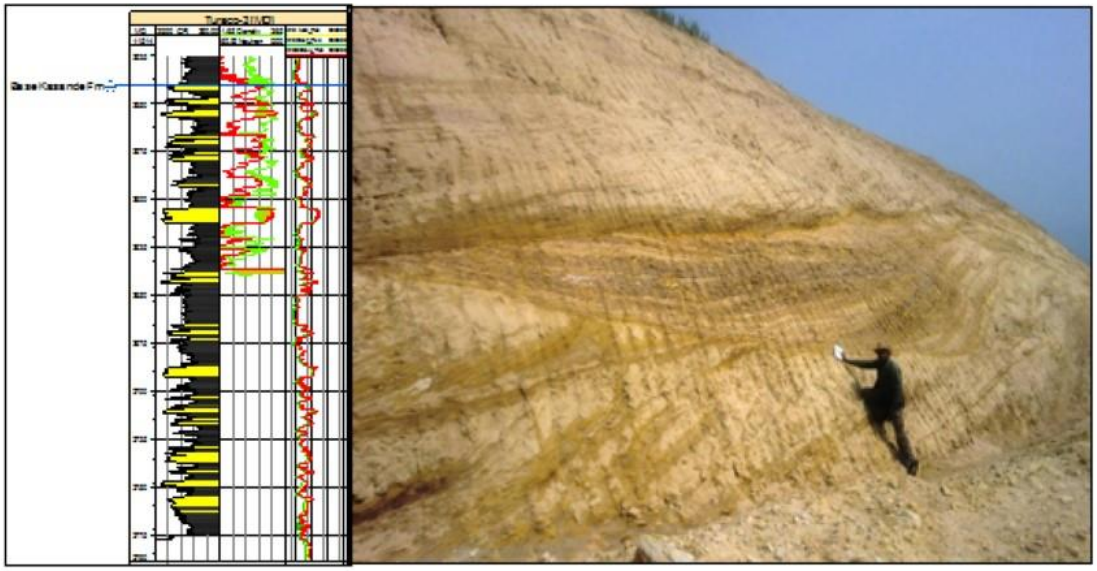
- Determination of facies associations & depositional Environment from core.
- Break down of logs - facies associations & depositional environment.
- Determination of thickness and distribution of different formations.
- Correlation using sequence stratigraphic techniques (*cautiously*)



Outcrop to Subsurface Correlation

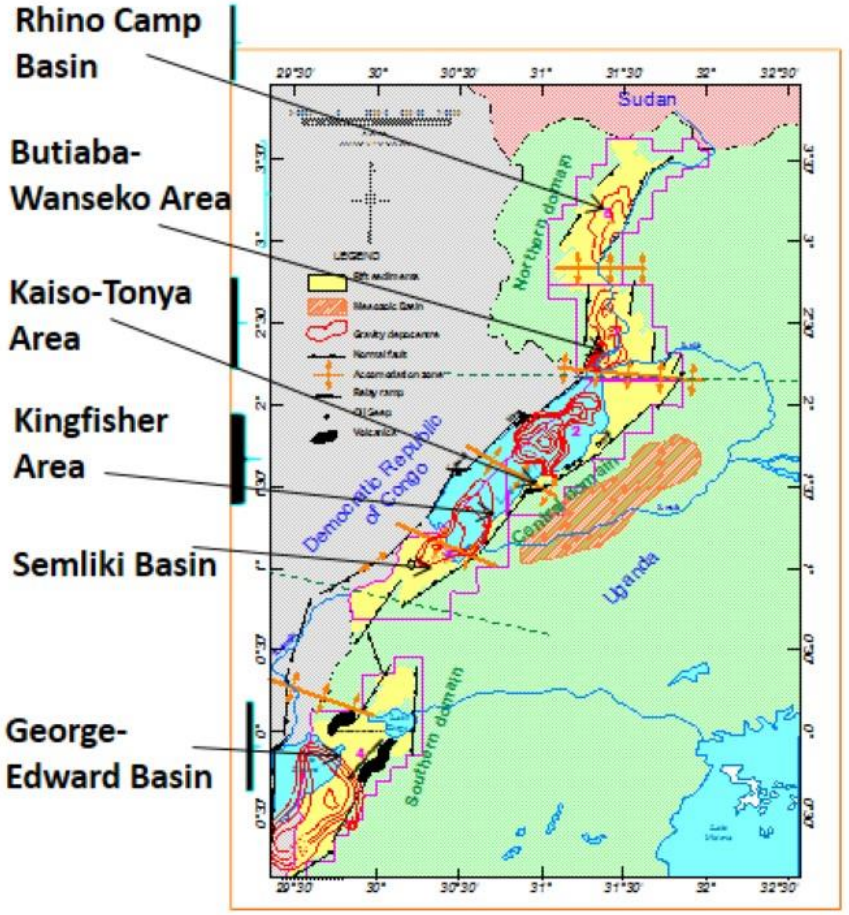
- Definition of 1st order (broad stratigraphic) packages
- Correlation between well data and outcrop
- Outcrop Gamma ray





