MAKERERE UNIVERSITY

COLLEGE OF NATURAL SCIENCES

SCHOOL OF PHYSICAL SCIENCES

DEPARTMENT OF GEOLOGY AND PETROLEUM STUDIES

A REPORT ON THE GEOLOGIC AND STRATIGRAPHIC LOGGING PROJECT OF SEMILIKI BASIN-ALBERTINE GRABEN IN NTOROKO DISTRICT WESTERN UGANDA FROM 08th JUNE TO 19TH JULY 2025

BY

SSEKAMATTE ANOLD DAVID

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SUBMITTED TO THE DEPARTMENT OF GEOLOGY AND PETROLEUM STUDIES MAKERERE UNIVERSITY IN PARTIAL FULFILMENT OF THE AWARD OF BACHELOR OF SCIENCE DEGREE IN PETROLEUM GEOSCIENCE AND PRODUCTION

DECLARATION

I **SSEKAMATTE ANOLD DAVID**, hereby declare that the content of this report, submitted to Makerere University for the award of a Bachelor of Science degree in Petroleum Geoscience and Production, is my own work compiled under the guidance and supervision of various lecturers at the Department of Geology and Petroleum Studies of Makerere University as well as knowledge and information obtained throughout the field study period, internet research as well as fellow students and research and has never been presented before to this or any other institution.

Signed........ Date 13th-06-2026

PROJECT COORDINATOR: Dr. MUTEBI DENIS.

Signed........ Date 13th/06/2026

DEDICATION

I dedicate this work to the God Almighty who has seen me throughout my academics right away from childhood till this level. I also dedicate this work to my parents, Mr & Mrs MUSAJJAAKAAWA, and my brothers, for their great support throughout my entire academic experience including this project. I also dedicate this report to my lecturers who have guided me in different ways. In a special way, I also dedicate this work to my fellow course mates, KAWEESI PAUL, KISOMBO GEORGE, KIYINGI HENRY, NAKABUUBI JOSEPHINE and KEMIGISA SUNNY with whom we shared knowledge and this academic experience, God bless you all.

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I am very grateful and express my sincere thanks to the Almighty God for His protection and the gift of life and the strength to successfully complete this project. I would like to express my sincere gratitude to project coordinator Dr. Denis Mutebi and to all my supervisors Dr. Simon Echegu, Dr. John Mary Kiberu, Dr. Betty Naggudi as well as all the other lecturers in the department of geology and petroleum studies, Makerere University headed by Dr. Arthur Batte Godfrey for their guidance, intellectual support, advice, encouragement and supervision that enabled me to successfully complete this report.

Lastly, I extend my sincere gratitude to all my fellow colleagues KAWEESI PAUL, KISOMBO GEORGE, KIYINGI HENRY, NAKABUUBI JOSEPHINE and KEMIGISA SUNNY with whom we did the field study. Thank you so much for the cooperation and teamwork spirit you exhibited.

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ABSTRACT

This report presents a comprehensive geological and stratigraphic study of the Semliki Basin, a half-graben within the western arm of the East African Rift System (EARS), located south and east of Lake Albert in Ntoroko District, Western Uganda. The basin has its shallow end in Uganda and deeper end in Congo, and sediment thickness exceeding 6 km. The field study was conducted as a field training exercise for fourth-year Petroleum Geoscience students at Makerere University targeting areas like Kichwamba, Kibuku Quarry, Itojo, Makondo Fault, and the Turaco well site. It aimed at building skills in lithological description, stratigraphic logging, facies analysis, structural interpretation, and geophysical data assessment, while investigating the basin's depositional environments, sedimentological processes, sequence stratigraphy, and petroleum potential.

Its basement of the Semliki basin consists of high-grade metamorphic rocks like granitic gneisses and migmatites, overlain by sedimentary sequences classified into seven formations based on lithological characteristics and age. These include Kisegi, Kasande, Kakara, Oluka, Nyaburogo, Nyakabingo, and Nyabusosi (Lukaye, 2016). Stratigraphic logs revealed fluvio-lacustrine sequences, including sandstones, silts and clays, with fining-upward and coarsening-upward sequences, cross-bedding, cross-stratification, and blocky clays, indicating deposition in fluvial-deltaic to lacustrine settings influenced by intense tectonic activity.

Tectonic forces formed diverse structures, including faults, joints, bedding, laminations, mud diapirs, plunging folds, and normal faulting, observed on outcrops. Geophysical data, including magnetic and gravity surveys, confirmed the basin's sedimentary nature, while petrophysical analysis of the Turaco-2 well identified moderate-quality sandstone reservoirs interbedded with thick clays and evaporites, suggesting reservoir potential. The presence of Sempaya hot springs and oil seeps in the Kibuku area indicates a high geothermal gradient and organic-rich source rocks, supporting source rock maturation and an active petroleum system.

The study confirms the Semliki Basin contains all essential components of a petroleum system including source rock, reservoir, structural traps, and seal. Future exploration should prioritize high-resolution 3D seismic surveys, basin modeling, and geochemical analysis to assess gas origins and trap viability. The basin's geothermal potential, driven by high heat flow and active faulting, also warrants further investigation.

CHAPTER 1: INTRODUCTION

1.1 Background

The field study is intended for students pursuing the degree of Bachelor of Science in Petroleum Geoscience and Production who have completed Year-III at the Department of Geology and Petroleum studies, School of Physical Sciences- College of Natural Sciences, Makerere University. The fieldwork and field excursion held within the Albertine Basin, South and East of the Lake Albert Basin, it lasted 10 days from 08th to 19th June 2025 (including travelling days from and back to the department) with the respective target areas being Kichwamba, the Turaco wells, Sempaya hot-springs and the Semliki basin. During the field study, there was stratigraphic logging, geological studies and description from which interpretations such as depositional environments and their history, paleo flow, basin and facies analysis among others were deduced.

1.2 Study area

1.2.1 Location.

The study areas (kichwamba and semliki basin) are found in Karugutu-Ntoroko district, Southwestern Uganda. This area is in the Albertine Graben, South and East of the Lake Albert basin. It forms northern part of the western arm of the East African Rift System (EARS). The Semliki basin occupies an area of approximately 1200km^2 with 740km^2 in the Ugandan part of the Albertine graben with the rest in the Democratic Republic of Congo and it is bounded by the steep escarpments of the Rwenzori Mountains to the South East, Lake Albert to the North, rivers Lamia and Semliki to the west.

The Ugandan portion of the Semliki basin covers the southern part of the Ugandan portion of the Lake Albert, plus a landward area to the south of the lake. This includes the eastern part of the floodplain of the Semliki River and Lake Albert, known as the Semliki flats and the adjacent Toro plain, a slightly more elevated escarpment area to the east of the flood plain. It is bordered to the South East by steep escarpments rising almost 1000m to the northernmost spur of the Rwenzori Mountains. The low-lying undulating areas of the Toro plain are separated from the semliki flats, flood plains on the Eastern banks of the Semliki River by the major Kibuku and Makondo fault. The Semliki River itself forms the present border between Uganda and Democratic Republic of Congo.

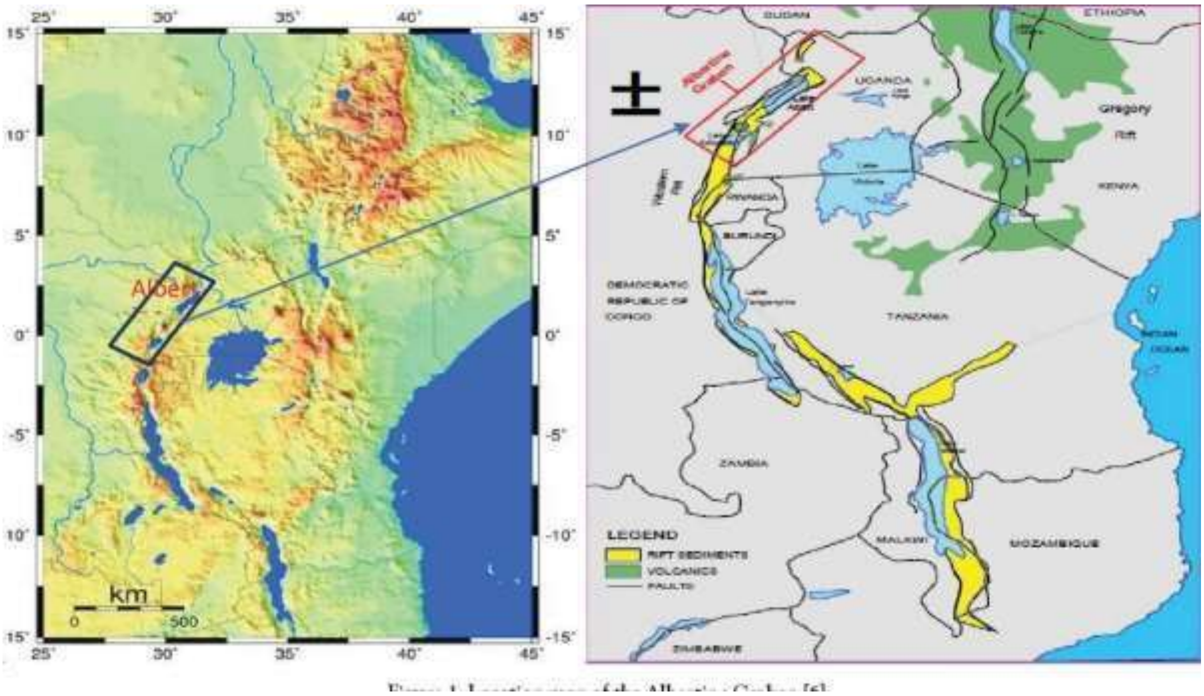


Figure 1 A map showing the location of the semliki basin

1.2.2 Accessibility

The area was accessed by road transport from Kampala to Ntoroko district using the Kampala-Mubende Road, to FortPortal (290km) and then to Ntoroko (study area) using the Fort portal – Bundibugyo highway for about 78km. The camp was set up about 44km from Fort Portal town at Karugutu Secondary School, in Karugutu town.

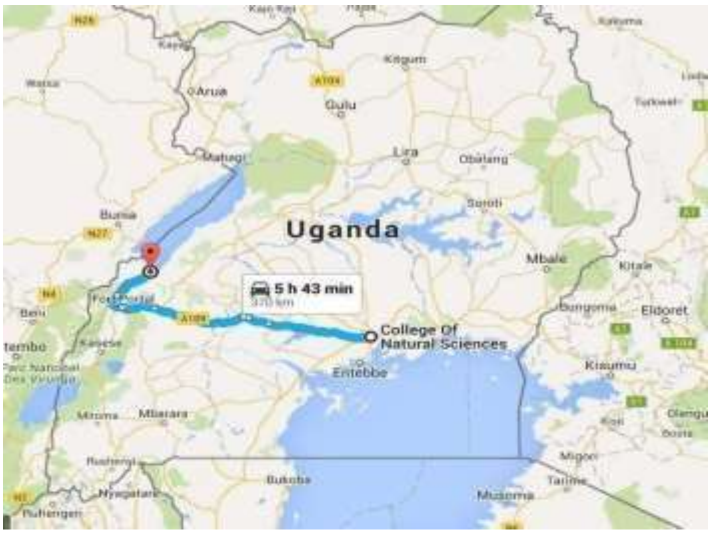


Figure 1.2.2.1 Map showing a road (in blue) to the Kibuku area

1.3 Objectives

The main objective of the field work study was to learn how to collect and interpret stratigraphic, petrographic, sedimentologic and structural data which are important for hydrocarbon exploration.

1.3.1. Main objectives;

- To study the environments and processes of deposition of sediments in the area
- To understand physical, sedimentological and sequence stratigraphic formations

1.3.2 Specific objectives;

- To identify the different lithologic types in the area
- To identify and explain depositional processes based on textural and structural characteristics of sedimentary deposits.
- To study the lithologies and environment in order to identify different elements of a petroleum system.
- To identify and relate structures observed in the basement and in the sediments.
- To sketch scaled sedimentary sections showing strata as seen on the outcrops.
- To identify the facies and depositional environments.
- To apply facies analysis to interpret sedimentary successions.
- Use surface water chemistry and temperature to characterize the geothermal system.

1.4 Geologic setting of the area

1.2.1 Formation and evolution of the albertine rift system

The Albertine Graben is part of the Northern-most extension of the Western arm of the East African Rift System (EARS). The Graben stretches from the border between Uganda and Sudan in the north to Lake Edward in the south, a total distance of over 500km with a variable width of 45 km. Bounded by the Azwa lineament to the north and by the Virunga volcanic province to the south, this system is characterized by an outstanding 5000-meter-high relief located between Lake Albert and Lake Edward, the Rwenzori Mountains (*Survey and Mines of Uganda, 1966 and GTK Consorsium, Jenett et al. 2009).*

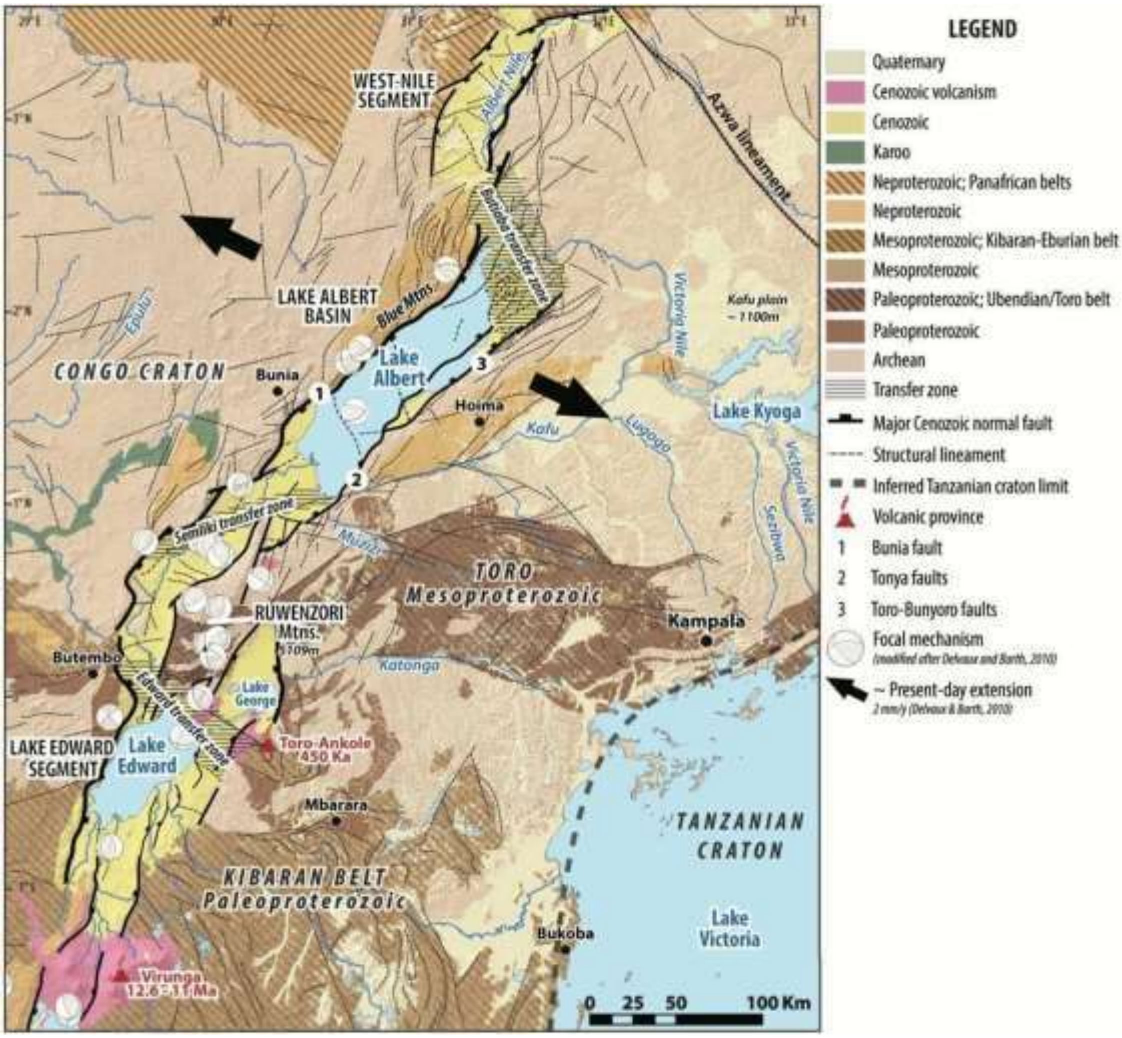


Figure 1.4.1.1 The Albertine Rift System. Geological and Structural map of the Albertine Rift System from the Azwa lineament to the Virunga volcanic province

The Lake Albert Basin was traditionally considered as an asymmetric half-graben dipping to the north-west where the major bounding Bunia fault system (Fig. 1) probably led to the uplift

of the 2100m high Blue Mountains (Ebinger, 1989). The eastern boundary consists of westward-dipping antithetic Toro Bunyoro and Tonya fault systems (Fig. 1) which controlled the uplift of the 1200m high topographic escarpment observed at the eastern border of the lake. Basing on new seismic data and gravity re-processing, Karp et al. (2012) shows that the Lake Albert Basin is rather a full-graben that "has subsided symmetrically and continuously in the Late Cenozoic along two extensive boundary fault systems on either side of the basin".

Albert Basin is located at the interface of the Archean Congo Craton and the Paleo- to Meso-Proterozoic Kibaran mobile belt of which the basin follows its roughly NE–SW trend. The age of the rifting initiation in the Lake Albert Basin is debated because the first Early Miocene sediments preserved in the basin have been considered pre-rifting fluvial sediments and not syn rift sediments. Based on the biostratigraphy available at this time, the first syn-rift lacustrine sediments were considered to be Late Miocene in age following a first volcanic episode of the Virunga Province dated from 12.6 to 9.0 Ma (Kampunzu et al., 1998; Pouclet et al., 2016).

This first major rifting phase might have been responsible for the formation of a paleo-lake (Lake Obweruka) covering the entire Albertine Rift area until the Rwenzori uplifted around 2.5 Ma (Pickford et al., 1993). Recent petroleum exploration and bio-stratigraphical investigations argue for an older rifting initiation, uppermost Early Miocene in age (≈17.0 Ma; Abeinomugisha and Kasande, 2012). On the basis of micro tectonic measurements and focal mechanism analysis, the tectonic setting of the Rwenzori Mountains is assumed to be dominated by strike-slip movements.

Two main mechanisms are proposed to explain the extreme uplift of the Rwenzori Mountains: Isostatic response related to the removal of crustal material in the hanging wall of a normal fault (Koehn et al., 2016, 2010)

The delamination of the lower crust and mantle lithosphere due to pre-existing weak- zones (Wallner and Schmeling, 2010).

According to Simon et. al (2017), a four-staged evolution of the Lake Albert Basin has been defined by Roller et al. (2010) by performing a sedimentary study of the Kisegi-Nyabusosi area outcrops.

From 14.5 to 10 Ma, the first stage corresponds to a sag basin with little accommodation space creation infilled by fluvial sediments.

From 10.0 to 4.5 Ma, the second phase is characterized by the creation of limited accommodation space and records successive rises in the lake level, as indicated by a transition from a distal fluvial plain to a lacustrine environment. The increase in the accommodation/sediment supply ratio is believed to record an initial rifting activity.

Between 4.5 and 2 Ma, the third stage corresponds to a classic rift controlled by sediment- supply rather than by accommodation.

Finally, from 2 to 1.5 Ma, an overall increase in the subsidence associated with a significant sediment supply is responsible for the acceleration of the uplift of the flanks. This infilling corresponds to stacked transgressional cycles from a fluvial to lacustrine environment.