PROJECT RESULTS

THE STRATIGRAPHIC COMMISSION



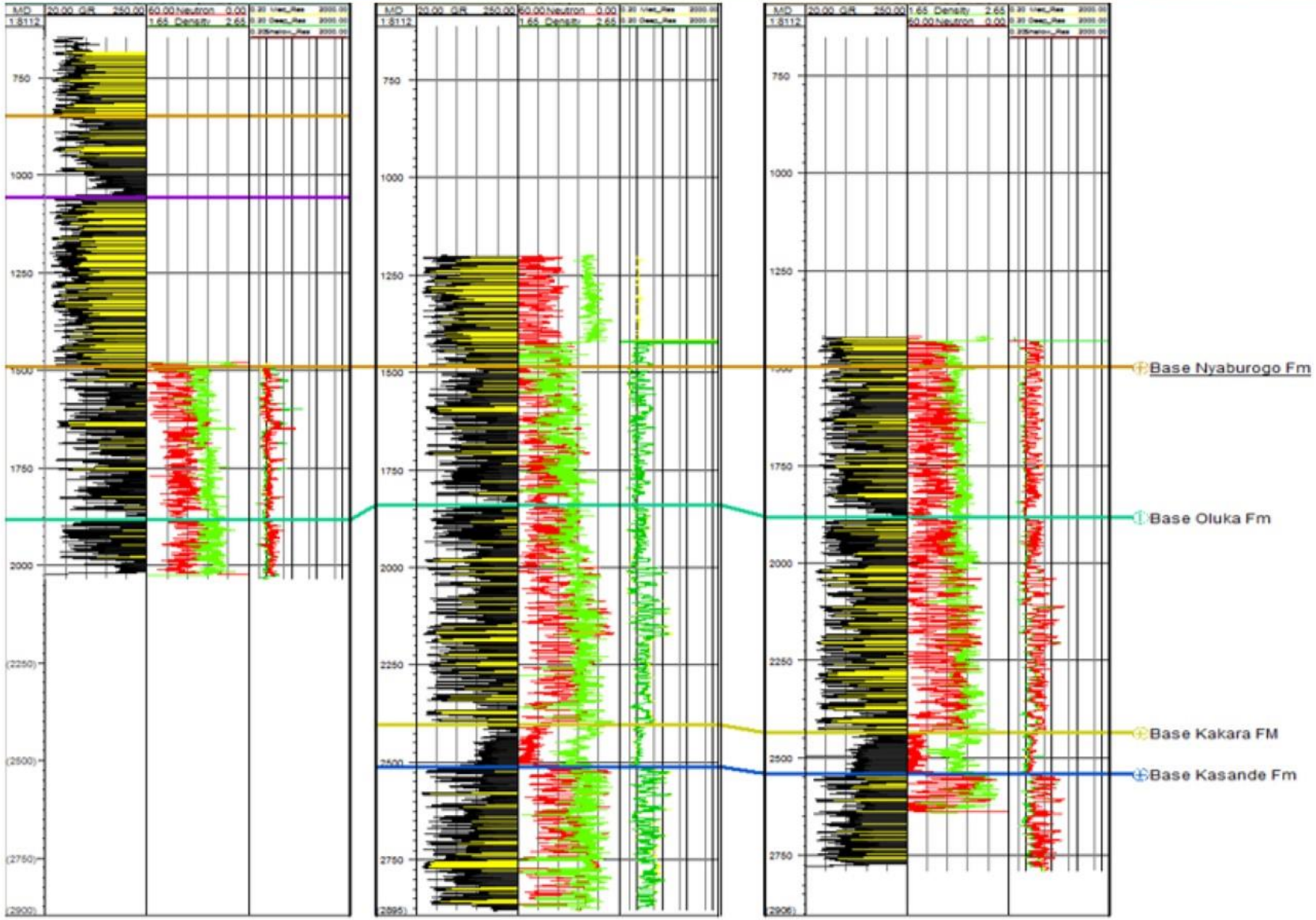
Completed Work

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

Work in Progress

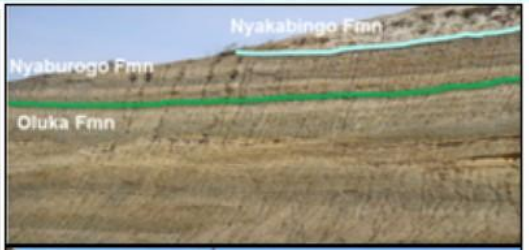
- Lake Edward - George Basins
- Rhino Camp Basin and