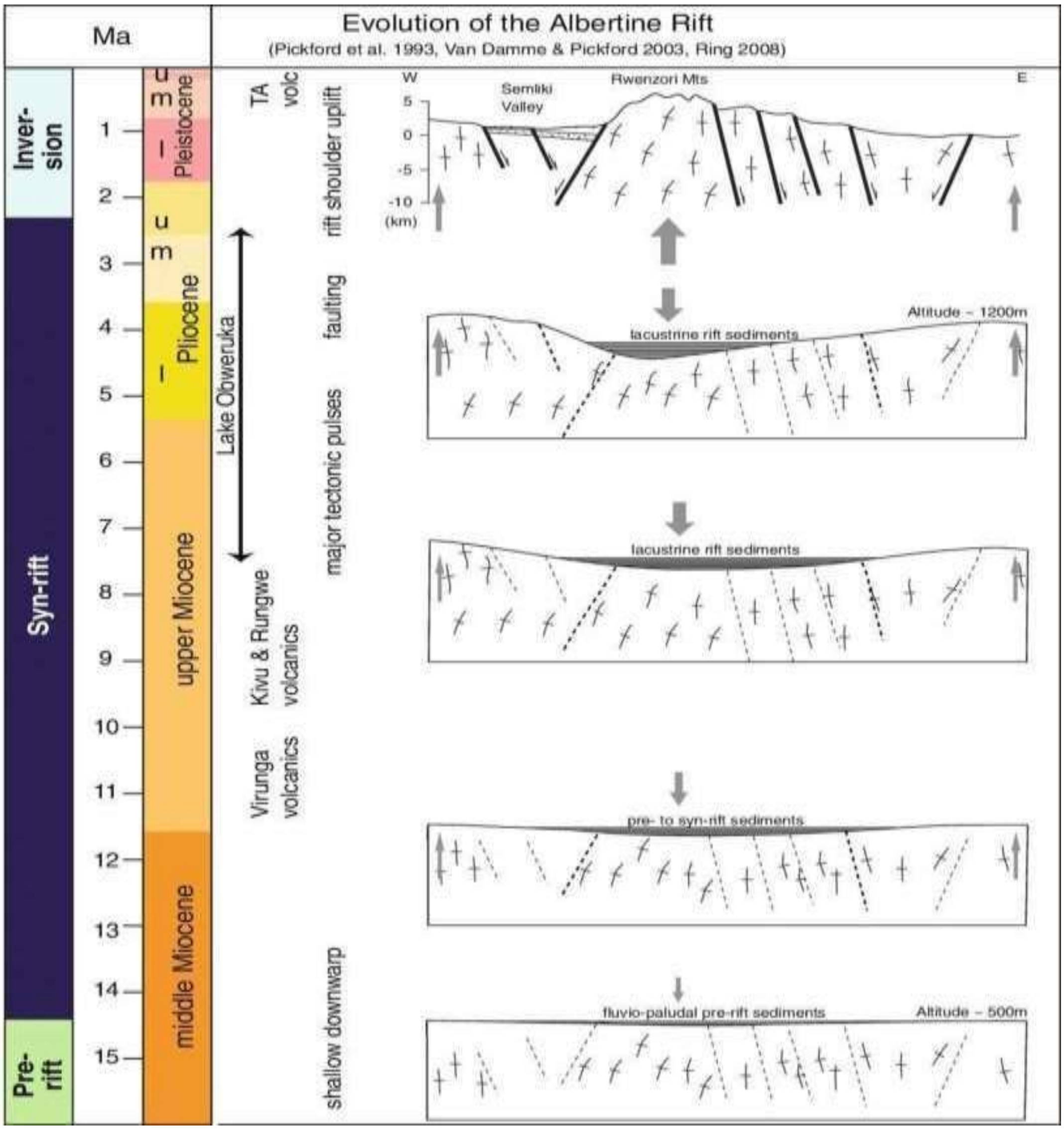


Figure 1.4.1.2 Schematic evolution of the Albertine Rift Basin with major phases of tectonic and volcanic activity and indicated sedimentary evolution (modified after Pickford et al. 1993; Van Damme and Pickford 2003; Ring 2008)

1.2.2 STRUCTURAL SETTING

The Albertine Graben is a Cenozoic rift basin formed and developed on the Precambrian orogenic belts of the African Craton. Rifting was initiated during the late Oligocene/Early Miocene. The Graben has undergone several tectonic episodes of both extensional and compressional regimes. Evidence of stress regimes oblique and perpendicular to the boundary faults is seen through the geometry and orientation of the fault systems defining the basins in the Graben. The Albertine Graben terminates at a known sinistral strike slip shear zone, the Aswa shear zone. Other shear zones can be interpreted in the south of the Graben, around Kivu and Rukwa areas in the Tanzania part of the East African Rift. The Albertine Graben could therefore, have evolved in a strike slip dominated regime similar to the other basins developed in the Central African Rift System (Figure, 1.4.1.2).

The Albertine Graben can be divided into **three structural domains;** the **Southern** Domain, the **Central** Domain and the **Northern** Domain (Figure 1.6). The northern domain that trends in a NNE- SSW direction encompasses the Rhino Camp and Pakwach basins, the central domain in a NE- SW direction where the Lake Albert (Butiaba-Wanseko and Kaiso-Tonya areas) and Semliki basins (where the study was conducted) are located in the southern domain trends in a NNE-SSW direction where the Lakes Edward-George basin is found. The central domain is an almost full graben while the southern and Northern domains are typically half grabens. The Graben trends in a NE-SW direction through most of its length, probably following the pre- existing basement fabric.

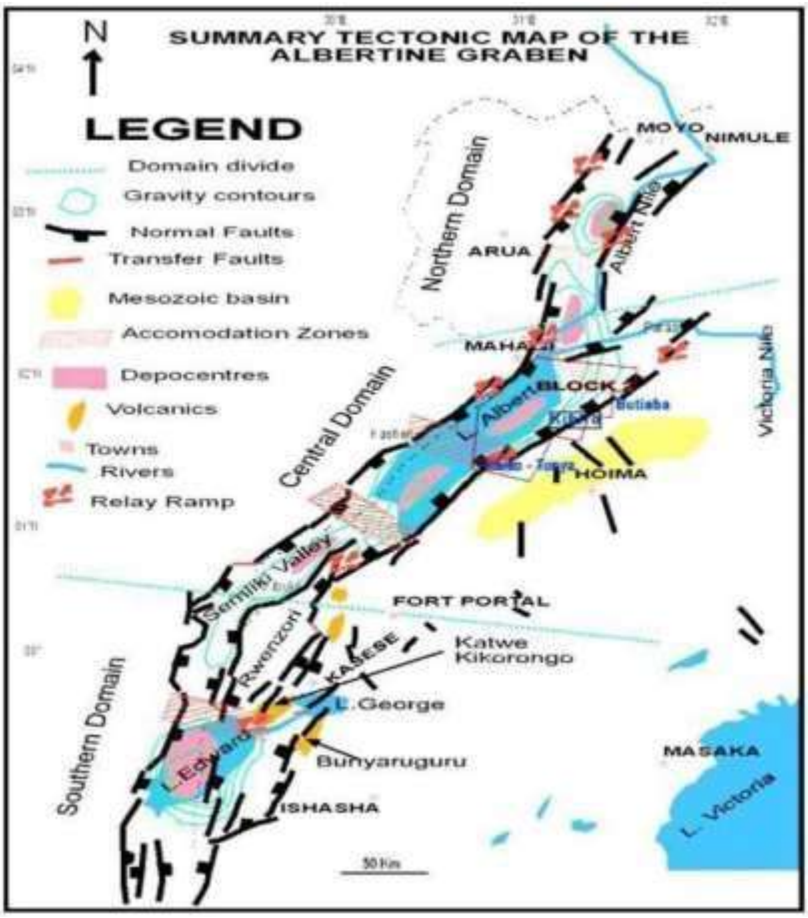


Figure 1.4.2.1 Map showing the structural elements in the Albertine Graben (Dozith, 2012)

1.2.3 STRATIGRAPHY OF THE ALBERTINE GRABEN

The stratigraphy of the Albertine Graben majorly consists of fluvial-deltaic and lacustrine deposits. The stratigraphy of the area has been greatly affected by tectonism, climate and Lake level fluctuations.

A number of geologists including Wayland (1925), Bishop (1965) and Pickford (1993) have given varying accounts of the stratigraphy. Studies by PEPD and the oil companies operating in the country have been carried out in an attempt to harmonize the variations in descriptions of the past and produce a unified stratigraphy for the Graben. Generally, the oldest units, the Proterozoic is well exposed on the rift flanks and shoulders of the Albertine Graben. It comprises mainly high-grade metamorphosed and igneous rocks of Pre-Cambrian age. Seismic data points to a Pre-Cenozoic rift sedimentary section in some parts of the Graben, mainly restricted to the Lake Albert depocenters. The syn-rift section of the Albertine Graben was first recorded in the **Waki- 1B well,** which was drilled in 1938. This well penetrated both the Mid and Upper Cenozoic syn-rift sections which are characterized by conglomerates and sandstones. The well went through the Mesozoic pre-rift section before reaching basement. The Kisegi and Kaiso formations of the Cenozoic are also quite well exposed in the Graben, consisting mainly of intercalation of conglomerates and sandstones deposited in fluvial and shallow lacustrine environments. The Kisegi Formation in some cases overlies the meta-quartzite Basement. Although the Lower Cenozoic may overlie the crystalline basement in many parts of the Graben, there is a possibility that it overlies a Mesozoic section (Karoo) in some parts of the Graben. The Lower Tertiary may overlap the crystalline basement in many parts of the Graben but there is a possibility that it overlies a Mesozoic section (Karoo) in most parts of the Graben (Heritage Oil and Gas, 2001).

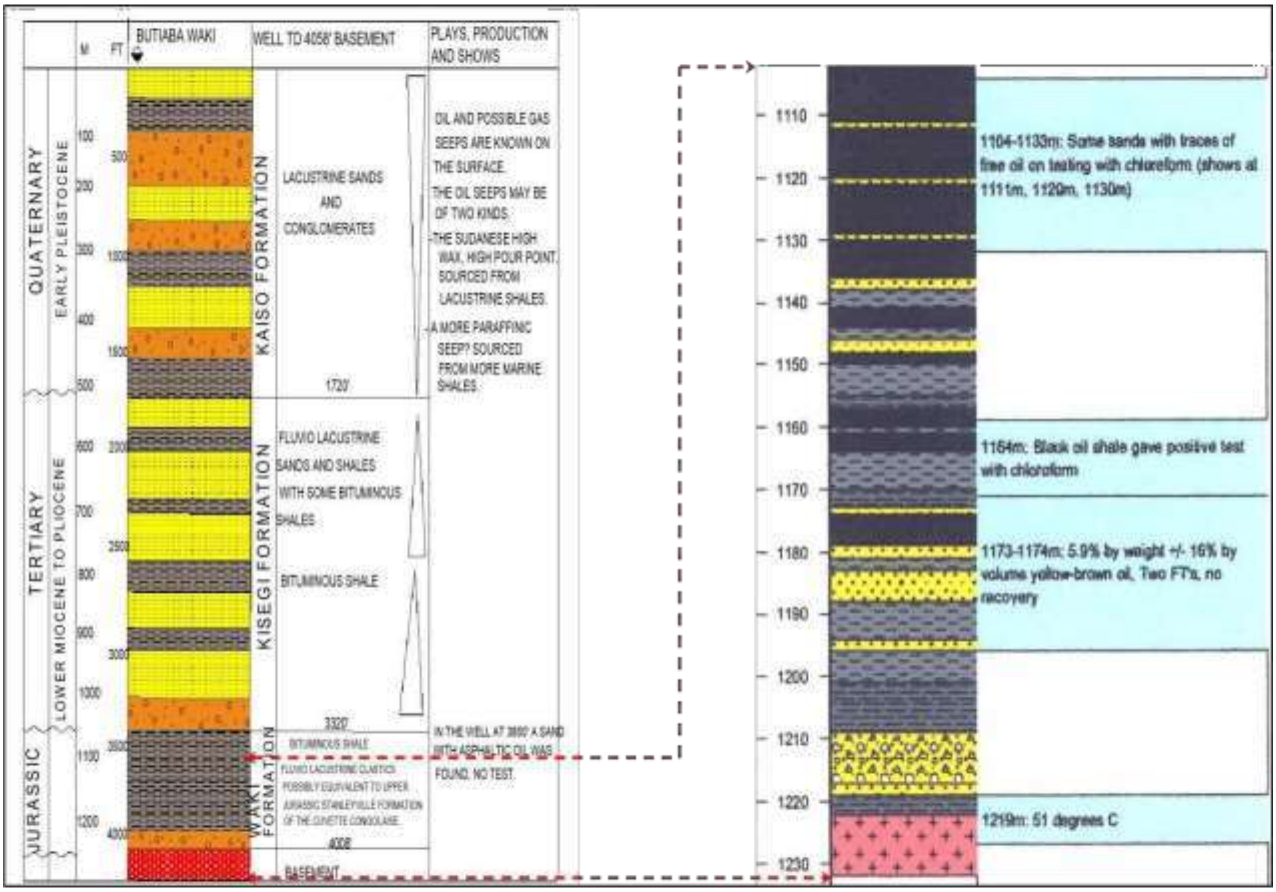
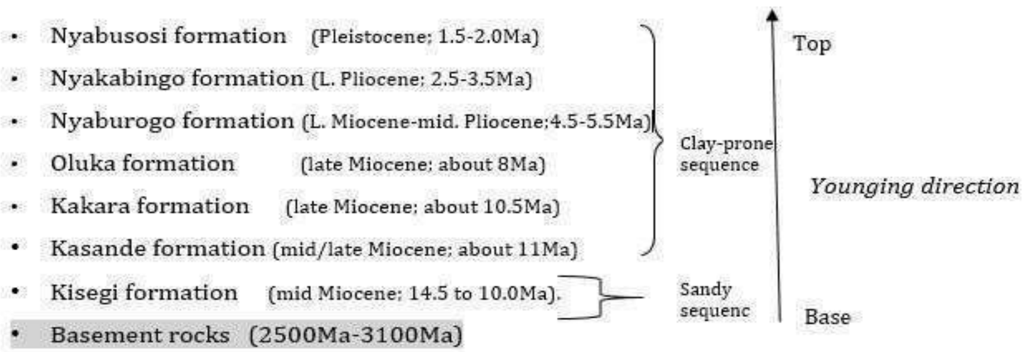


Figure 1.4.3.1 A section through the Waki-1B well demonstrating the stratigraphy of the Albertine Graben

Basing on age relationships of strata and bed successions, the stratigraphy of the Semliki basin has been divided by Pickford et al. (1993) into seven formations namely Kisegi, Kasande, Kakara, Oluka, Nyaburongo, Nyakabingo, and Nyabusosi as shown below. These deposits show the most complete sedimentary succession in the entire Albertine graben, spanning the period from the middle Miocene (ca. 15Ma) to recent, with a great thickness of fossiliferous sediment beneath the oldest fossil found, probably extending downward into the lower Miocene (Lukaye et al., 2016).



1.2.4 The semliki basin

Semliki basin is generally at a low elevation of about 650m above mean sea level compared with about 1650m for the adjoining rift shoulders. It comprises of the Semliki flats (eastern part of the floodplain of the Semliki River and Lake Albert) and the adjacent Toro plain (slightly more elevated escarpment area to the east of the flood plain) bounded by major fault escarpments

along with other prominent faults. A major fault; Makondo separates the Toro Plain from the Semliki Flats. Trend of the rift in the Semliki basin is NNE-SSW (shifts from NE-SW in the Lake Albert basin). The Semliki Basin is separated from the Lake Albert Basin to the north by an accommodation zone (Figure 1.8). The trend of the rift changes from NE-SW in the Lake Albert Basin to NNE-SSW in the Semliki Basin. The Semliki Basin terminates against the Rwenzori Mountains to the southeast.

The Semliki basin is characterized by two major types of lithologies; the syn-rift and pre-rift lithology. The syn-rift lithology comprises of both clastic (resulting from the weathering of the basement rocks) and non-clastic sediments (resulting from the precipitation within the basin of deposition or from volcanic activity). The syn-rift mega-sequence unconformably overlies the pre- rift rocks and most of the syn-rift rocks are of Cenozoic age (possibly ranging from the Paleogene (Early Miocene) to Recent). The pre-rift lithology is comprised of Uganda's oldest rocks; the Pre- Cambrian Basement rocks (2900Ma-3500Ma) that underlie the Kisegi Formation. These are exposed on the rift flanks and consist high-grade meta-sedimentary rocks, gneisses, granitic gneisses and quartzites schists, granites, basic intrusive rocks, amphibolites and meta-calcareous rocks that stratigraphically underlie (form the base) and are apparently older than the rock groups or formations that have been assigned to different systems or series of Uganda geology. These rocks have no source potential but could prove to act as reservoirs if fractured and sealed.

1.2.4.1 Physiography of the Semliki Basin

The area comprises of the Semliki flats and the adjacent Toro plains South-west of Lake Albert. The largest part of the Semliki flats has a flat or very gently undulating surface with savannah vegetation. The undulating areas of the Toro plain are separated from the flood plains on the Eastern banks of the Semliki River by the major Makondo fault. The Semliki River meanders within the Semliki flats and forms the boundary between Uganda and the DRC. The Semliki Basin covers about 340 km^2 of the

Northern Rwenzori Block. The Rwenzori Mountains are seen to plunge northwards beneath the Semliki Flats, with steep, fault-controlled escarpments on both sides of northernmost spur of the Rwenzori Mountains. The Semliki basin is bordered to the South-east by a steep fault escarpment rising almost 1,000 m to this spur. It is also is bordered on its western side by two major faults namely, the NNE- SSW trending Semliki fault and the NE-SW trending Bunya faults **(Figure 1.4.4.1.1).** These two separate the Congo escarpment and the basin.

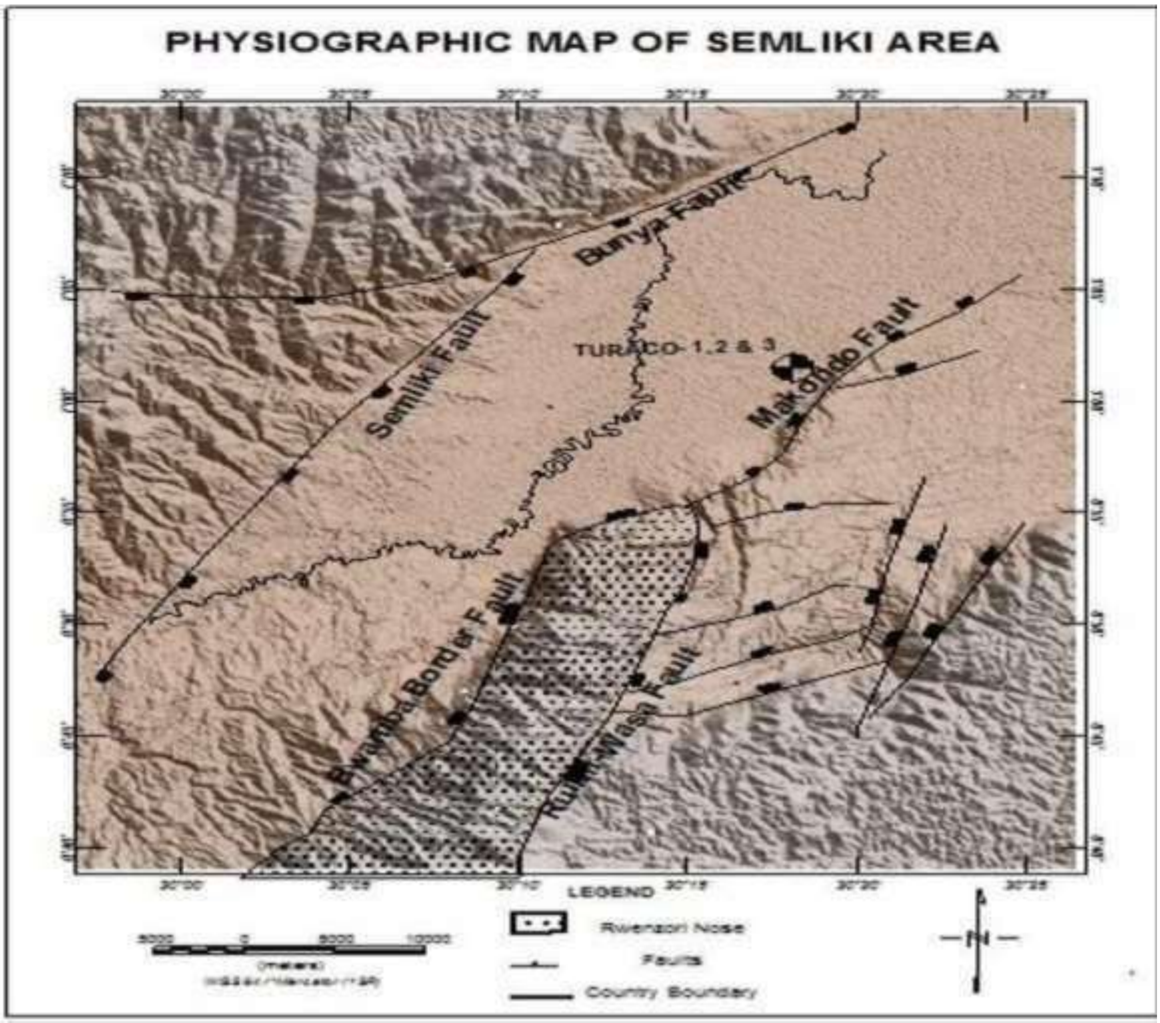


Figure 1.4.4.1.1 showing the physiography of the Semliki Basin

1.2.4.2 Topography of the Semliki basin

The topography of the Semliki basin is distinct from the rest of western Uganda largely because of its lower elevation of about 650 m above mean sea level compared with about 1650 m for the adjoining rift shoulders. In the Semliki basin, a major fault separates the Toro Plain from the Semliki Flats (Kiconco, 2006). The Semliki Valley is bordered on its eastern side by the west- facing, NNE-SSW trending, Bwamba Border Fault (BBF) which forms the eastern fault-bounded margin to the main Rwenzori Mountains horst block to the east. Movement on the Lubero Border Fault (LBF) has been much greater than that on the BBF resulting in an asymmetric graben forming down the Semliki basin. The Kichwamba fault is in the Eastern side of Mt. Rwenzori and separates the Rwenzori microplate from the Victoria micro-plate and Nubian plate. The fault is seen to die out towards the Semliki flats. The Kichwamba fault appears to cut off the Rwenzori micro plate hence the possibility of its rotation. River Semliki meanders in the flats and demarcates out the Uganda-DRC border. This meandering therefore, brings about switching in the border line with change in the river coarse hence

bringing about border issues.