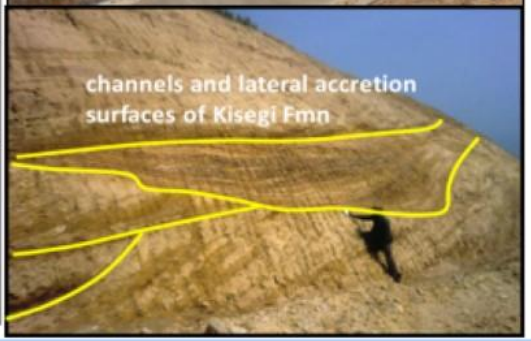
SEMLIKI: SOUTHERN LAKE ALBERT BASIN



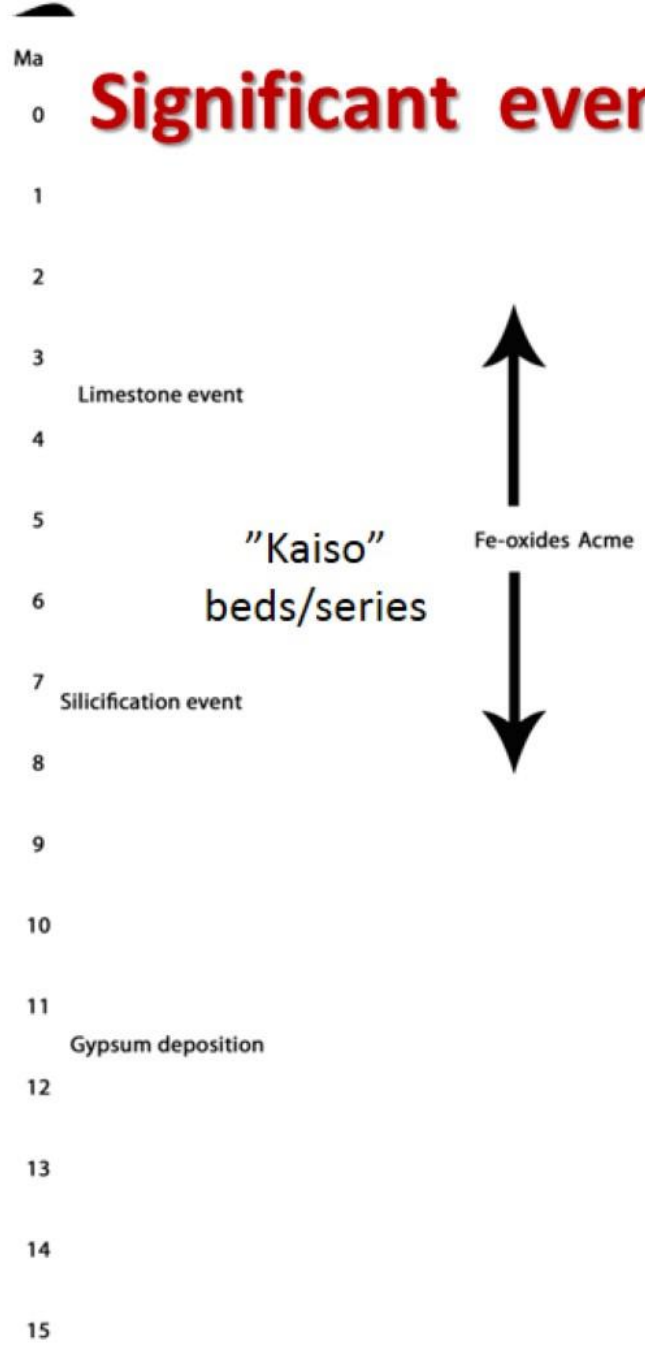
SEMLIKI: SOUTHERN LAKE ALBERT BASIN

Age	Formation	Thickness (m)	Strat-column	Major depositional environments
Pleistocene	Nyabusosi	600-700		Fluctuating coastal to shallow lacustrine
Late Pliocene	Nyakabingo	150-200		Repeated prodeltaic to delta front progradations
Mid-Late Pliocene	Nyaburogo	400-500		Delta plain to delta front
Late Miocene-Early Pliocene	Oluka	300-400		Lacustrine passing up into delta plain with minor fluvial intercalations
Late Miocene	Kakara	500-600		Mainly Deltaic with influence of channels
Mid/Late Miocene	Kasande	50-120		Lacustrine
Early-Middle Miocene	Kisegi	>300		Stacked/amalgamated fluvial sandstones in semi-arid conditions





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?

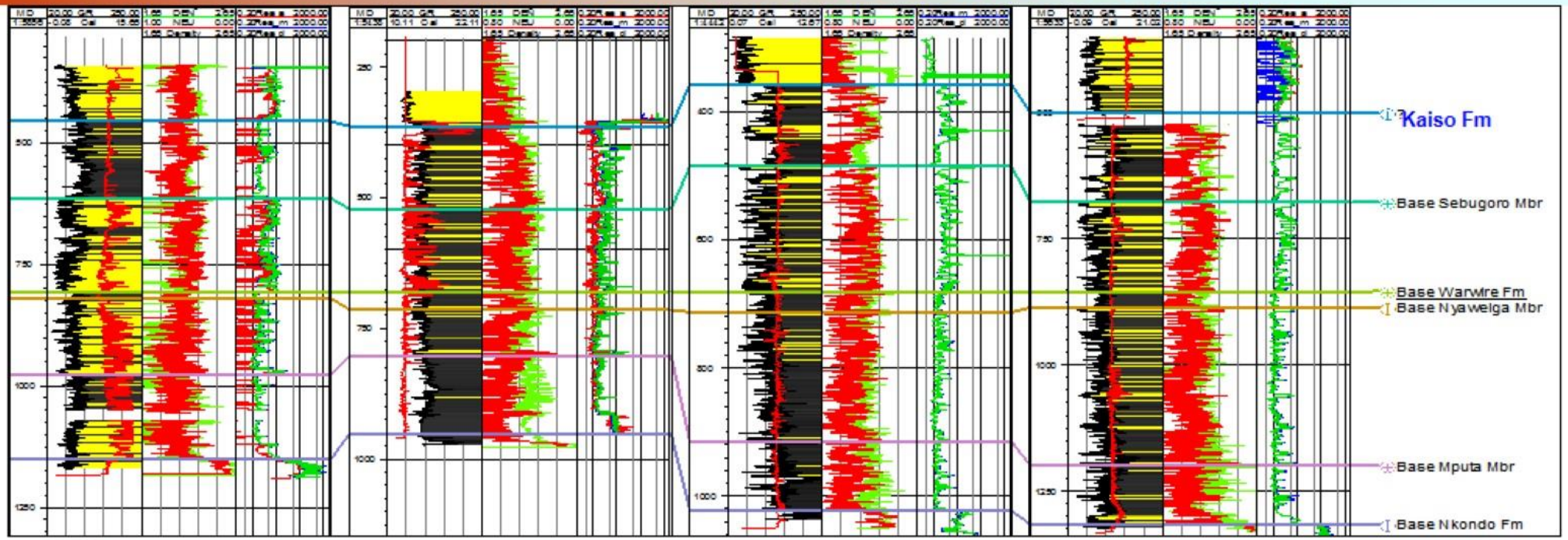
Ironstone onset base Kakara Fm

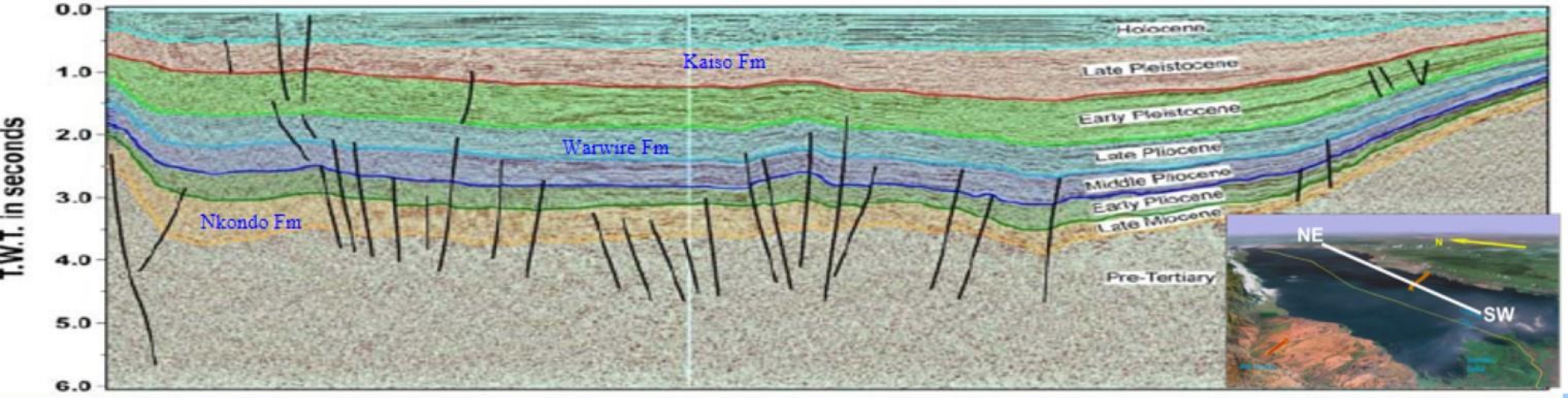
Major "Kasande" rifting &
"transgression" just before climate change?

Semiarid/arid Kisegi fluvials

From Pickford *et al* 1994

MID LAKE ALBERT SUB-BASIN
KAISO TONYA AREA





MID LAKE ALBERT SUB-BASIN
KAISO TONYA AREA

Age	Formation	Thickness (m)	Strat column	Depositional environment
Pleistocene	Kaiso Village	300-500		Channel deposits
Mid-Late Pliocene	Warwire	150-300		Deltaic-Marginal Lacustrine
Early Pliocene	Nyaweiga	100-200		Lacustrine
Late Miocene	Nkondo	150-400		Stacked/amalgamated fluvial channel sands