Figure 1.4.4.2.1 Topography of the Semliki plain cross section from East to West (Source; PEPD, 1995)

CHAPTER TWO: MATERIALS AND METHODS.

2.1 <u>MATERIALS</u>

The fieldwork involved the utilization of a variety of equipment and materials, each serving specific purposes essential for geological investigations. Here is a breakdown of the tools and their respective uses:

- **Jacob's staff**: Used for measuring vertical thicknesses of beds during stratigraphic logging, providing crucial data for understanding sedimentary sequences.

Figure 2.1.1 Collapsible jacobs staff

- **Geological compass**: Instrumental in determining direction and describing structures by enabling the measurement of strike and dip of joints and beds, as well as the trend of faults, aiding in structural analysis.

Figure 2.1.2: geological campus

- **Geographic Positioning System** (GPS): Employed for locating positions in the field and on maps, with readings configured to metric units and specific coordinate systems, facilitating precise mapping and elevation determination at various stops.

Figure 3 GPS

- **Base maps** (topographic and geologic): Utilized for orientation in the field, providing context regarding the geological structural framework, such as the identification of faults like the Makondo fault, aiding in navigation and interpretation.

- Measuring tapes: Used for measuring bed thickness, providing quantitative data essential for lithostratigraphic analysis.
- **Hand lens**: Provided close examination of rocks, sediments, soils, sand, minerals, and other materials with tiny features, facilitating detailed observation and identification of small fossils.

FIGURE 4 1 HAND LENS

- **Hoes and spades**: Employed for cleaning sediment surfaces to enable clear visualization of beds for logging purposes, ensuring accurate descriptions and observations.

Figure 5 Spade and hoe

- **Digital cameras/Phones**: Used for capturing photographs of interesting geological features, providing visual documentation for further analysis and reference.

Figure 6 digital camera

- **Field notebooks**: Essential for recording field observations, including descriptions of basement rocks, sediments, and other geological features, as well as sketching exposures, serving as a basis for report writing and analysis.

Figure 7 field notebook

- Graph papers, pencils, and rulers: Utilized for the construction of lithostratigraphic logs, enabling the visualization and interpretation of sedimentary sequences and structural characteristics.
- **Hammers**: Used for breaking rocks to obtain samples and exposing less weathered sediments, facilitating detailed examination and analysis of rock properties and composition.

Figure 8: Hammer

- **Grain size scale**. The Wentworth grain size scale was used to evaluate the grain size of the particles. The finest particles were designated clay, followed by silt, sand, granules, gravel, pebbles, cobbles, and boulders.

Grain Diameter millimeters	microns	phi		Wentworth Size Class	
				Boulder	Gravel
256		-8.0			
				Cobble	
64		-6.0			
				Pebble	
4.0	4000	-2.0			
				Granule	
2.0	2000	-1.0			
			vcU	Very coarse sand	Sand
1.41	1410	-0.5			
			vcL		
1.0	1000	0.0			
			cU	Coarse sand	
.71	710	0.5			
			cL		
0.5	500	1.0			
			mU	Medium sand	
0.35	350	1.5			
			mL		
0.25	250	2.0			
			fU	Fine sand	
0.177	177	2.5			
			fL		
0.125	125	3.0			
			vfU	Very fine sand	
0.088	88	3.5			
			vfL		
0.0625	62.5	4.0			
				Silt	Mud
0.002	2.0	9.0			
				Clay	

Figure 9: Grain size scale

These tools and materials collectively contributed to the successful execution of fieldwork activities, enabling data collection, analysis, and interpretation essential for geological studies and exploration efforts in the Albertine Graben region.

2.2 METHODS

The methods used while in the field to achieve various aims include the following;

2.2.1 Desk Study.

This involved the study of all available literature and geologic maps of the Albertine area and the Semliki basin in order to have overview information of the study area. This also involved getting acquainted with all materials and equipment to use in the field study.

2.2.2 Structural measurements

The dip and strike of structures encountered in the field were measured by the right-hand rule using a geologic compass both in Basement and sedimentary rocks. Structures measured included the joints, bedding and faults and foliations. Other parameters like bed thickness were measured using a Jacob's staff and tape measure.

2.2.3 Rock descriptions

All properties of the rocks encountered were macroscopically described using unaided eye and using a hand less. The properties described include rock name, grain size, color, minerals present and structures.

2.2.4 Lithostratigraphic logging.

Logging was done from bottom to top on fresh rock exposures. Contacts between lithologies were identified basing on differences in color, grain size variations, difference in structural orientation and bed thickness. The information obtained was used to construct the sedimentary logs in the field by using graph papers and also using Sedlog 3.0 version software to obtain the large-scale stratigraphic logs of the area. These logs were then analyzed and interpreted to obtain information about the environment of deposition, direction of sediment flow and the grading of the rocks.

Logging procedure.

- ❖ Cleaning up the outcrop using a hoe to obtain a clearer view of the outcrop.
- ❖ Dividing the outcrop into different units according to lithology or other features.
- ❖ Measuring the vertical thickness each unit using a tape measure.
- ❖ Describing the outcrop fully.
- ❖ For outcrops whose basement was not seen or not clear, a zigzag shape was used at the base of the log when constructing it on the graph paper.
- ❖ Indicating structures, and fossils (if any) on the log using appropriate symbols.
- ❖ Indicating facies on the log, and determining their depositional environment and depositional processes.

In-depth observation of the exposed facies was then conducted to identify facies, primary and secondary structures. The dip and axial trend of these structures were measured. Facies encountered included basal conglomerates, cross bedded and massive sands, white and yellow silts, brown blocky clays. Grain size was determined using a grain size scale and the sizes ranged from fine through medium to coarse. Through in-depth analysis, facies were identified, descriptions recorded and logs were plotted on graph papers. These logs were then used to deduce the depositional environments, depositional sequences and system tracts.

2.2.5 Determination of grain size and shape.

The shape of grains was determined observing the clasts with help of a hand lens to estimate sphericity, roundness of clasts, sorting and cementation at the exposures, road cuts and outcrops. These were used to understand the type of depositional environment as well as conditions that existed in that environment at the time of deposition. Roundness and sphericity of the grains were used to determine the type of transporting agent and the transportation distance. They also give information about the maturity of the sediments which is important in petroleum potential evaluation.

The grain size ranges from very coarse sand to very fine sand and it was determined using a grain size scale. This was used to define the grading of sediments in beds i.e., coarsening upward or downward in order to determine the type of deposition environment. It also gives information about the energy of the deposition agent.

Grain Diameter: millimeters	Grain Diameter: microns	Grain Diameter: phi	Wentworth Size Class		
				Boulder	Gravel
256		-8.0			
				Cobble	Gravel
64		-6.0			
				Pebble	Gravel
4.0	4000	-2.0			
				Granule	Gravel
2.0	2000	-1.0			
			vcU	Very coarse sand	Sand
1.41	1410	-0.5			
			vcL	Very coarse sand	Sand
1.0	1000	0.0			
			cU	Coarse sand	Sand
.71	710	0.5			
			cL	Coarse sand	Sand
0.5	500	1.0			
			mU	Medium sand	Sand
0.35	350	1.5			
			mL	Medium sand	Sand
0.25	250	2.0			
			fU	Fine sand	Sand
0.177	177	2.5			
			fL	Fine sand	Sand
0.125	125	3.0			
			vfU	Very fine sand	Sand
0.088	88	3.5			
			vfL	Very fine sand	Sand
0.0625	62.5	4.0			
				Silt	Mud
0.002	2.0	9.0			
				Clay	Mud

Figure 2.2.5.1 Showing the grain size scale

2.2.6 Determination of paleocurrent flow direction.

Sedimentary structures such as cross stratification, pebble imbrications and current ripples were used to deduce the direction of paleocurrent flows that deposited the sediments. The dip direction of angular and tabular cross beds encountered in the sand layers indicates the paleocurrent direction of sediment transport. Most of the ripples observed in the Kisegi river flood plains were asymmetrical.

2.2.7 Interpretation of the depositional environment.

Deposition in the Semliki Basin is characterised by fluvial and lacustrine sediments. These sediments are noted to include sands, basal conglomerates, clays and silts. The distribution, orientation and internal geometry of fluvial/deltaic deposits is controlled by a number of factors; including but not limited to climate, water discharge, sediment load, river mouth processes, waves, tides, currents, winds, shelf width and slope and the tectonics and geometry of the receiving basin (Selley, 1978). The depositional environment in the Kisegi formation is mainly fluvial, with meandering, alluvial, inter-channel, flood plain and over-bank deposits. The outcrops show a series of meandering channels downcutting into each other with the uppermost

abandoned channel filled with mixed silt and sandstone. In the subsurface, specifically in the Turaco-3 well, the penetrated

300 m of the formation suggest a dominantly fluvial environment in a relatively quiescent tectonic regime, with low energy small-scale channel systems. The climate at the time was warm to hot and dry (semi-arid conditions). These conclusions are supported by the presence in outcrop of evaporitic minerals such as gypsum which was very common in clays during the logging process.

2.2.8 Degree of metamorphism.

This was analysed by studying the foliation trends (planar orientation of minerals) in the basement rocks. Foliations helped in indicating the direction of stress/pressure since the direction of mineral orientation is perpendicular to the direction of the stress or pressure. Gneisses in the basement rock indicated high grade metamorphism and contact metamorphism was also observed around intrusive rocks. Grade of metamorphism helped in explaining the rock type distribution, mineral composition and texture hence tracing the diagenetic history of rocks.

2.3 THE SEMPAYA HOT SPRINGS

A hot spring is an area where the temperature of water is significantly above the mean annual air temperature of the region. Sempaya hot springs are located in Semliki National Park in Sempaya, Bundibugyo district, western Uganda, 40km from the border to DRC. The park is within the Albertine graben and approximately 220km2. It is bordered by D.R Congo to the west, Rwenzori Mountains to the SE, Lake Albert and Semliki flats to the North. The Sempaya hot springs are associated with the Rwenzori mountains and are found in the Buranga geothermal field (Bahati, 2016).

Sempaya hot springs boil at very high temperatures of up to 95-99 ^{o}C and are found in two swampy areas enclosed by the dense rain forest; the male and the female hot springs.

The male hot spring is hot and larger while the female hot spring has a jet like structure that ejects water above the surface. The area where the hot-spring is located is in close proximity with the Bwamba fault that is approximately seven miles from the surface of the super-heated rocks.

The hot water gushed out is based on the rain water which percolates into the porous sedimentary rocks. It descends through the rock dissolving a variety of materials, from radium to Sulphur. As this water and groundwater moves further beneath the surface, it heats up from the primal heat of the earth, the mantle which is closer to the surface than in other areas. The pressure forces this superheated water to come back to the surface through cracks and fault lines in form of hot springs. The male hot springs are a pool of steamy hot water with a strong pungent smell of sulphur. The pool diameter was about 30m and average water temperature is 86°C, down to a depth of 5m, and has a carbonate cone formed from calcium carbonates (travertine) precipitating out of the water. The female hot springs on the other hand consist of a series of steamy water jetting out of the subsurface with a strong pungent smell of hydrogen sulphide (H2S) gas, carbon dioxide gas, carbonates and other salts. It occupies an area of about 60 x 40 m and average water temperature is about 98.4°. These hot springs are located in a faulted zone near the rift flanks. They are a result of active tectonism occurring in the Albertine rift.

The high temperatures in the area are thought to contribute to the geothermal gradients that have accelerated the maturity of source rocks in the Albertine graben. However, increase of these temperatures above the oil window (60-120^{0}C) would lead to thermal cracking of the hydrocarbons.

The active fault system associated with the seismic activity in the Graben could provide fractures/faults which act as the migration pathways or conduits for hydrocarbons from source rock to reservoir.

The minerals in the water range from Calcium, sodium, fluorine, to lithium and these minerals accumulate and end up blocking the water passages; this increases pressure in the subsurface forcing the water to come to the surface in another place. This water from the hot springs moves in channels to river semliki which flows to the Nile.

Figure 2.3.1 water gushing out of the female hot spring

Figure 2.3.2 A photograph showing the male hot spring

The Geothermal potential of Buranga area

Like a petroleum system, a geothermal system is composed of elements such as a source rock or a highly radioactive rock directly in contact with magma, a reservoir rock with high porosity to hold the fluids, a cap/seal rock for preventing heat escape from the reservoir rock and a reservoir fluid such as ground water or ordinary water that passes through the reservoir. This therefore implies that the area has potential for geothermal energy which can be used to generate electricity (which is a clean source of energy) due to high heat flow evidenced by the high temperatures that have converted organic matter to hydrocarbons in the source rocks.

2.4 Makondo and Turaco Field study

The visited Makondo fault site is located within the Nyakabingo-Nyabushozi formation at a location of 0201154/0110008, 692. The aim of visiting the site was to obtain a better understanding of geophysical and magnetic data which was acquired from the area using airbone surveys by Kenting Earth Sciences Limited, Canada around

1982 to 1984. Two faults (Kibuku and Makondo) were discovered during the aeromagnetic surveys. In 1988, Heritage Oil Company Limited obtained 2D seismic data from the area to further interpret the faults. It was also observed that positive flower structures were present, and these occur when there is compression regime and a fault boundary.

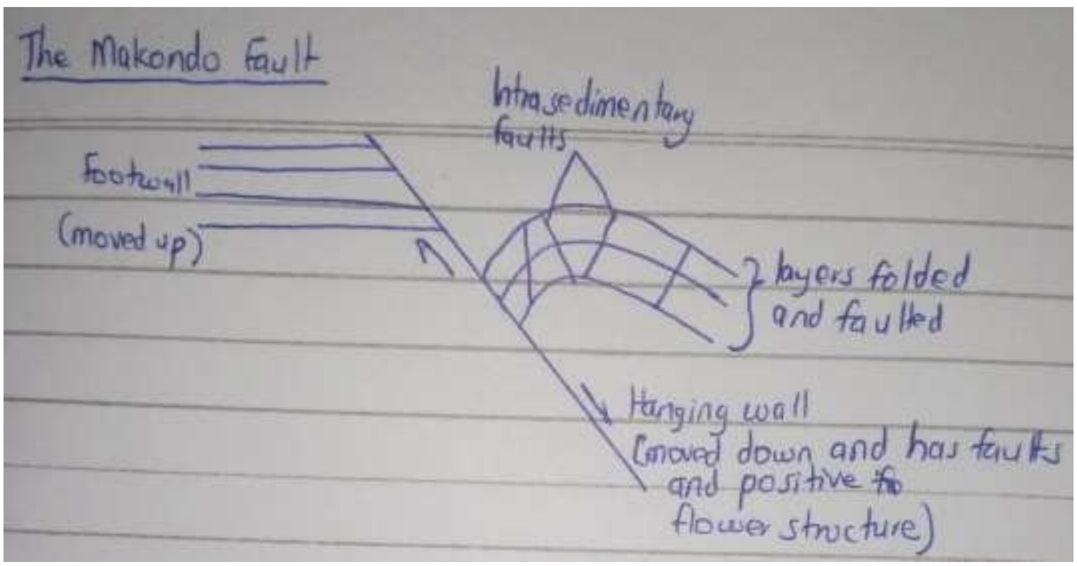


Figure 2.4.1 the Makondo fault with a positive flower structure

The sediments in this area were majorly composed of laterite and clay sediments. There is also presence of animal fossils (oysters and bivalves) deposited in the clays which are oxidized in some areas. These fossils are an indicator of fresh shallow water lacustrine environment .The area is believed to have been covered by former Lake Obweruka which dried up probably due to climatic changes best explained by Milankovitch cycles.

Figure 2.4.2 showing clay pebbles and fossils in the area

Turaco wells

The Turaco wells (0199712, 0113863, 632) are located on the hanging wall of the Makondo fault and they were the second wells to be drilled in the Albertine Graben by Heritage Oil Company Limited with an aim of encountering oil in the Kisegi sand formations but unfortunately there were no economic accumulations found.

Revision of previous drilling history indicted that the Turaco-1 well, drilled in 2002 up to a depth of 2487m encountered hydrocarbon shows but were not in commercial quantities while Turaco-2 well drilled in 2003/2004 10m away from Turaco-1 as a side track well to a depth of 2963m had significant hydrocarbon shows. Three dimensional (3D) seismic surveys carried out in the area in 2004 led to drilling of Turaco-3 well 100 m from Turaco-1, to a depth of 2980m and encountered some natural gas which was also highly contaminated with carbon dioxide. The project was stopped here because there was no success and the area was not economically viable. The company moved North-wards and the Turaco area was plugged and decommissioned.

2.5 Geophysical tools, procedures and methods

Geophysical studies were in form of exercises done at camp and on personal computers back at the university. During these exercises, magnetic and gravity survey field data from Semliki basin, seismic sections of data from Semliki basin and Gulf of Mexico were provided. The magnetic and gravity field data were used to create gravity anomaly and magnetic intensity maps of the Semliki basin by use of Geosoft Oasis Montaj software that were interpreted and discussed. An interpretation on the seismic sections from Gulf of Mexico and the Semliki basin in western Uganda was also done. The seismic lines from the Gulf of Mexico were interpreted by marking stratal terminations and key stratal surfaces and identifying seismic facies. procedure for making the interpretation on the seismic lines from the Gulf of Mexico was as follows; Considering strike/seismic line S6 (which has visible/distinguishable facies).

- Reflection terminations such as truncation, onlap and downlap were located and marked.
- After identifying the types of seismic facies and listing their main properties, they were lightly colored on the section.
- This was followed by identifying the types of chronostratigrahically significant seismic surfaces that bound units with different seismic facies and color coding them.

2.6 Report writing

This was the final stage of this project that involved the formal writing of a report comprising of the comprehensive study done in the field, data acquisition, analysis, interpretation procedures, discussions and conclusions about the petroleum system of the study area.

The report is organized into eight chapters describing field work in Semliki basin. In their order, the chapters include; Introduction, Materials and methods, Lithology and stratigraphy, Basin and facies analysis, Structures, Geophysics of semliki sedimentary basins, Discussion and Conclusions and Recommendations with other sections which include references and appendices.

CHAPTER THREE: LITHOLOGY AND STRATIGRAPHY

3.1 Lithology

The lithology of the Semliki Basin is made up of both crystalline basement rocks and younger sedimentary deposits. The basement complex mainly consists of high-grade metamorphic rocks, especially gneisses, which indicate that the area has undergone intense tectonic deformation and metamorphism. These older rocks are overlain by sedimentary successions ranging from the Miocene to the Recent period. The main formations include Kisegi, Kasande, Kakara, Oluka, Nyaburongo, Nyakabingo, and Nyabusosi.