MID LAKE ALBERT SUB-BASIN
KAISO TONYA AREA

Significant Events in Kaiso-Tonya evolution

Partial outcrops earlier miscorrelated

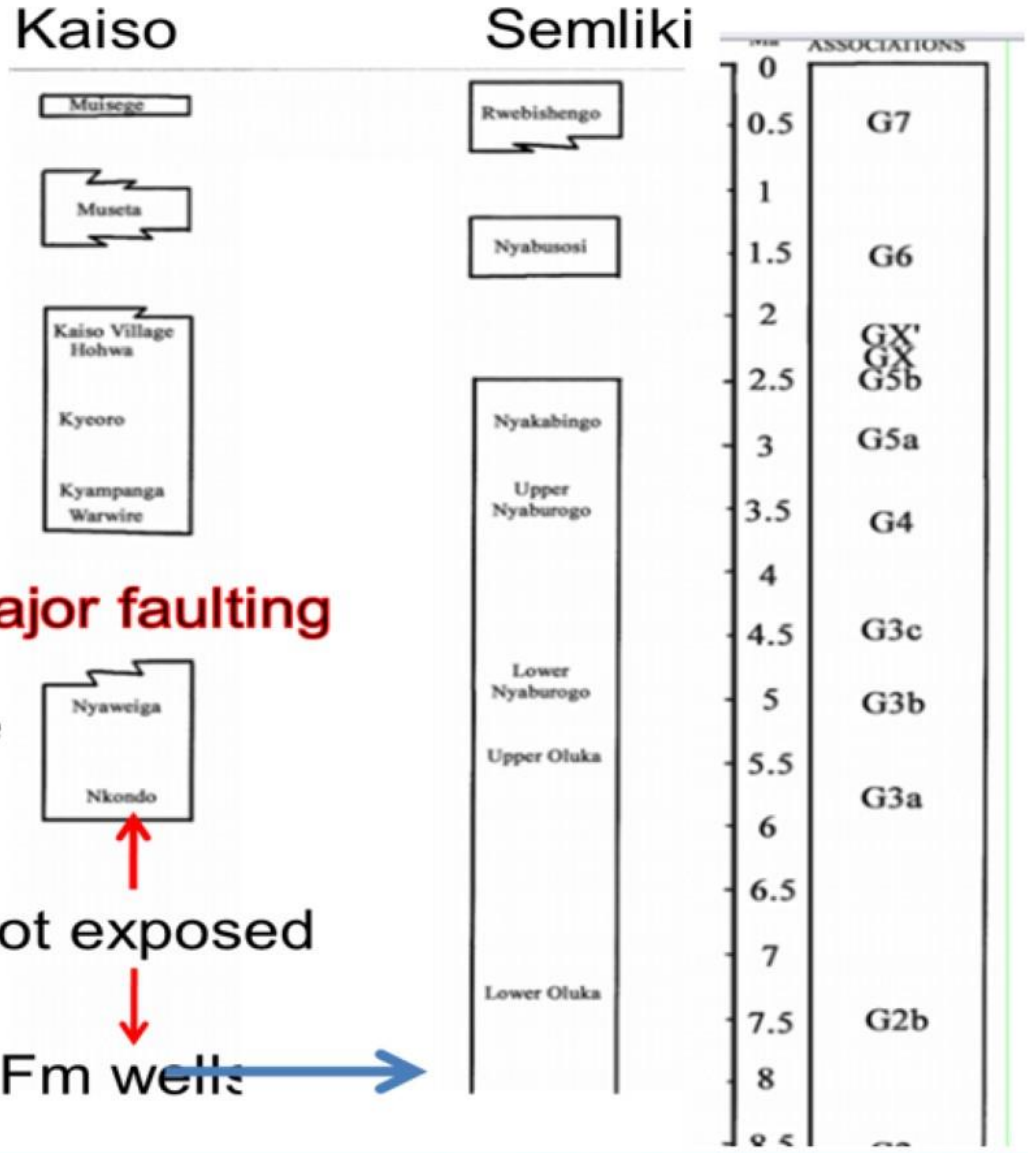
Major faulting

Nyaweiga lacustrine incursion

Not exposed

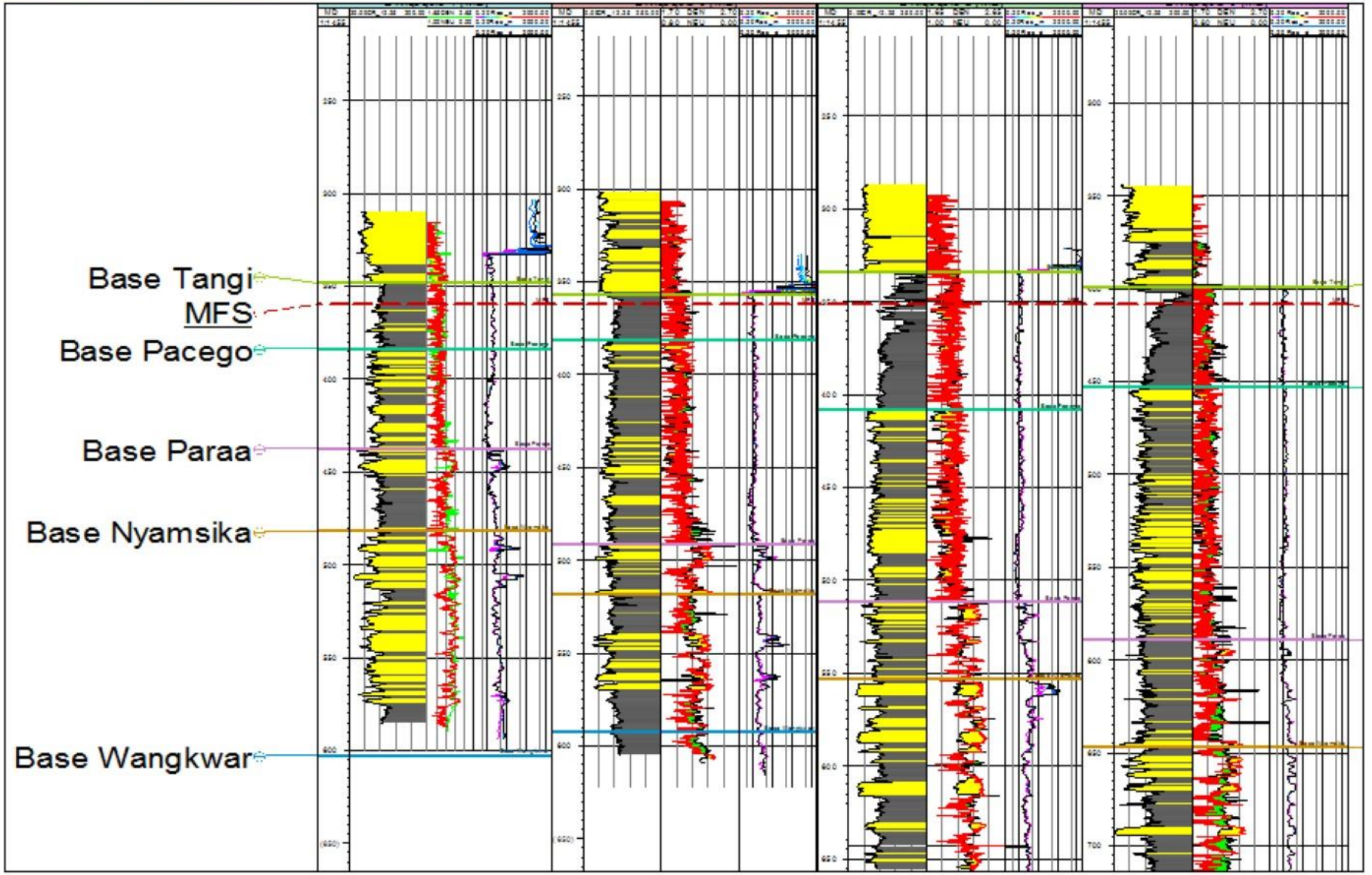
Major reservoir interval!