The sedimentary units are largely composed of conglomerates, sandstones, clays, and fine-grained lacustrine deposits. These rock types suggest deposition under different environmental conditions, including river-dominated fluvial systems and lake-dominated lacustrine settings. The presence of well-preserved fossil-bearing layers further shows that the basin experienced diverse palaeoenvironmental conditions and changing sedimentation patterns through time.

3.1.1 Basement Lithology

The basement rocks of the Semliki Basin belong to the Buganda-Toro System. They are mainly composed of high-grade metamorphic rocks such as gneisses, amphibolites, and quartzites. These rocks are of Proterozoic age and represent ancient crustal materials that were subjected to strong tectonic and metamorphic processes.

The gneisses commonly display foliation, which reflects deformation under directed pressure. Other metamorphic rocks also show schistosity due to the alignment of platy minerals during metamorphism. Quartzites, which were formed from the metamorphism of sandstone, are also present and indicate formation under high-temperature and high-pressure conditions. In some places, the basement rocks are intruded by granitic bodies. Together, these rocks form the foundation upon which the younger sedimentary deposits of the Semliki Basin were laid down, and they strongly influence the structural and geological setting of the basin.

Amphibolites

Amphibolites in the Semliki Basin occur mainly as dark grey to black mafic intrusions. They are composed of amphiboles, plagioclase, pyroxenes, and small amounts of biotite and quartz. The rocks are highly jointed and commonly show porphyroblastic textures, with grain sizes varying from fine to medium.

These amphibolites are interpreted to have formed through the metamorphism of diorite or dolerite dykes that intruded into the granite gneiss basement. The intrusion of these mafic bodies along zones of weakness caused shearing and foliation within the surrounding granite gneiss. Quartz veins in the amphibolites also show evidence of brecciation and strong foliation. One notable amphibolite intrusion was observed at a road-cut exposure located at coordinates 1869069, 79373, at an elevation of 1616 m.

The contact between the amphibolite intrusion and the surrounding basement rocks is sharp. This suggests that the magma cooled relatively quickly after intrusion and therefore caused only limited thermal alteration of the adjacent basement rocks.

FIGURE 2.5-1 A GRANITE

Granite Gneisses

Granite gneisses form the dominant basement rock type in the Semliki Basin, making up more than 90% of the exposed basement lithology. These rocks are commonly exposed in artificial outcrops produced during road construction, especially along the northern nose of the Rwenzori Mountains. One such exposure occurs at coordinates 192405, 101773, at an elevation of 678 m.

The granite gneisses are generally white to grey in colour and range from fine- to medium-grained. Their main mineral constituents include K-feldspar, quartz, and biotite. They are believed to have originated from granitic rocks that later underwent high-grade metamorphism. This is shown by their distinct mineral banding and foliation.

The rocks are intensely fractured, and some of the joints are filled with quartz introduced by hydrothermal fluids during different tectonic events. Most joints and foliations trend in a northwest-southeast direction, while the joints commonly dip towards the northeast. Because of their high degree of jointing and fracturing, these granite gneisses may act as potential migration pathways or reservoirs for hydrocarbons, since the fractures can enhance permeability.

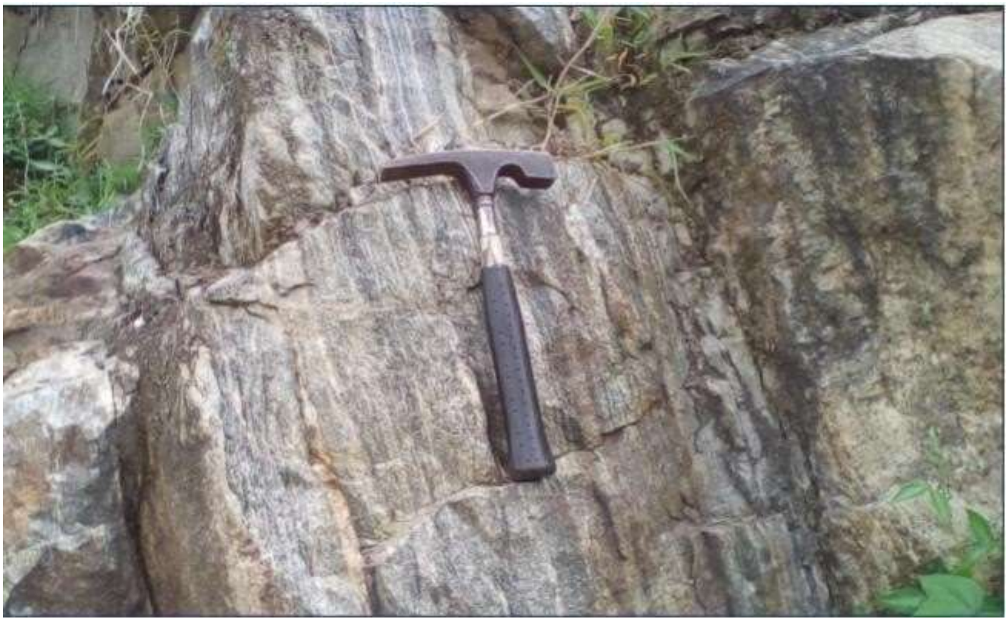


FIGURE 2.5-2 A GRANITIC GNEISS

Granites

The granites observed in the area are generally massive and vary in colour from pink to grey. Weathered surfaces often appear brownish-grey due to the alteration of feldspar minerals into clay minerals. These granites are mostly medium- to coarse-grained and are composed mainly of K-feldspar, quartz, biotite, and muscovite.

However, many of the minerals appear altered, most likely as a result of active faulting and weathering processes in the region. The outcrops also show extensive jointing and fracturing, indicating that the area has been affected by considerable tectonic activity.

3.1.2 Lithology and Stratigraphy of the Sediments

The colour, mineral composition, and distribution of sediments in the Semliki Basin suggest that the surrounding Rwenzori Mountains and escarpments are the main sediment source areas. Since the uplift of the Rwenzori Mountains occurred later than the beginning of rifting, it is possible that some of the sediments were derived from earlier water bodies such as Lake Obweruka, which corresponds to the present-day Lake Albert.

The sediments were probably transported by rivers flowing from the mountain areas into the basin, where they accumulated over time. These deposits, which include sandstones, clays, silts, and conglomerates, rest on the basement rocks. Their characteristics indicate deposition in both fluvial and lacustrine environments.

Sandstones

Sandstones are the most common sedimentary rocks in the Semliki Basin. They occur in a wide range of grain sizes, from very fine to very coarse. In many places, they overlie basal conglomerates and display colours ranging from pale yellow to reddish brown. The yellowish colour is associated with iron oxide minerals and may indicate deposition in shallow-water or sub-aerial conditions.

The sandstones vary from well-sorted to poorly sorted and extend laterally over considerable distances. Their thickness also varies, and they are frequently interbedded with clay layers, conglomerates, and gypsum-bearing beds. Many of the sandstones are matrix-supported and cemented by reddish-brown iron minerals, which form laminations in some beds.

The grains range from sub-angular to sub-rounded, while the degree of consolidation varies from well-consolidated to moderately or loosely compacted. The main minerals present include quartz, iron oxides, clay minerals, and gypsum. The relatively uniform grain-size distribution in several sandstone units suggests deposition by river systems, where changing flow energy controlled the type and size of sediments deposited.

Some sandstone beds display fining-upward sequences, which indicate a decrease in depositional energy over time. Other beds show coarsening-upward trends, suggesting changes in flow conditions, climate, or seasonal sediment supply. Sedimentary structures observed in the sandstones include cross-bedding, laminations, tabular bedding, joints, and gypsum-filled veins.

Due to their relatively good sorting and moderate to low consolidation in some intervals, these sandstones have favourable porosity and permeability. As a result, they may serve as potential reservoir rocks for hydrocarbon accumulation.

FIGURE 2.5-3 SANDSTONE

Conglomerates

The conglomerates in the Semliki Basin are generally coarse-grained and poorly sorted. They consist of cobble- and pebble-sized clasts ranging from about 5 mm to 35 mm in diameter, cemented by fine- to coarse-grained sand. Their colour varies because of the presence of iron-rich minerals.

The conglomerate beds are often discontinuous and show variable thicknesses. Thin conglomeratic layers commonly occur within sandstone and clay successions, indicating periodic changes in depositional energy. Most of the conglomerates are matrix-supported by fine yellow sand.

The clasts are angular to sub-angular and vary in size and colour. Their sub-angular shape suggests that they were transported over relatively short distances before deposition. The dominant clast types include gneisses and quartzites, which were most likely derived from the nearby basement rocks.

FIGURE 2.5-4 CONGLOMERATE

Clay Sediments

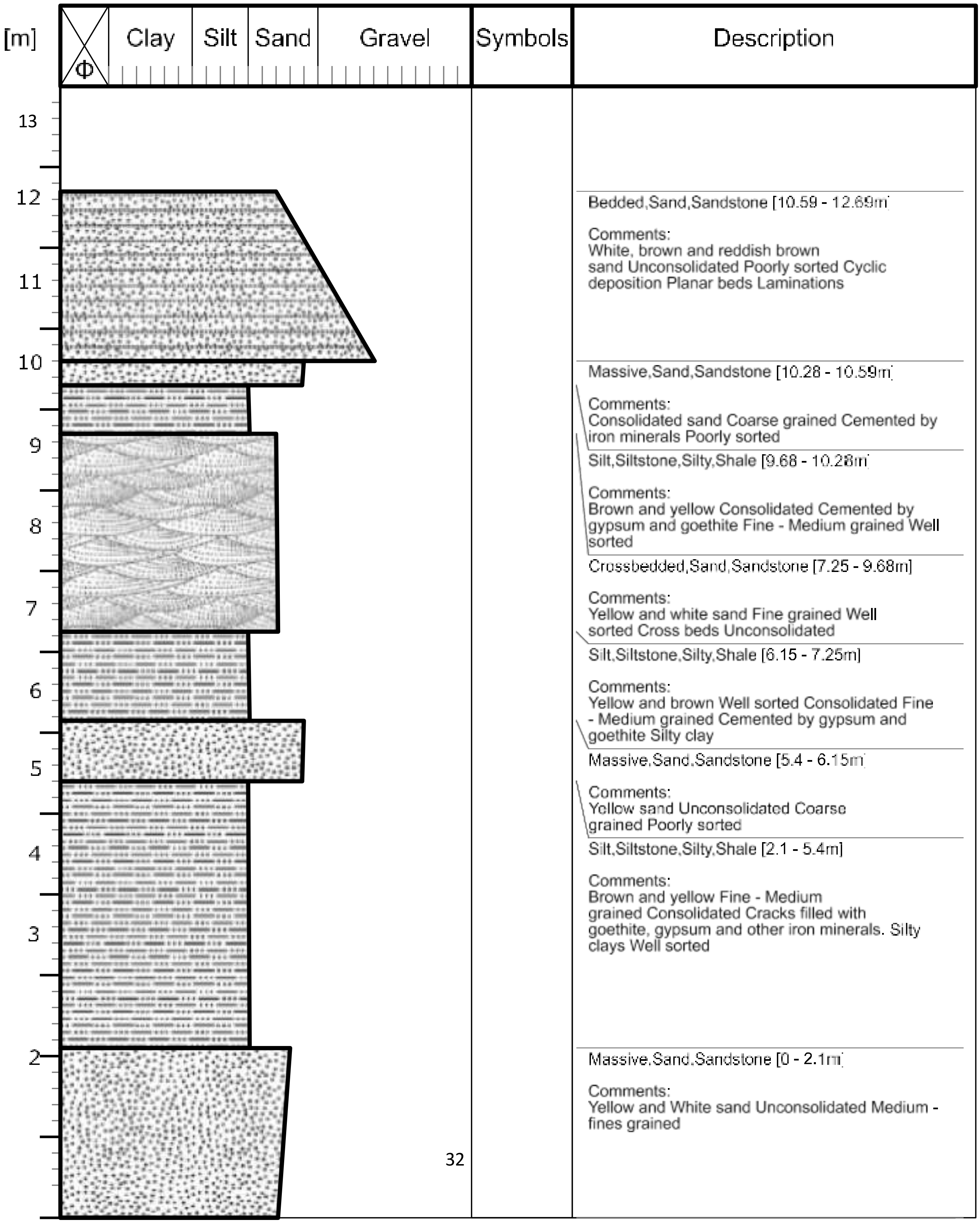
Clay deposits in the area occur in different colours, including brown, grey, and dark grey. These colour variations may reflect differences in organic matter content and depositional conditions, particularly preservation under oxygen-poor environments. The thickness of the clay beds varies significantly. Some layers are thick, reaching up to about 112 cm, while others are only a few centimetres thick.

The clay beds may be massive or laminated. Some also contain gypsum-filled fractures and veins. The gypsum probably formed from the precipitation of calcium sulphate-rich fluids that were associated with the original clay deposition or later fluid movement through the sediments.

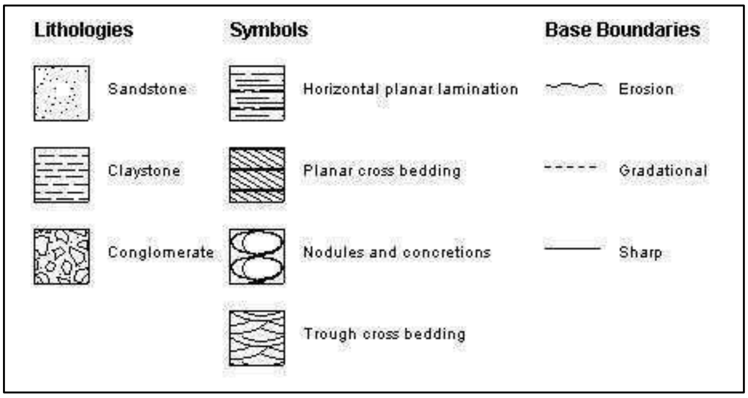
The clays commonly occur in repeated cycles with sandstone layers, suggesting alternating phases of deposition. They were likely deposited during low-energy periods, such as river flooding or quiet-water conditions. Because some of the clay layers are relatively thick and fine-grained, they may act as effective cap rocks in a petroleum system.

FIGURE 2.5-5 CLAY SEDIMENTS

3.2 LITHOSTRATIGRAPHIC LOG



Legend.



Layer Descriptions

Layer 1 – Unconsolidated massive sands / sandstone

- **Depth interval** – 0 to 2.1 m
- **Thickness** – 210 cm
- **Colour** – Yellow and white
- **Lithology** – Massive sand / sandstone
- **Matrix** – Sandy matrix, mostly unconsolidated
- **Grain size** – Medium to fine-grained sand
- **Mineralogy** – Mainly quartz, with possible minor feldspar and clay minerals
- **Grain shape** – Probably angular to sub-angular
- **Sorting** – Moderately to well sorted
- **Structures** – Massive bedding, with no clear internal lamination shown
- This layer represents fairly uniform deposition of sand under moderate-energy conditions.

Layer 2 – Consolidated siltstone and silty shale

- **Depth interval** – 2.1 to 5.4 m
- **Thickness** – 330 cm
- **Colour** – Brown and yellow

• **Lithology** – Silt, siltstone and silty shale

• **Matrix** – Silty-clay matrix

• **Grain size** – Fine-grained to medium-grained silt

• **Mineralogy** – Gypsum and other minerals are present within cracks

• **Grain shape** – Very fine grains, therefore grain shape is not clearly visible, but likely angular to sub-angular

• **Sorting** – Well sorted

• **Structures** – Fine laminated or massive silty beds

• The layer is consolidated and contains cracks filled with gypsum and other minerals, suggesting later mineral precipitation after deposition.

Layer 3 – Unconsolidated massive coarse sandstone

• **Depth interval** – 5.4 to 6.15 m

• **Thickness** – 75 cm

• **Colour** – Yellow

• **Lithology** – Massive sand / sandstone

• **Matrix** – Sandy matrix, poorly consolidated to unconsolidated

• **Grain size** – Coarse-grained sand

• **Mineralogy** – Mainly quartz, with possible iron-stained grains

• **Grain shape** – Angular to sub-angular

• **Sorting** – Poorly sorted

• **Structures** – Massive bedding

• The coarse grain size and poor sorting suggest rapid deposition under relatively high-energy conditions.

Layer 4 – Consolidated siltstone and silty shale

• **Depth interval** – 6.15 to 7.25 m

• **Thickness** – 110 cm

• **Colour** – Yellow and brown

• **Lithology** – Silt, siltstone and silty shale

• **Matrix** – Silty-clay matrix

• **Grain size** – Fine to medium-grained

• **Mineralogy** – Gypsum and goethite cement

• **Grain shape** – Mostly fine grains, likely angular to sub-angular

• **Sorting** – Well sorted

• **Structures** – Fine silty beds, with no major sedimentary structures shown

•The presence of goethite shows oxidation, while gypsum cement suggests mineral precipitation during diagenesis.

Layer 5 – Cross-bedded unconsolidated sandstone

• **Depth interval** – 7.25 to 9.68 m

• **Thickness** – 243 cm

• **Colour** – Yellow and white

• **Lithology** – Cross-bedded sand / sandstone

• **Matrix** – Sandy matrix, mostly unconsolidated

• **Grain size** – Fine-grained sand

• **Mineralogy** – Mainly quartz

• **Grain shape** – Angular to sub-rounded

• **Sorting** – Well sorted

• **Structures** – Cross-bedding

•The cross-bedding indicates deposition by moving water, probably from migrating ripples, dunes or channel bars.

Layer 6 – Consolidated siltstone and silty shale

• **Depth interval** – 9.68 to 10.28 m

• **Thickness** – 60 cm

• **Colour** – Brown and yellow

• **Lithology** – Silt, siltstone and silty shale

• **Matrix** – Silty-clay matrix

• **Grain size** – Fine to medium-grained

• **Mineralogy** – Gypsum and goethite cement

• **Grain shape** – Very fine grains, likely angular to sub-angular

• **Sorting** – Well sorted

• **Structures** – Fine silty beds

•This layer represents deposition under lower-energy conditions, where finer sediments settled from suspension.

Layer 7 – Consolidated coarse massive sandstone

• **Depth interval** – 10.28 to 10.59 m

• **Thickness** – 31 cm

• **Colour** – Brown to yellowish brown

• **Lithology** – Massive sand / sandstone

• **Matrix** – Sandy matrix cemented by iron minerals

• **Grain size** – Coarse-grained sand

• **Mineralogy** – Quartz with iron mineral cement

• **Grain shape** – Angular to sub-angular

• **Sorting** – Poorly sorted

• **Structures** – Massive bedding

• The layer is thin, coarse and poorly sorted, suggesting a short period of stronger current activity or rapid deposition.

Layer 8 – Bedded sandstone

• **Depth interval** – 10.59 to 12.69 m

• **Thickness** – 210 cm

• **Colour** – White, brown and reddish brown

• **Lithology** – Bedded sand / sandstone

• **Matrix** – Sandy matrix, mostly unconsolidated

• **Grain size** – Fine to coarse-grained sand

• **Mineralogy** – Mainly quartz, with iron minerals causing reddish-brown staining

• **Grain shape** – Angular to sub-rounded

• **Sorting** – Poorly sorted

• **Structures** – Planar beds and laminations

• The layer shows cyclic deposition, meaning the depositional energy changed repeatedly during sediment accumulation.

Interpretation of the Whole Log

Based on the observations from the log, the sediments in the logged area were deposited under changing environmental conditions. The presence of siltstone, silty shale, clay minerals and gypsum suggests that part of the succession was deposited in a quiet-water setting, possibly a **lacustrine environment**. Such fine-grained sediments usually settle from suspension when the water energy is low. The gypsum also suggests evaporitic conditions, which may occur in shallow lakes or areas affected by evaporation, However, the presence of several sandstone layers, especially the cross-bedded sandstone between 7.25 m and 9.68 m, shows that the area was also influenced by **fluvial conditions**. Cross-bedding forms when sand is transported by flowing water and deposited by migrating ripples, dunes or channel bars. Therefore, the environment may have shifted between quiet lacustrine conditions and higher-energy fluvial conditions.

The reddish brown, brown and yellow colours in some sandstone and siltstone layers indicate the presence of iron minerals such as goethite. These colours suggest oxidation, which may have resulted from subaerial exposure or weathering after deposition. This shows that the sediments were not always permanently covered by water and may have been exposed during dry periods or changes in water level, the sorting varies throughout the log. Some layers, especially the siltstone and silty shale units, are well sorted, indicating calm and steady deposition. Other layers, particularly the coarse sandstone beds, are poorly sorted, suggesting rapid deposition by stronger currents. This change in sorting shows that the energy of the transporting medium was not constant.