Probable base Nkondo Fm wells



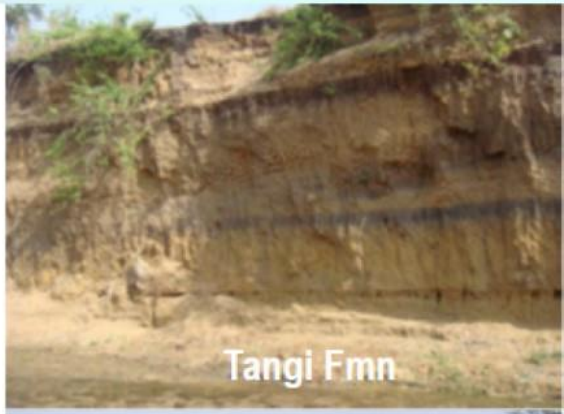
From Pickford

NORTHERN LAKE ALBERT SUB-BASIN
BUTIABA- WANSEKO & PAKWACH AREA

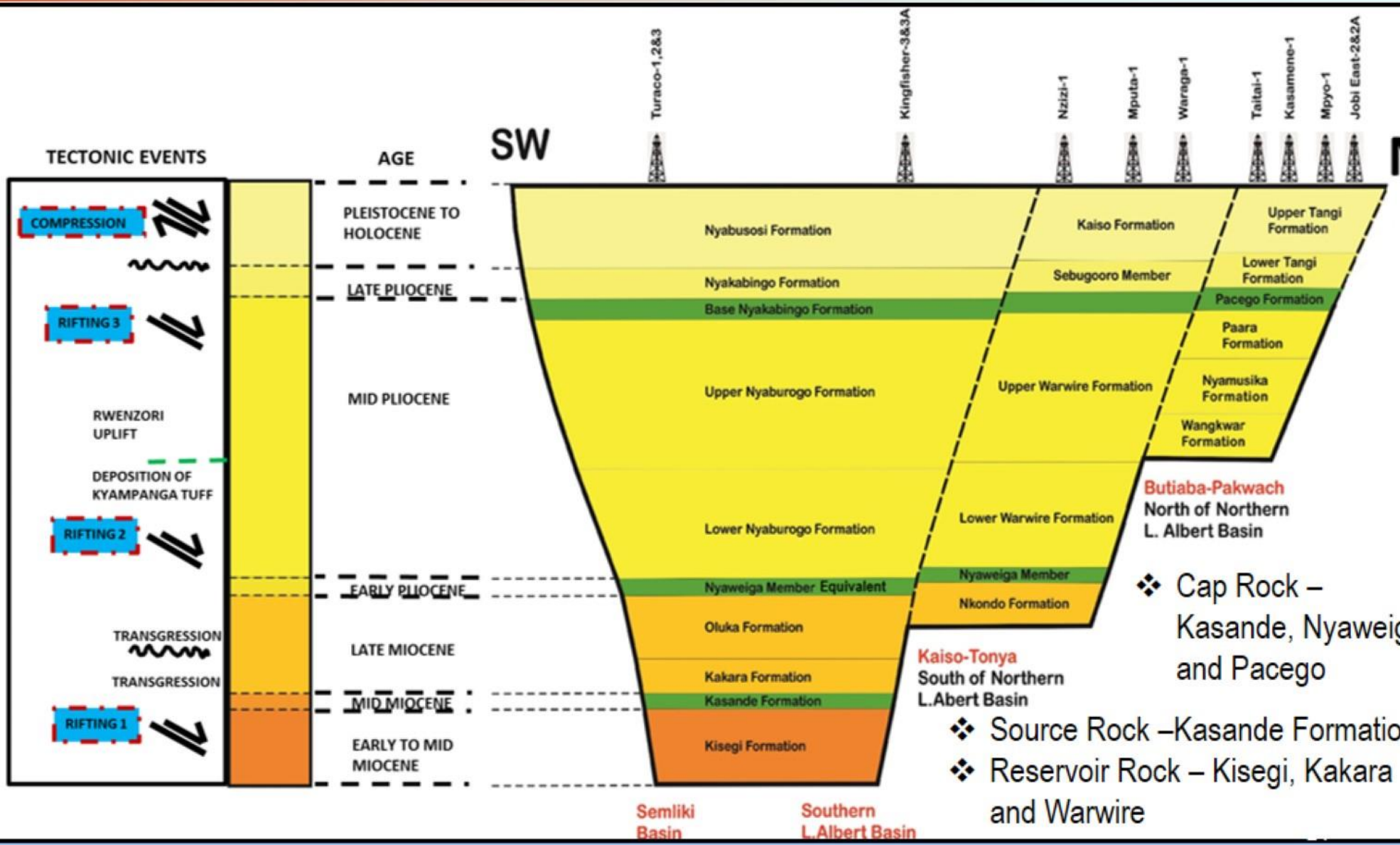


NORTHERN LAKE ALBERT BASIN
BUTIABA- WANSEKO & PAKWACH AREA

Age	Formation	Thickness (m)	Strat column	Depositional Environment
Pleistocene	Tangi	100-400		Predominantly fluvial (young) channel sands
Late Pliocene	Pacego	30-100		Lacustrine