The overall grain size ranges from fine clay and silt to coarse sand. The fine-grained layers point to low-energy deposition, while the coarse sandstone layers indicate higher-energy events. The grain shape is likely angular to sub-rounded, suggesting that some sediments were transported over a relatively short to moderate distance before deposition, the repeated alternation of coarse sandstone with fine siltstone and silty shale suggests cyclic deposition. This may have been caused by seasonal changes, flooding events, changes in lake level, variations in sediment supply, or changes in the strength of transporting currents. The planar beds, laminations and cross-beds also support the idea that deposition was controlled by changing flow conditions.

The loosely consolidated nature of many sandstone layers suggests that they may have good porosity and permeability. This means they could act as potential reservoir rocks. However, layers cemented by gypsum, goethite or iron minerals may have reduced pore spaces, which can lower permeability. The finer siltstone and silty shale layers may act as barriers or seals because they are less permeable than the sandstone units.

CHAPTER 4: BASIN AND FACIES ANALYSIS

4.0 Introduction.

Basin analysis is a geologic method by which the formation and evolution history of a sedimentary basin (sediment provenance, sedimentation processes and facies) is revealed, by analyzing the sediment fill and subsidence (Duppenbecker and Eliffe, 1998).

From the small area studied, the results obtained were extrapolated to other areas using these concepts to understand and deduce the potential of the rest of the basin. Primary sedimentary structures and faults within the basin were mapped and lithofacies bounded together to achieve a lateral correlation across the basin as well as predict petroleum generation and accumulation.

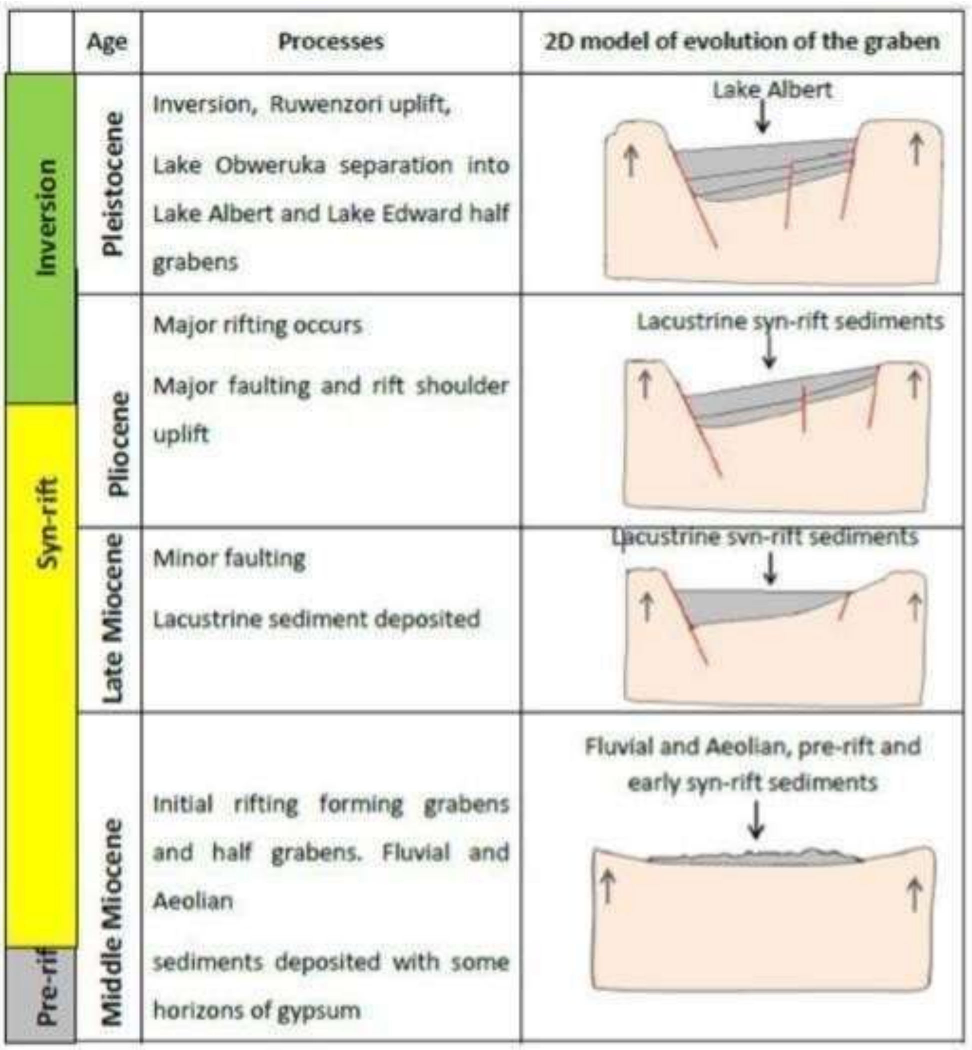
Facies sequence focuses on vertical arrangement of facies as opposed to the lateral movement which tells us which type of environment the sediments were deposited. For instance, coarsening up sequence (ie lower sediments being finer and the upper ones being coarser) implying deltaic environment.

From the studies carried out in the area, it was concluded that there are three sedimentary environments which include deltaic, fluvial and lacustrine environments. In addition, two depositional environments were found to exist in some areas evidenced by the situations where we had coarsening up and fining up sequences.

4.1 Integration of basin analysis concepts in interpretation of Semliki Sedimentary Basin

4.1.1 Formation mechanism of Semliki basin

Semliki basin is part of a string of half graben basins in the western arm of the East African Rift system (EARS) characterized by the dominance of a large boundary fault (Semliki fault) making it asymmetric. This basin was formed during the formation of the Western arm of the EARS. Several discussions have been centered on whether the rift and hence the basins were formed by active or passive rifting. A schematic model for the formation and evolution of the rift system is illustrated in Figure 4.1, obtained from Morley at el.,1999 and combines the observations made from seismic refraction, seismological, seismic reflection, and surface geological studies. The asthenosphere rises underneath the rift by both active and passive mechanisms triggering partial melting of the upper mantle and the emplacement of magma bodies within the crust. Rifting in the crust begun by the formation of high-angle deep penetrating, large normal faults, leading to the development of large half grabens. As rifting progressed, the brittle-ductile transition zone within the crust raised and this is responsible for rising the earthquake epicenters in the region.



4.1.2 Semliki basin structure and Sediment Accumulation

0-1IGURE 4.1.1 STAGES OF THE EVOLUTION OF THE SEMLIKI BASIN (MODIFIED AFTER PICKFORD ET AL 1993; VAN DAMME AND PICKFORD 2003; RING 2008)

The Semliki basin is structurally, a wedge shaped (half graben) basin dominated by sediments characteristic of fluvial, deltaic and lacustrine sedimentary processes. Basin geometry has been predicted from lithology and structures. Source rocks developed mainly during the synrift, in deeper portions while reservoirs in shallow lacustrine and flexural areas as well as in deep lacustrine zones in form of sub-lacustrine sands or turbidites encased in mudstones or clays. The sediment immediately on top of basement are fluvial-deltaic and a possibility of deep sub lacustrine 'turbidite' sands. Alluvial fan sediments deposited as far as almost 6 km show numerous pinch outs into deltaic sandstone formation (later cut by faults on the right side) and partly into the lacustrine mudstone/clays. The lower most sediments immediately above the nonconformity are fluvial- deltaic. The basin fill is dominated by lacustrine mudstones/clays interbedded with fluvial-deltaic deposits. Sedimentary facies are laterally discontinuous with strong facies contrasts. These features are typical of freshwater sedimentation where precipitation outstrips evaporation resulting in fluvial-lacustrine facies association (Carroll and Bohacs, 2001).

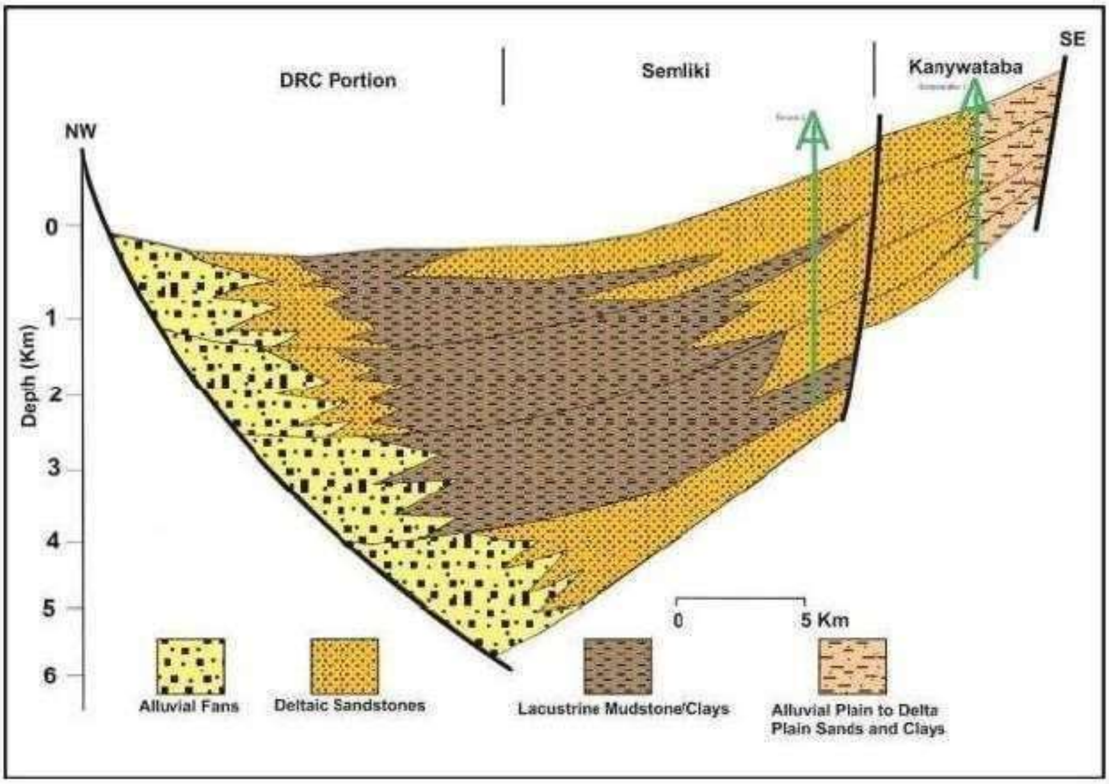


Figure 4.1.2.1 simple idealized NW-SE cross section through Semliki basin including the DRC portion (PEPD 2013). Note the position of the different sediment deposits relative to the basin

4.1.3 Basin stratigraphy

As sediments accumulated in the Semliki basin, further subsidence occurred and the basin shape kept on being modified and thus the sediment transport. The Table below shows the interplay of different environments. Changes in conditions during deposition also led to the deposition of different sediments in the same place and at different times. Seven Formations are now recognized for Semliki basin distinguished by difference characteristics off the lithologies they contain. These Formations are described below to further understand the basin.

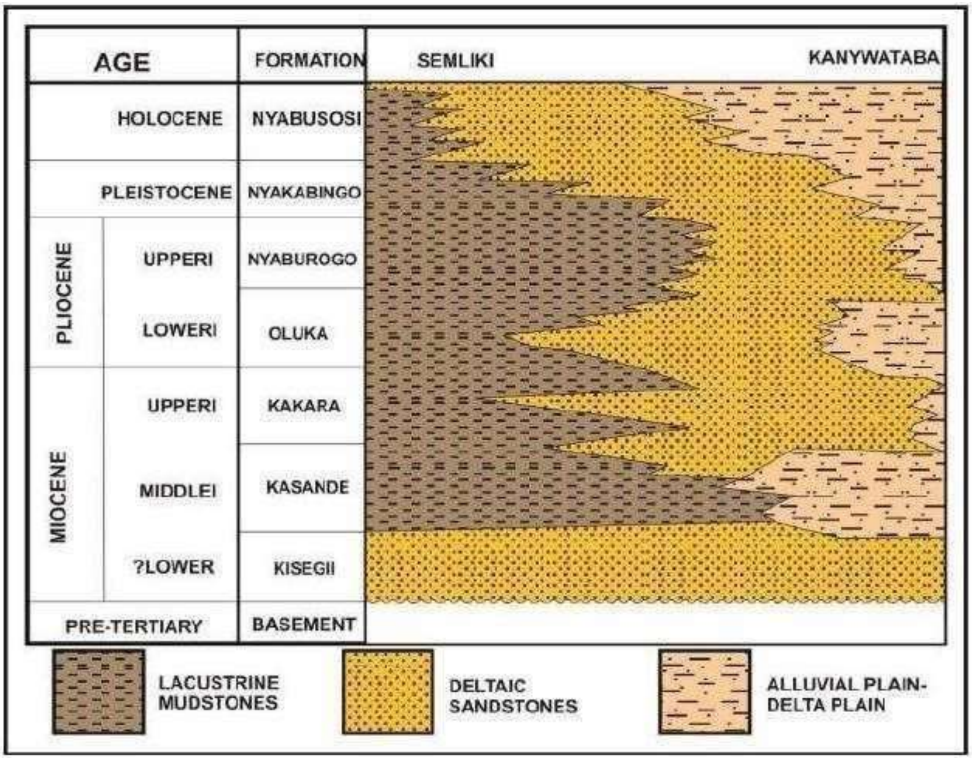


Figure 4.1.2.2 Arrangement of the formations of the Semliki basin from youngest (Nyabubosi) to oldest (Kisegi) (source: PEPD 2013)

Kisegi Formation

This Formation was described in Semliki area by Pickford. et. al. based on localities along the river Kisegi. Here, basal conglomerate overly the crystalline basement as. The basal conglomerates then pass out into thick channeled and cross bedded sandstones with thin interbeds of tuff.

Kasande Formation

This overlies the Kisegi formation and is characterized by dark brown to yellow-brown mudstone that were intercalated with yellow sandstone, it has grey, brown-grey dark grey claystone and mudstone (Joshua Lukaye 2016).

Kakara Formation

This was introduced by Pickford et al for clays and silts with ironstones. It is mostly prominent around the road cut normally sand dominated and no typical of the formation. According to Pickford the contact with the underlying Kasande formation is not seen in outcrops, but believes that it is marked by the first development of ironstones or ferruginous sandstones in succession.

Oruka Formation

The formation base in the typical section is exposed on the ridge between Nyaburongo and Kisegi rivers. The base is defined by dark shales overlaying a well-developed widespread conglomeratic ironstone with large smooth rounded quartz pebbles. The formation is a secondary reservoir. Exposures comprise an association of interbedded clay stone, shales, siltstone and sandstone.

Nyaburogo Formation

Most of the formation is seen in the new road cut exposure where basal shales rest on a faulted and erosional surface of topmost Oruka shales and siltstones here displaying a micro-Graben structure.

In the outcrops thick sequences of claystone with numerous rusty brown to yellow brown siltstones, pisolitic ironstones, siltstones and paleosols are seen.

Nyakabingo Formation

It is defined by a base of a lacustrine shale unit. The exposure shows light grey to greenish grey claystone, iron stained siltstone, pebbly and coarse sands/sandstone and carbonate nodules.

Nyabusosi Formation

The boundary between the Nyakabingo and Nyabusosi formation is not clear in outcrop as they are juxtaposed across the major Makondo Fault Zone near Makondo Village. Alternating clays and silts are seen throughout the exposed parts of Nyabusosi formation.

4.2 Elements of facies analysis and facies analysis interpretations from observed lithologic units

A Facies is a body of rock characterized by a particular combination of lithology, texture, suite of sedimentary structures, fossil content, colour, geometry, paleocurrent pattern, etc. Sedimentary facies are bodies of sediment that are recognizably distinct from adjacent sediments that resulted from different depositional environments. Sedimentary facies reflect their depositional environment, each facies being a distinct kind of sediment for that area or environment. Facies can be; lithofacies based on lithology, biofacies based on fossil assemblage and ichnofacies based on trace fossil assemblage. In the study area, 5 lithofacies were identified and these are described in this section. This is followed by an interpretation of their processes and environments of deposition.

4.2.1 Lithofacies in the study field

Lithofacies 1-massive polymictic conglomerate facies

This facies consists of massive, brown to grey conglomerates, with sub-rounded to well-rounded pebbles and matrix supported in a medium to coarse grained sand. Clay is also part of the cementing material. This facies was deposited by high energy transporting medium such as rivers and thus point at a fluvial system of deposition. The rivers could have been I their youthful due to the size of pebbles in these conglomerates and the fact that this facies is vertically followed by sands, showing a reduction in energy of deposition.

Lithofacies 2-Cross bedded medium to coarse grained sands facies

These sands are white and/or brown with medium to coarse grains. They show several forms of cross stratification such as tangential, troughs and angular cross beds.

This facies is deposited by low energy. However, Tangential beds form in relatively higher energy compared to angular beds. This facies could have been deposited by a delta environment due to formation of sub-aqueous levees resulting into a mouth bar.

Lithofacies 3- Massive clays

These are grey, green and reddish-brown clays with thickness as high as 3meters. They mostly show no internal structures but contain organic matter.

These clays were deposited by lacustrine conditions. These are potential seals and source rocks.

Summary of the depositional environments in the Semliki basin from facies analysis

Facies sequence which focuses on vertical arrangement of facies as opposed to the lateral movement were used to give information on which type of environment the sediments were deposited. These facies sequences include coarsening up and fining up sequences.

Three sedimentary environments are found to exist in the area which include deltaic, fluvial and lacustrine environments and in some areas, two depositional environments were found to exist evidenced by the situations where we had coarsening up and fining up sequences.

The fluvial system has been deduced from the fining upward sequences shown on the log, point bar deposits found at the Kisegi river channel, floodplain deposits (fine sediments), cross beds, a meander channel observed in the coarse sands in the Kisegi formation and water fossils such as bivalves. Structures such as cross beds, ripples, were used to deduce the local paleocurrent directions. The shift from fluvial to lacustrine may have involved a delta as a transition zone of deposition. The deltaic environment is inferred from the presence of fine sediment loads like mud diapirs/muds, fine sand and silts. Semi-arid conditions were inferred due to the presence of red sands and gypsum which occurred in association with the clays and sands. Gypsum is as a result of high rates of evaporation and thus evaporate precipitation. Organic matter layers between the sand layers are indicative of anoxic conditions.

4.3 PETROLEUM POTENTIAL OF THE SEMLIKI BASIN

The study area has qualities that can qualify it be a good petroleum system. The massive clays can form potential source rocks since they have organic matter. These can also prevent the organic matter from escaping due to their low permeability and can thus acct as potential seals. The sands observed can act as potential reservoir rocks to the generated hydrocarbons with the faults acting as migration pathways.

Source rocks

An oil seep evidenced by dark paraffin-smelling sands observed near Kibuku town at the base of Kisegi formation/sediment-basement contact (0192691, 0101880, 677) demonstrates that oil is being generated in this part of the Semliki Basin and this suggests that there is a regionally mature source rock is present in the area.

The widespread lacustrine clays found in the region have the potential to become excellent source rocks over time, given sufficient burial and increased temperatures. The dark grey hue of some of these clays suggests a high organic matter content, which is essential for petroleum formation. Studies have also revealed that the basin contains a sedimentary layer ranging from 4 to 6 kilometers in thickness, which is adequate to reach the temperatures and pressures necessary for organic matter to mature into hydrocarbons within the oil window.

Figure 5.5.1 An oil seep in the Kisegi formation near Kibuku town

Reservoir

The Semliki basin consists of moderately to well-sorted sandstones whose grain size ranges from medium to very coarse which implies that they have good porosity and permeability. The above qualities enable them to act as good reservoirs for hydrocarbons. The sediments are also underlain by the basement rocks such as amphiboles and granite gneisses which are highly fractured and jointed and thus could provide migration pathways for the accumulated petroleum. Also, the flow of water in Sempaya hot springs at a fast rate of about 10-15litres/second is an indicator of high permeability in subsurface rocks.

However, the reservoir quality is reduced by the presence of secondary minerals like gypsum and iron minerals (iron oxides) which have reduced the reservoir porosity. The reservoir is also compartmentalized due to intense weathering in the area which reduces communication between the reservoir productive zones, leading to production problems.

Traps

The area was found to have both structural (fault) and stratigraphic (pinch-out) traps. A large number of small tilted fault blocks, apparent rollovers as well as anticlinal features associated with listric fault block rotation were identified from the seismic data acquired in the Semliki Basin (Rubondo,2001). Unconformities that were found in the area of study also provide for stratigraphic, combined stratigraphic and structural traps. Positive flower structures, such as that displayed at Turaco can be relied on as proven exploration targets for traps in the Semliki.

Seals/Cap rocks

In the study area, the Kasande clays provide good sealing geometry for the underlying Kisegi formation. The thickness of clay beds about 20m thick could be a potential regional seal. The shales of transgressive systems tracts also form good seals for the underlying low stand systems tracts. The presence of oil seeps in the area such as Kibuku oil seep indicate that there are intervals which are inadequately sealed.

Maturation and Timing

The high temperatures that exist in the Semliki basin and as evidenced by hot springs can facilitate the conversion of organic matter to hydrocarbons and its maturation. Good timing ensures that the reservoir, trap and seal are in place before the source rocks generate hydrocarbons and migration starts. Despite being the youngest rift basins of Cenozoic sediments in the world, the Albertine Graben has a high potential with recoverable reserves of about 1.4 Billion barrels of crude oil in the region. It is believed that there exists high geothermal gradient which initiated the thermal maturity in the shortest time possible.

4.4 Heat flow in the Semliki basin

The Albertine graben has a high level off seismicity and this is evidenced byy the several faults. These faults have led to the existence of several geothermal fields within the region such as Buranga geothermal field. These geothermal fields manifest in form of hot springs for example the Sempaya hot springs. Heat flow within the graben is reported to be in the range of

54 to 66 mWm-2 (Tugume & Nyblade, 2009). Although slightly lower than generic heat flow associated with rifting of 80mWm-2 (Allen and Allen, 2005), the values are adequate enough to cause maturity of any source rock facies beyond 2000m depth in the Semliki basin. As seen from the geothermal gradient and assuming a constant subsidence history, it is possible to have mature source rocks at depths slightly under 2000m.

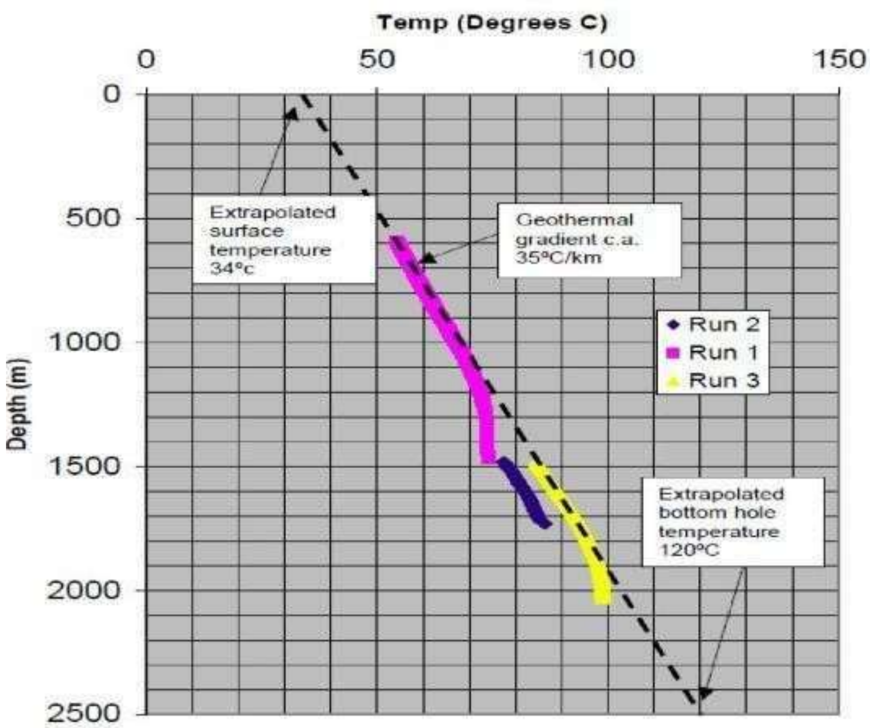


Figure 4.4.1 Geothermal gradient within the Albertine graben (Heritage oil and gas, 2001

CHAPTER 5. STRUCTURES.

5.1. Introduction.

Rock features known as geologic structures are created by a variety of mechanisms that impact sediments during deposition or by strong tectonic forces that occur within the earth after deposition and distort rocks. As rocks and sediments react to physical, chemical, and biological processes that tend to change, rotate, elevate, and internally twist them, structures are created. This can occur either during the development of the rock or during the deposition of the sediments, in which case it is referred to as primary structures, or it can occur after the formation of the rocks and the deposition of the sediments, in which case it is referred to as secondary structures. It can be stated that forces that tend to move and distort the rocks in a particular area of the earth will typically operate upon it (Bruce et al. 1976). The development of the structures is the outcome of the rock or sediments' reaction to these pressures.

This chapter focuses on the description of the various structures seen in both the basement rocks and the sediments in the area of study.

5.2. Structures in Basement Rocks.

5.2.1. Folds.

FIGURE 0-1. SHOWS AN ANTICLINAL FOLD, PLUNGE 39^{0}SW.

Folds are most evident in the migmatites at Itojo (0191057,0094333; Elevation 1044m). They are primarily caused by intense geological processes such as high-grade metamorphism, extreme pressure, and partial melting. These rocks form in regions experiencing mountain-building events or tectonic activity, where deep crustal movements create complex deformation patterns. The outcrop is characterized by synclinal folds.

5.2.2. Joints.

Rock fractures, also known as joints, result from the brittle nature of rocks under stress. Due to both active tectonic processes and the rocks' natural brittleness, the basement rock in the research area is made of granite gneiss and has a high degree of jointing. There are two main types of these joints: non-systematic joints, which lack a uniform form, spacing, or orientation, and systematic joints, which exhibit a planar or parallel orientation and occur at regular intervals. By reducing stress and causing the rock to expand, exfoliation, caused by weathering and erosion of the overburden. These were found at the foot of mountain Rwenzori at the boundary between Fort Portal and Ntoroko District (0186953,0079664). Various joint sets exit in the rock and they preferentially break along foliation planes.

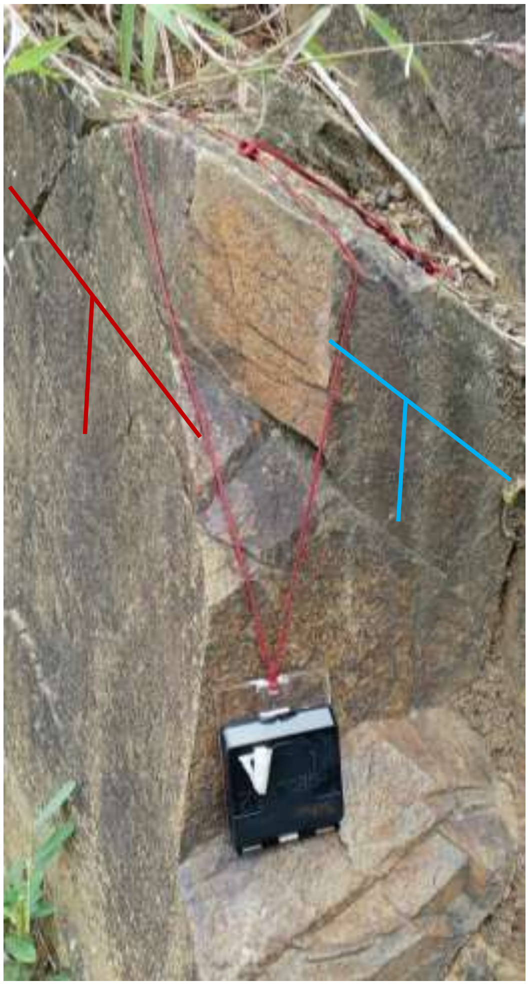
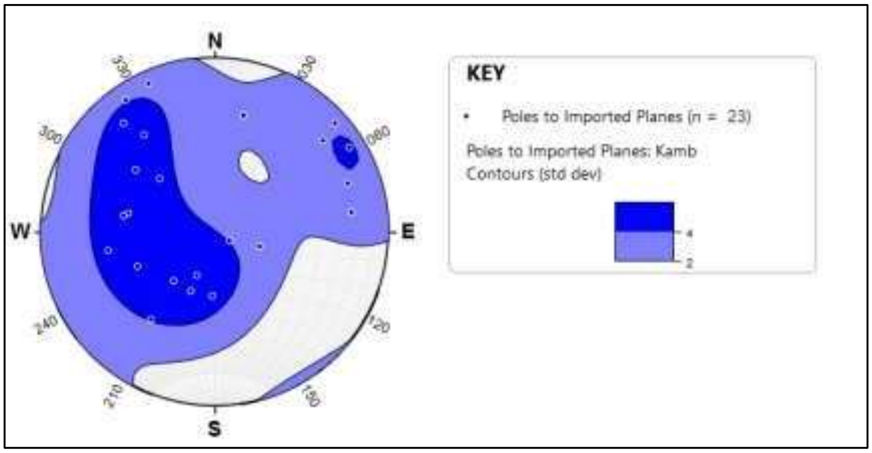
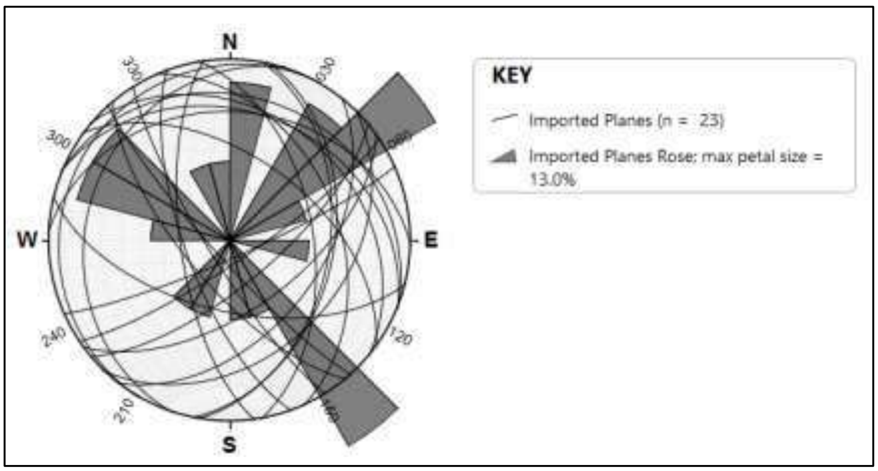


FIGURE 0-2. SHOWS ARE HIGHLY JOINTED ROCK OUTCROP WITH VARIOUS JOINT SETS.

FIGURE 0-3. SHOWS A ROCK OUTCROP WITH EXFOLIATED SURFACE CONTRIBUTING TO THE JOINTING.

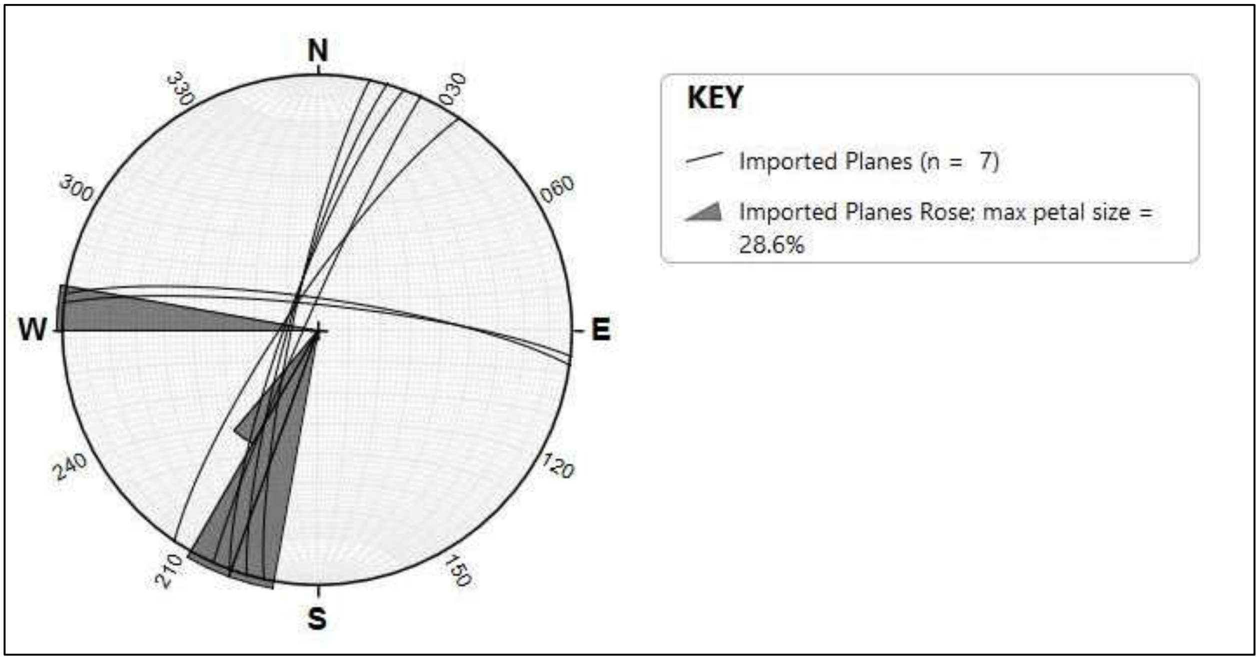
The dominant joint set trends in a northwest-to-southeast direction, dipping toward the northeast, while another set trends in a northeast-to-southwest direction, dipping toward the southeast. Notably, these joint surfaces align parallel to the foliation of the rock.





5.2.3. Foliation.

The granite gneisses of the Semliki basin exhibit foliation, which is defined by the parallel alignment of platy or elongated minerals in metamorphic rocks. Minerals align parallel to the direction of the shear force or perpendicular to the direction of high pressure as a result of directed pressure, shearing forces, or heat. Significantly, minor foliations trend in the NW-SE direction, reflecting the joint tendencies, while major foliations trend in the Northeast-South West direction. By taking advantage of weak points in the basement rock, a dolerite dyke may have intruded into the granite gneiss to generate the foliations that were seen.



Because of the tremendous heat carried by the igneous body, this intrusion caused shearing and differential mineral alignment in the granite. Quartz and the minerals mafic and felsic show clear elongation, creating a gneissic texture. Another event that contributes to the foliation within the dike is the intrusion itself, which exhibits foliation.

FIGURE 0-4. SHOWS A HIGHLY FOLIATED ROCK OUTCROP WITH FELSIC MINERALS ALIGNING IN A CERTAIN DIRECTION.

FIGURE 0-5. SHOWS A FINE GRAINED ORIGINALLY DOLERITE DYKE

5.2.4. Faults.

Dip-slip normal faults, which are created by tensional forces impacting the area, are the most common type of fault in the Semliki basin. These faults, which include both large-scale and minor faults, are oriented mostly in the NE-SW direction. Their pattern is consistent with the larger fault pattern found in the Albertine rift. The Makondo fault, which lies between the Semliki flats and the Toro plains, and the steep fault escarpment to the southeast, which rises towards the northernmost point of the Rwenzori Mountains, are two of the main faults in the Semliki basin. Furthermore, two major normal faults that separate the Congo escarpment from the basin are the Semliki fault, which trends NNE-SSW, and the Bunya fault, which trends NE-SW.

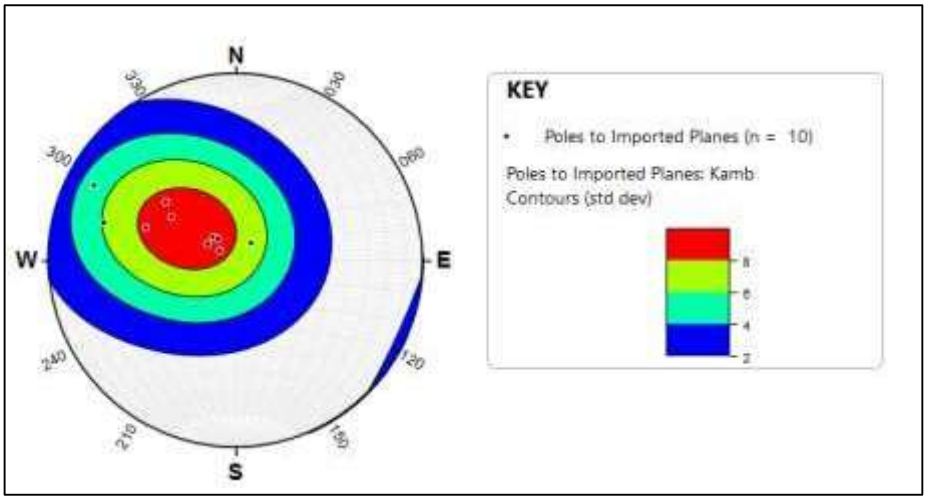
The graben architecture seen in the basin was formed in part by these conjugate normal faults, which have identical dip magnitudes but opposing directions. The Kichwamba normal fault, which trends NE-SW with a Western dip, is particularly important in regulating the escarpment and affecting the drainage patterns in the region. It's important to note that these large faults frequently appear as shorter, discontinuous faults that somewhat deviate from the overall fault orientation. Their presence has a major effect on drainage patterns because water can erode the weathered and brecciated rocks along fault lines, creating seasonal streams and gullies.

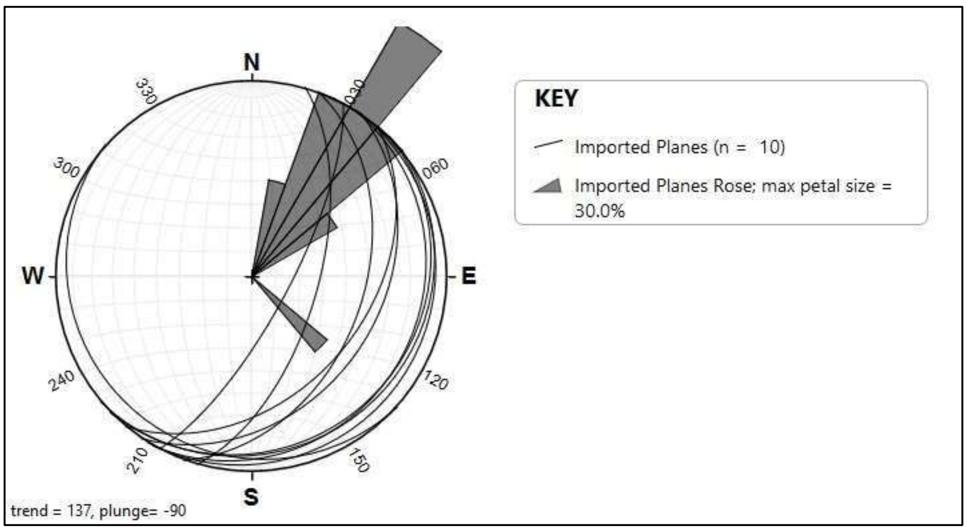
5.3. Structures in Sediments.

In the sedimentary layers overlaying the basement rocks, a variety of primary and secondary structures were identified. Primary structures, reflecting the original depositional environment, comprised beds with various types such as cross-beds, tangential beds, tabular beds, and angular beds, along with laminations, unconformities, ripple marks, and mud cracks. These features provide insights into the sedimentary processes and conditions at the time of deposition. Additionally, secondary structures were present, including faults, veins, and joints, indicating subsequent tectonic activity and deformation in the sedimentary sequence. These structures collectively contribute to understanding the geological history and processes shaping the sedimentary basin over time.

5.3.1. Bedding.

Bedding refers to the layering observed within sedimentary deposits, resulting from variations in sedimentation patterns. These layers are characterized by differences in grain size, colour, texture, mineralogy, and thickness, reflecting changing environmental conditions during deposition. The types of beds formed are influenced by factors such as water depth, grain size, and current energy. Several types of beds were identified, including planar beds, cross-beds, and graded beds. In the study area, the predominant trend of bedding is oriented in a North East – South West direction, with a dip towards the South East direction from the rose diagram below.