Mid-Late Pliocene	Paara	50-200		Deltaic with occasional fluvial influence
Mid-Late Pliocene	Nyamsika	15-80		isolated fluvial channel complex
Mid-Late Pliocene	Wangkwar	100-200		Stacked/amalgamated fluvial channel complex



ALBERTINE GRABEN TECTONO STRATIGRAPHIC CHART

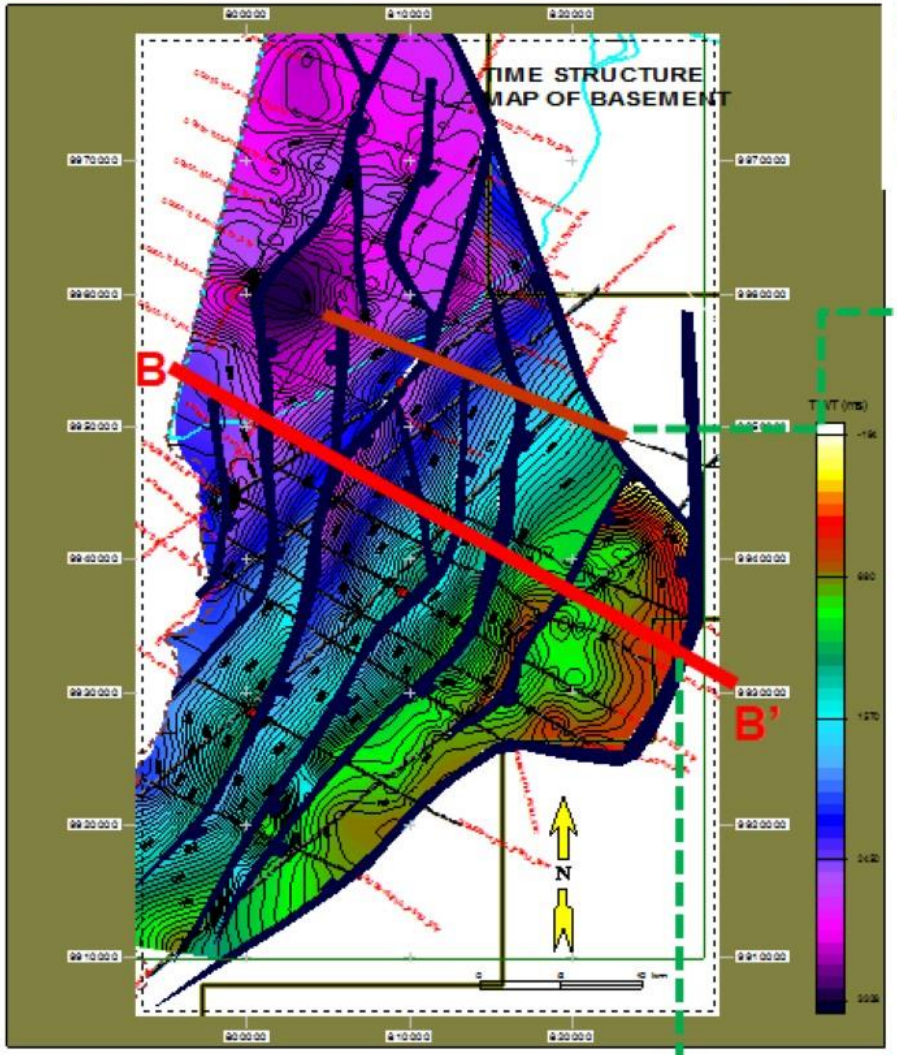


- Cap Rock – Kasande, Nyaweiga and Pacego
- Source Rock –Kasande Formation
- Reservoir Rock – Kisegi, Kakara and Warwire