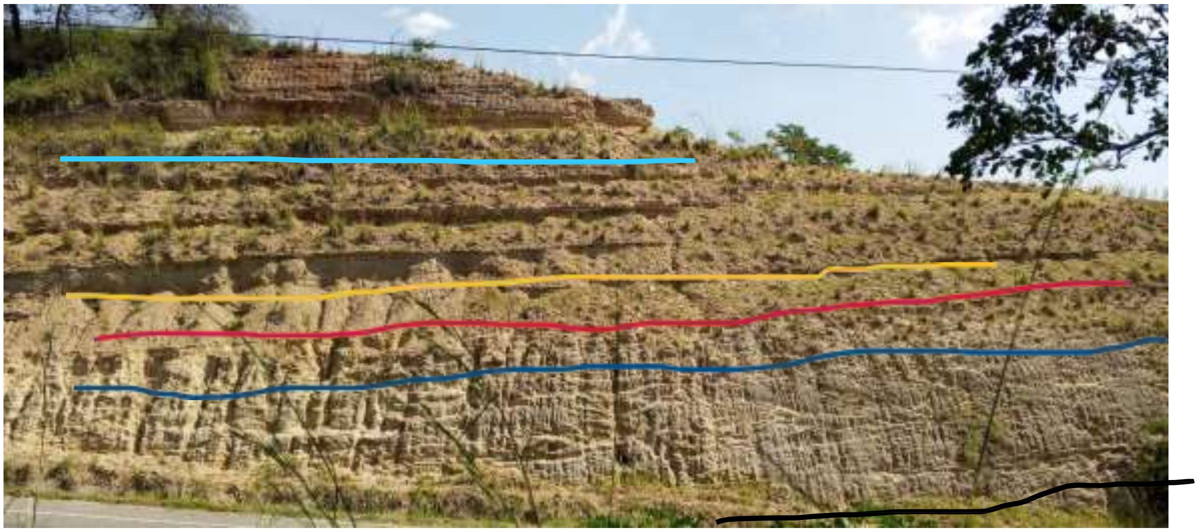




Types of Beds Observed in the Field.

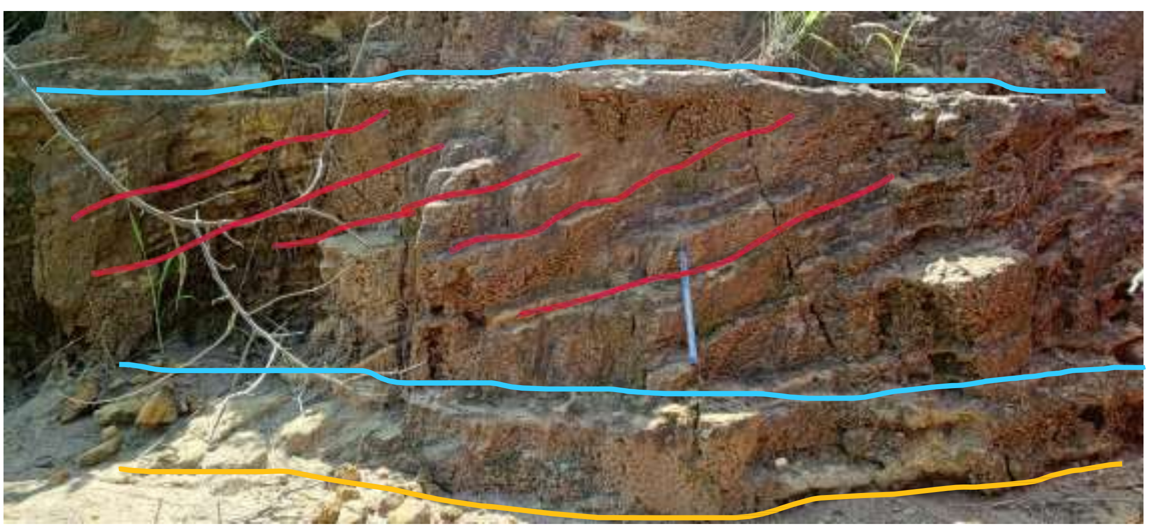
a) Planar bedding.

Planar beds were sedimentary layers that were usually deposited almost horizontally and had flat, parallel bedding planes. They developed when weak currents that were unable to move the incoming silt caused sediment to settle on a level surface. These beds had laminae of different thicknesses, which could be identified by variations in grain size and color.



b) Cross bedding.

In geology, layering within a stratum that takes place at an angle to the main bedding plane is referred to as cross-bedding, also called cross-stratification. As a result, units made up of inclined layers are roughly horizontal. When bedforms like ripples or dunes move downstream in a flowing fluid, such water or wind, cross-bedding occurs. Sand grains gradually slide down the downstream side of the bedform due to gravity as they travel up the upstream side and gather at its apex. The layers dip in the direction of the paleocurrent flow when this process is repeated, resulting in cross-bedding.



5.3.2. Laminations.

Laminations are thin sedimentary layers that are frequently seen in fine sand deposits. They are usually less than 10 millimeters thick. They arise when fine-grained particles settle from suspension in calm water conditions, including deep lacustrine settings, and are caused by cyclical changes in the supply of sediment. These layers are distinguished by their parallel or angled features and have a finer scale than bedding layers. Grain size variations, size grading within layers, and compositional changes between neighboring layers can all result in laminations. Laminations, which depict the minute internal structures within sedimentary strata, were mostly found in clays and silts in the field.

5.3.3. Mud Cracks.

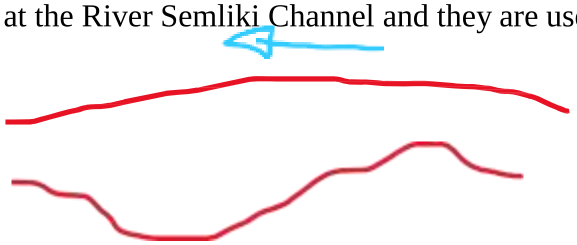
When water-rich sediments dry out from extreme heat, the mud cracks forming polygonal forms with concave upward surfaces. The Kisegi seasonal river flood basins exhibited these characteristics. Mud cracks are important for figuring out the stratigraphic up-direction because the tapering end represents the direction of rock maturity, while the concave side shows the direction of younging. Mud that has been dewatered and exposed to air develops these polygon-shaped fissures. Mud fissures are helpful as geopetal constructions because they curve upward. Mud cracks in the clays in the research region indicate that the lake that deposited the clays dried up, exposing the sediments to the atmosphere.

And also they were attributed to the lacustrine environment which was discussed at the location (201131, 110298; Elevation 681m) found associated with fossils like mollusks and bivalves where the formally lake Obweruka was and currently part of lake Albert.

0-6 FIGURE 5.3.3 SHOWING MUD CRACKS

5.3.4. Ripples

On the surfaces of sediments, ripple marks are tiny, wavy ridges and troughs created by wind or water flow. Geologists employ these bedforms, which function as nature's tape recorders, to map the Earth's paleogeography, reconstruct ancient ecosystems, and ascertain the direction of prehistoric currents. These were observed at the River Semliki Channel and they are used to depict the direction of flow of the river.



CHAPTER 6: GEOPHYSICS OF THE SEMLIKI SEDIMENTARY BASIN

Geophysics applies the principles of classical physics to probe the interior of the Earth by analyzing variations in the physical properties of rocks. Different geophysical methods correspond to specific rock properties: gravity methods to density, magnetic methods to magnetic susceptibility, seismic methods to velocity and density, and resistivity or electromagnetic (EM) methods to electrical conductivity. These methods are either passive (e.g., gravity, magnetic, radiometric) or active (e.g., seismic, electrical), with the latter creating more detailed subsurface images but at increased cost.

In the Semliki Basin, several geophysical surveys have been conducted with the aim of demystifying its structure and geological configuration, focusing on petroleum system evaluation in the Albertine Graben. Gravity and aeromagnetic surveys conducted between 1999 and 2002 over an area of 9578 km^2 produced maps of Bouguer anomaly and intensity of magnetization using the Oasis Montaj software. Earlier, in 1983, airborne magnetic surveys conducted by Kenting Earth Sciences recognized the Makondo Fault, which was also confirmed using 1998 seismic data having a strike of NE-SW and folded hanging wall with a positive flower structure.

Although no new data acquisition occurred during recent fieldwork due to equipment limitation, the focus was interpreting and correlating earlier data of the Semliki Basin and Gulf of Mexico, including seismic sections, gravity and magnetic maps, and Turaco well petrophysical data. These datasets helped in facies correlation and formation evaluation essential for understanding subsurface structures and hydrocarbon potential.

6.1 POTENTIAL FIELD SURVEY METHODS

Geophysical exploration in Semliki Basin utilized gravity and magnetic methods collectively termed potential field surveying methods because they utilize naturally occurring fields within the earth, that is the gravitational and magnetic fields.

Gravimetry determines spatial and temporal variations of the Earth's gravity field, and magnetometry determines corresponding variations of the magnetic field. These techniques aid in defining single field elements or total field values, thereby enabling geophysicists to interpret subsurface rock geometry. The information is utilized for the detection and mapping of geological anomalies, depth, size, and coverage of subsurface structures, qualitative description, as well as quantitative estimation of anomaly sources e.g., density and geometry, thereby facilitating structural and resource mapping of the basin.

6.1.1. Gravity data interpretation for Semliki Basin

Gravity survey methods, utilizing the Bouguer anomaly, play a crucial role in understanding subsurface geological structures. The Bouguer anomaly is calculated by correcting the measured gravity values for the effects of elevation, latitude, and topographic relief of the survey area. This correction removes the gravitational effects caused by factors other than subsurface geology, allowing for a clearer interpretation of the gravity data. Positive Bouguer anomalies indicate areas of higher-density rocks, such as igneous intrusions or mineral deposits, while negative anomalies suggest areas of lower density, like sedimentary basins or void spaces. By analyzing these anomalies, geophysicists can delineate subsurface structures, identify potential mineral or hydrocarbon deposits, and better understand the geological history of the surveyed area.

Results of gravity interpretation for Semliki Basin

Using Geosoft Montaj software, a Bouguer anomaly map of the gravity data of the Semliki basin was generated.

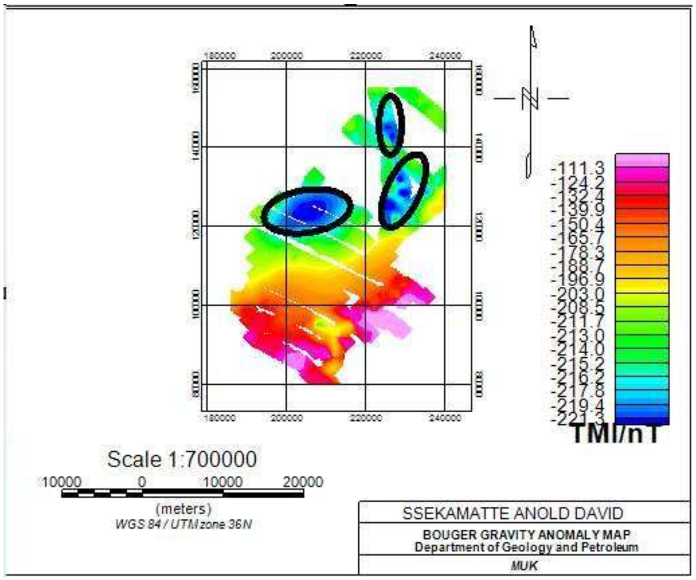


FIGURE 0-1 THE BOUGUER GRAVITY ANOMALY MAP GENERATED USING THE GEOSOFT SOFTWARE.

From the map, all the gravity anomaly values are negative, indicating low density rocks (sediments). The values, however, vary from -221.3mgal to -111.3mgal indicating variation in the thickness of the basin. The parts with more negative values (-208 to -221 mgals) have thick sediment accumulations (blue colors) than those with less negative values (pink-98red colors).

Thus, the north-eastern (generally the northern part) part of Semliki is deeper than the southern part of the basin. This means that more sediments accumulated in the deeper parts than in the shallower parts. The Semliki basin is thus asymmetric with the deeper parts being on the northern part, more specifically the North-Eastern part, which is on the DRC side. This architecture is typical of half grabens since the side of the major controlling fault is always deeper than the

opposite side. In the middle of the Semliki basin, the gravity anomaly values are average indicating that there is also average thickness of sediments. The southern part of the basin has the less negative values (111mgals to -203mgal) of the gravity anomaly. This part of the Semliki basin is thus the shallowest compared to other parts of the basin.

The variation in the gravity anomaly across the Semliki basin is because different parts of the basin have different thicknesses of sediment accumulation. The parts with less negative values have the least thickness of sediments such that the basement rocks (which give high gravity anomaly values) are relatively close compared to the deeper parts of the basin where the basement rocks which would give high values are deeply buried by the thick sediment accumulation. Low gravity anomaly values represent low density rocks, and these are obviously sediments with possible hydrocarbon entrapments/accumulations. The difference in thickness of sediment accumulation was brought about by the variation in depths (accommodation space) in the different parts of the basin.

6.1.2 Results of Magnetic Data Interpretation of the Semliki Basin

Magnetic surveys are geophysical methods used to detect anomalies in the Earth's magnetic field caused by variations in the magnetic susceptibility of subsurface rocks. These surveys help determine the geometry, depth, and magnetic properties of rock formations, providing crucial insights into the composition and structure of the Earth's crust. Magnetic anomalie deviations from the regional magnetic field are typically presented on maps to highlight subsurface features.

The strength of the detected magnetic signal depends on both the amount of magnetic material and its distance from the sensor. Basic igneous rocks generate the strongest magnetic responses, sedimentary rocks produce weak signals, and acidic gneisses and metamorphic rocks give intermediate readings. Magnetic data interpretation for the study area was performed using Geosoft Oasis Montaj software, aiding in the identification of subsurface structures and supporting geological and resource exploration.

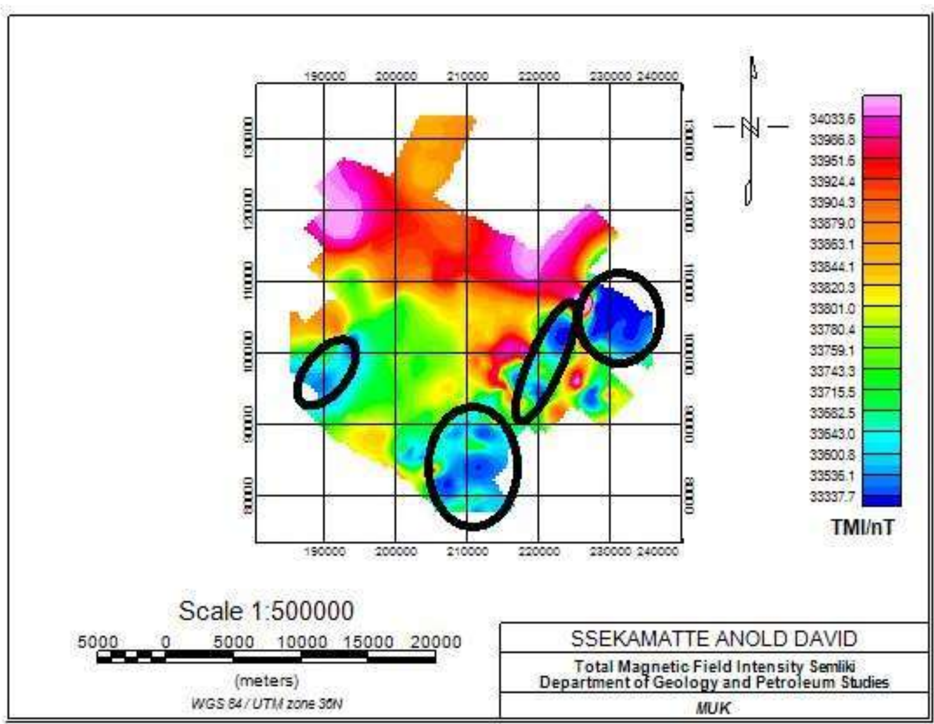


FIGURE 0-2 THE MAP INDICATING THE TOTAL MAGNETIC FIELD INTENSITY OF THE SEMLIKI BASIN

The magnetic anomaly map shows high magnetic field intensities (pink to yellow) in the northern part of the Semliki Basin, with values ranging from 33844.1 to 34033.6 nT, indicating the presence of igneous basement rocks with high magnetic susceptibility. These areas are bordered by steep gradients, suggesting that the magnetic sources are near the surface, likely marking the basin margin. In contrast, low magnetic intensities (green to blue, ranging from 33643.0 to 33337.7 nT) are observed in the southern part, corresponding to sedimentary rocks with low remnant magnetization. The tremendous changes from sedimentary to igneous rocks could be the cause of the abrupt change in the magnetic susceptibility or magnetite content necessarily to produce the observed magnetic anomalies.

The following are assumptions upon which the magnetic interpretation is based:

- Anomaly producing rocks are magnetically homogeneous and magnetized in the earth's field.
- Rock masses producing anomalies possess a plane surface and vertical sides and are of infinite depth extent.

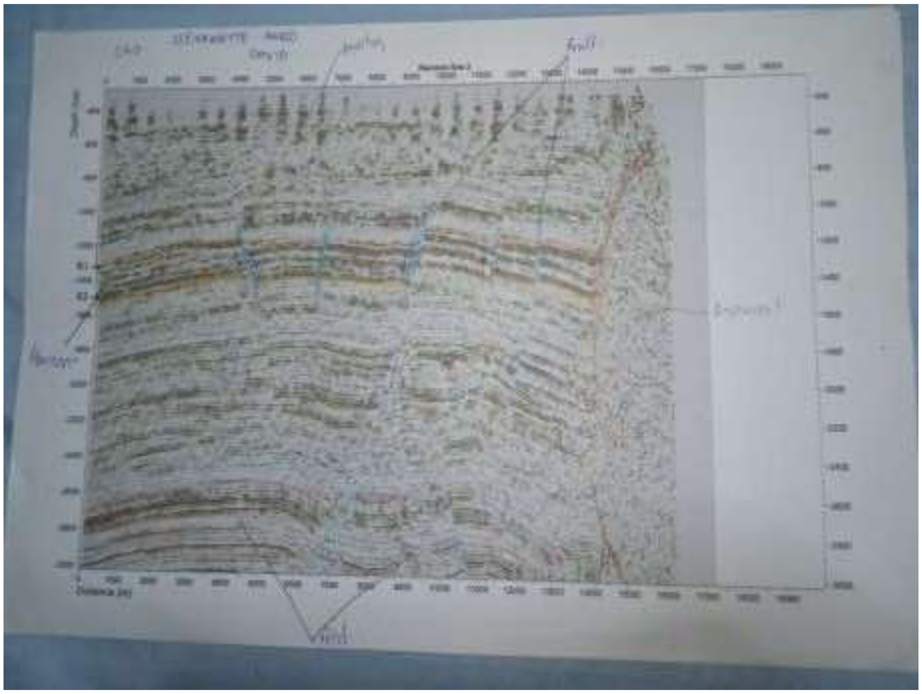
- Anomalies of large amplitude and wide areal extent are produced by contrasts in magnetic susceptibility (topographic relief of a magnetic rock unit generally produces only small amplitudes of anomalies).
- Remnant magnetization is in the direction of the earth's field (negligible).