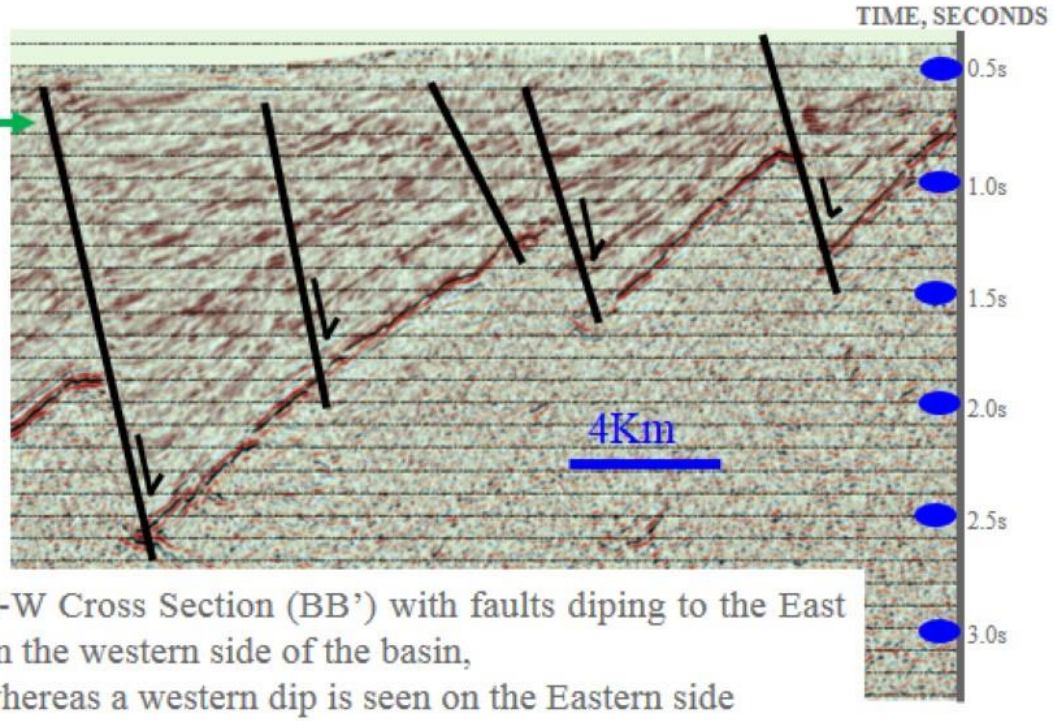
CHALLENGES

- 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.

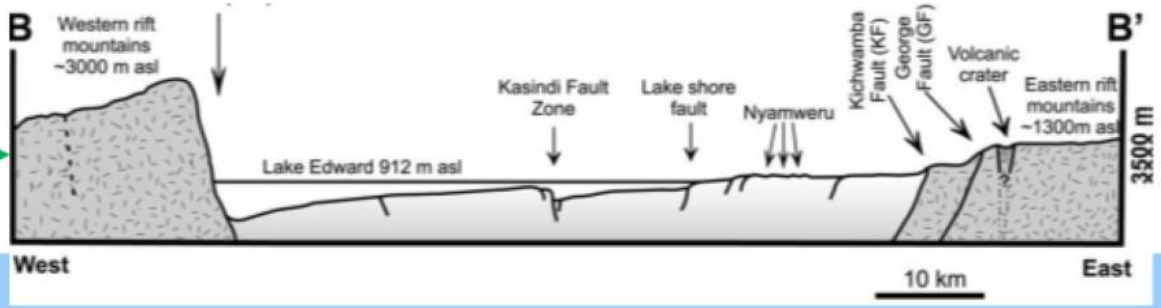
FURTHER WORK - Lakes Edward - George Basin



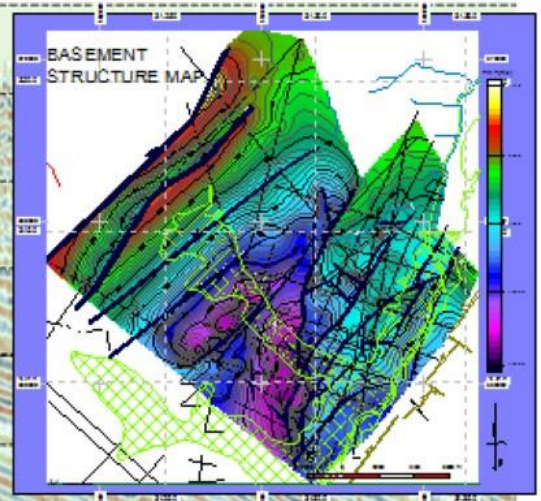
Finalize and link the Stratigraphy of Lakes Edward-George basin with Central part of Albertine Graben. Initial work has indicated that the basin has young stratigraphy than Central Albertine Graben, probably oldest strata is late Miocene.



E-W Cross Section (BB') with faults diping 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



500

1000

- 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 (2nd to 4th order) reservoir packages