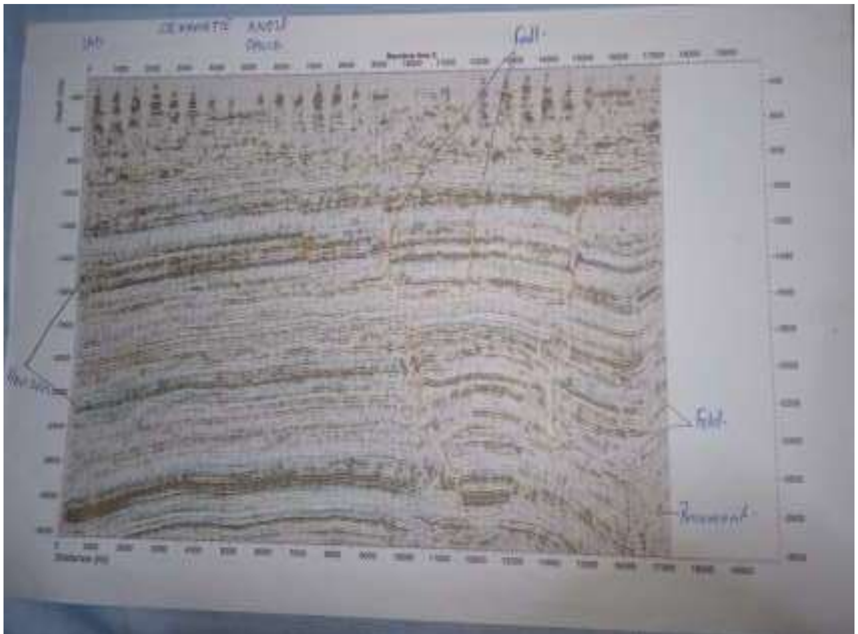
6.2 SEISMIC SURVEYS

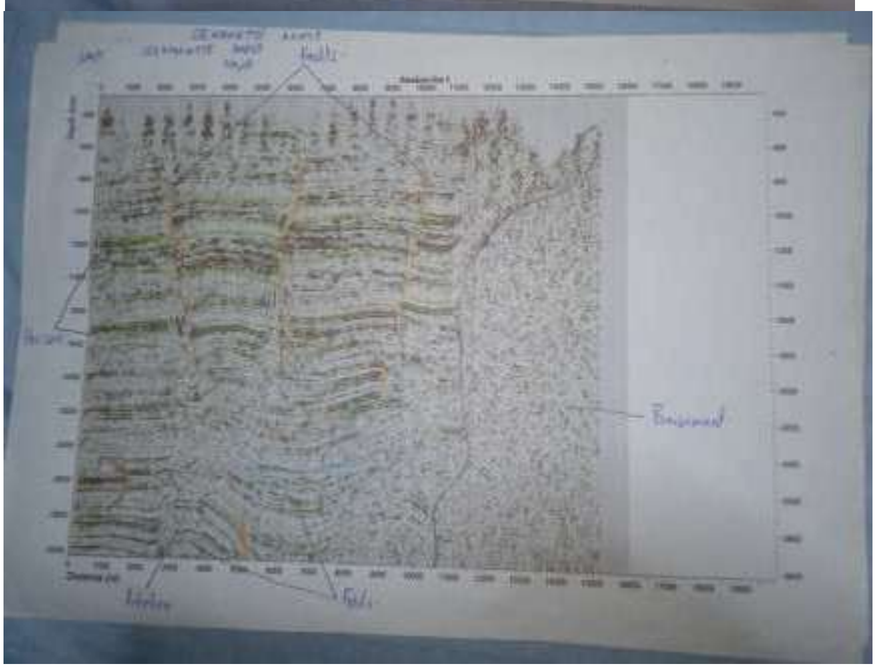
Of all geophysical exploration methods, Mondol and Bjørlykke (2010) discuss seismic as unequivocally the most important, primarily because it can detect large-scale to small-scale subsurface features. Seismic methods help in forecasting the shapes and physical properties of the subsurface layers of the Earth by analyzing the return of the sound waves that have been transmitted through the ground. This is achieved by developing a seismic pulse from a source at or near the surface of the Earth and recording the amplitudes and travel times of waves as they reflect or refract off different subsurface layers, gaining valuable information about the structure and composition under the surface.

The seismic data collected can be interpreted to identify various features such as sedimentary facies and structural characteristics. In the context of the Semliki Basin study, seismic data interpretation relied on data acquired both from the basin in the Albertine graben and from the Gulf of Mexico by ExxonMobil. The primary objective was to analyze the sedimentary facies present in the subsurface of these two regions.

6.2.1 Results of seismic interpretation of structures for the Semliki Basin.



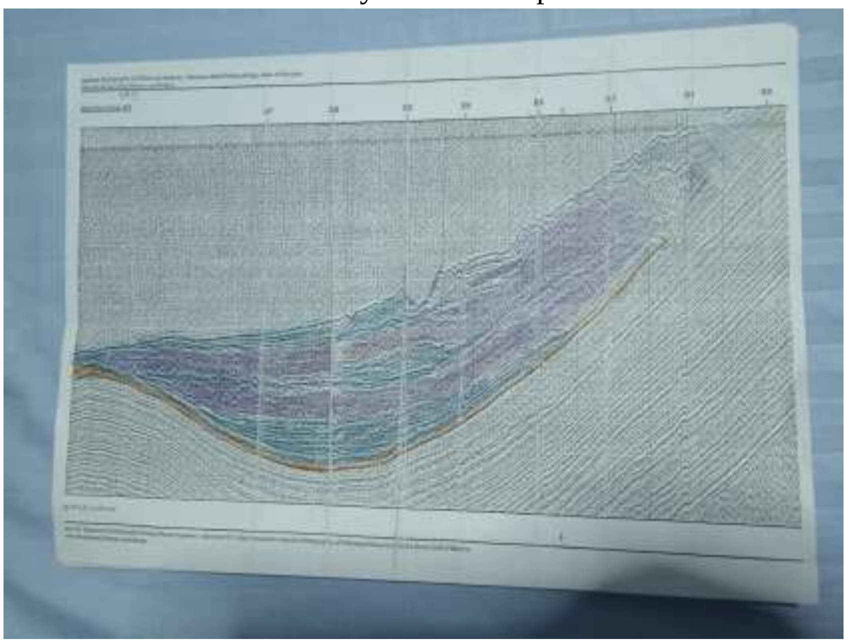


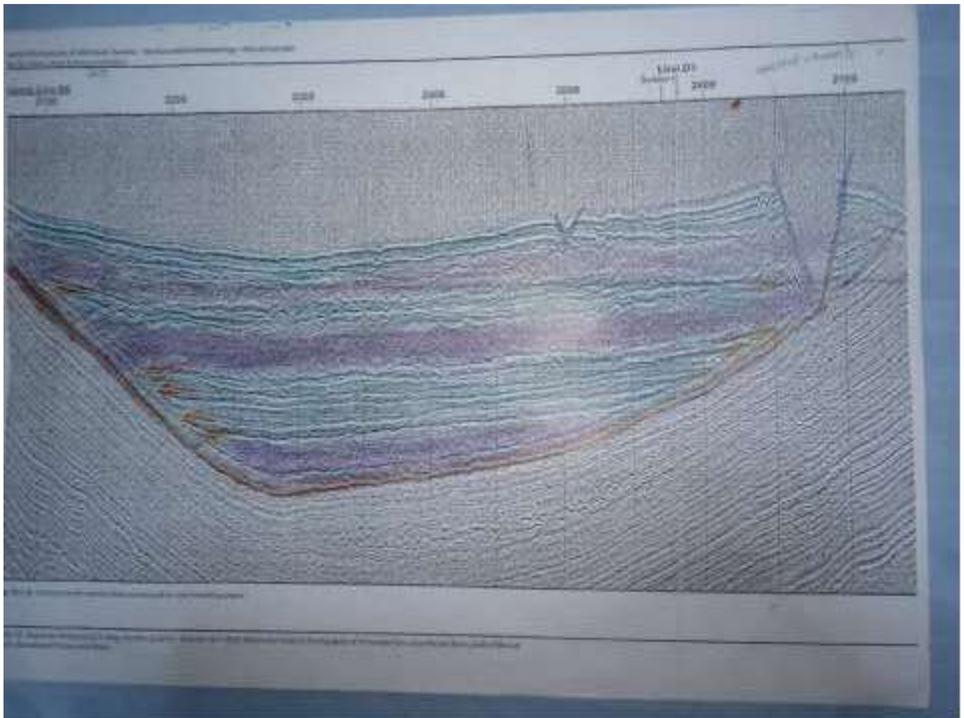


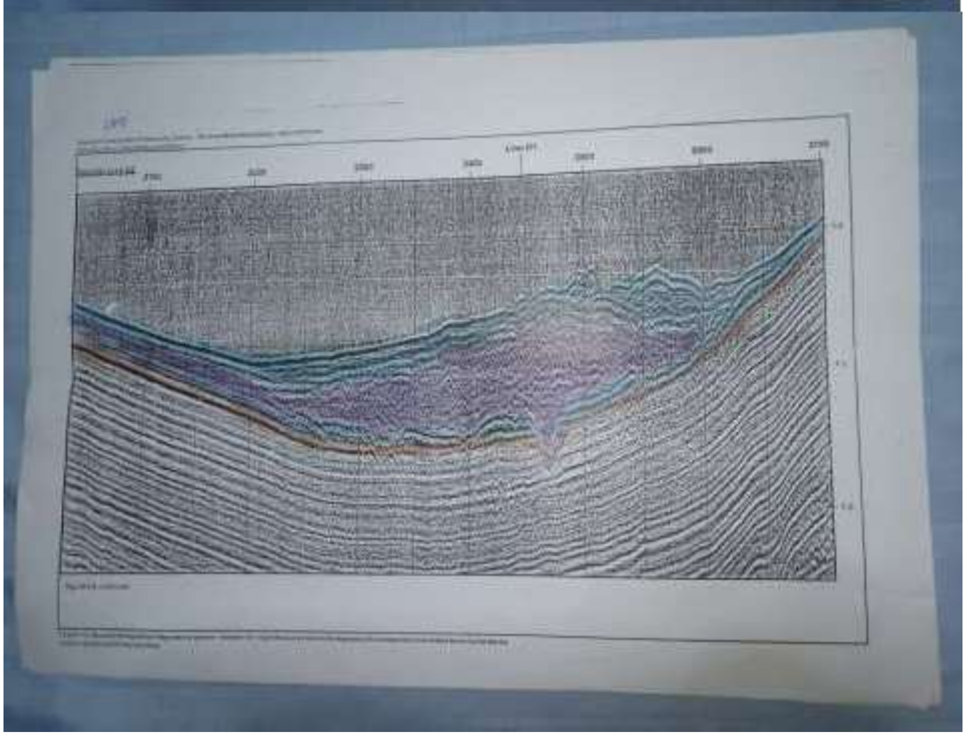
In the seismic section above, seismic reflection data was used to identify subsurface structures in the basin. The section shows several **normal faults**, recognized by the displacement and abrupt termination of reflectors. These faults mainly affect the sedimentary layers and are not clearly seen in the basement. The presence of normal faults indicates tectonic activity and extension within the basin, which is typical of the Albertine Graben. The faults may act as pathways for hydrocarbon migration or as traps if they are sealed by clay smear.

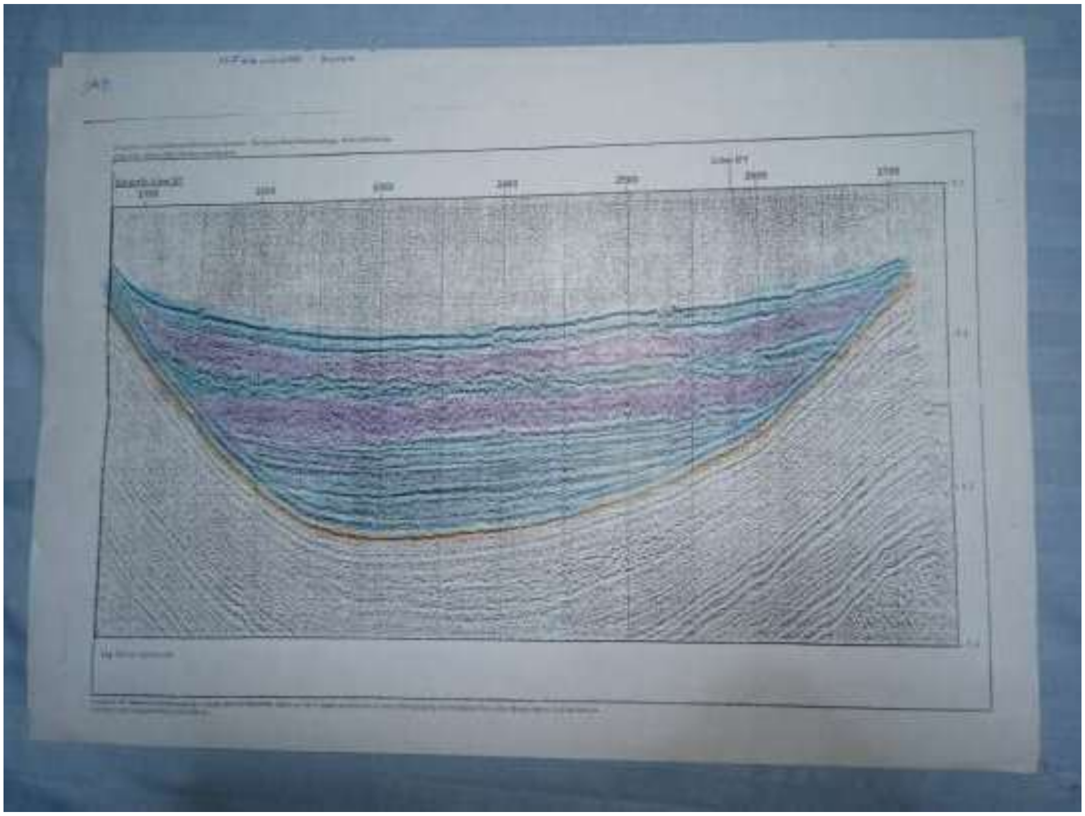
The **basement** is identified by chaotic and poorly continuous reflections, while the overlying sediments show clearer and more continuous reflectors. Some reflectors are folded, forming gentle anticlines and synclines. The anticlines may act as potential hydrocarbon traps. The traced horizons are mostly continuous but become displaced where they meet the faults. This confirms faulting within the sedimentary succession. Abrupt reflector terminations may also indicate faulting or erosion.

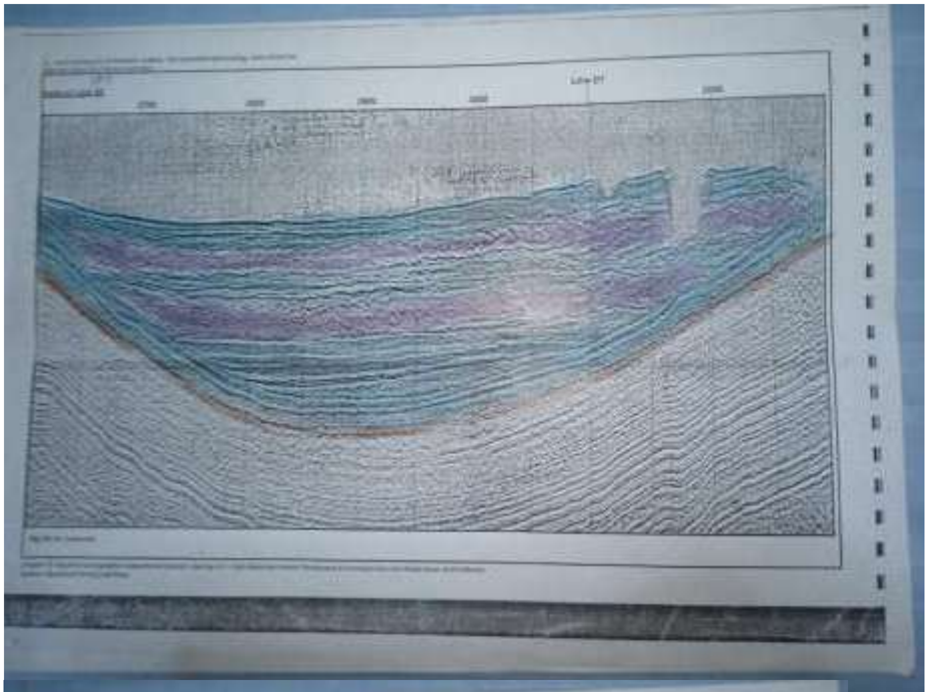
Results of seismic study and interpretation of facies/lithology for the Gulf of Mexico.

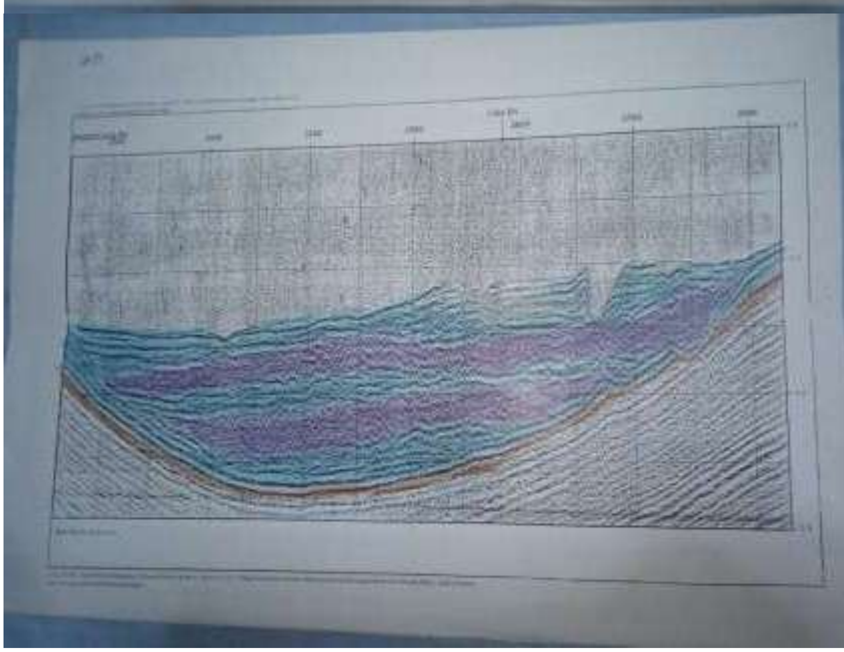


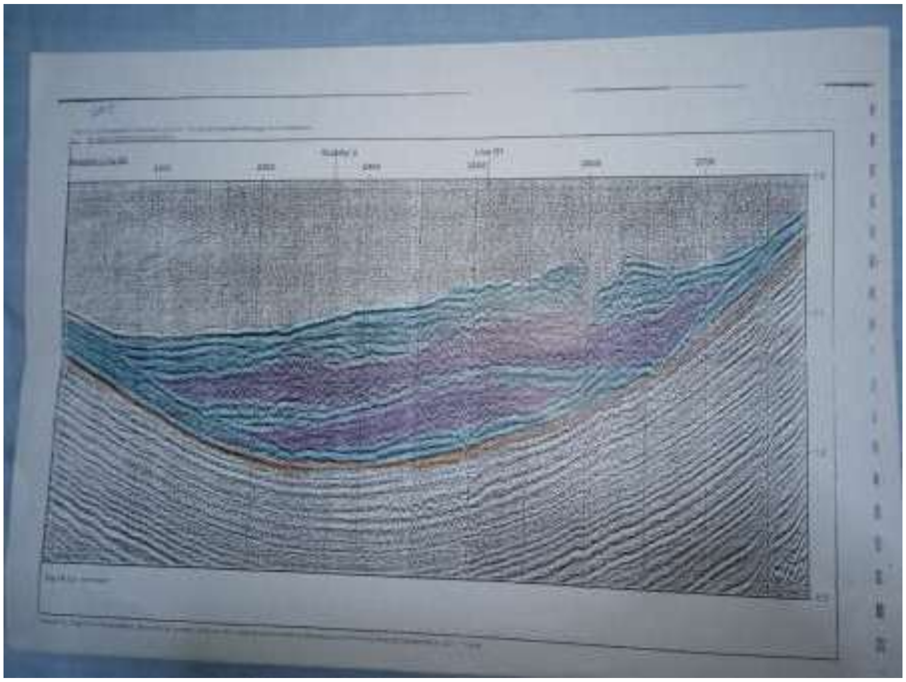












Seismic interpretation was carried out on the provided sections to identify subsurface structures, seismic facies, and depositional features. The sections show clear reflection patterns, faulting, folding, and changes in seismic character.

In the Semliki Basin seismic section, normal faults are observed from the displacement and abrupt termination of reflectors. These faults mainly affect the sedimentary layers and are not clearly visible in the basement. The basement is identified by chaotic and poorly continuous reflections, while the overlying sediments show more continuous reflectors. The presence of faults and folds indicates tectonic activity within the basin. These structures may act as hydrocarbon migration pathways or traps, especially where faults are sealed and anticlines are present.

In the Gulf of Mexico seismic section, two main sedimentary facies are identified. One facies has stronger and more continuous reflections, likely representing sandy deposits, while the other has weaker and thinner reflections, likely representing shale or clay. The lens-shaped body suggests an intraslope fan deposit within a deep-water environment. Reflection terminations such as onlap, downlap, and truncation indicate changes in sea level, sediment supply, and depositional energy.

Generally, the seismic sections show structurally and stratigraphically controlled basins. The Semliki section is mainly controlled by faulting and folding, while the Gulf of Mexico section shows deep-water fan deposition and facies changes. Both sections are important for petroleum interpretation because faults, folds, sandy facies, and sealing shale layers may create good conditions for hydrocarbon migration, trapping, and accumulation.

Results of Wireline logging study for Turaco 1,2, and 3

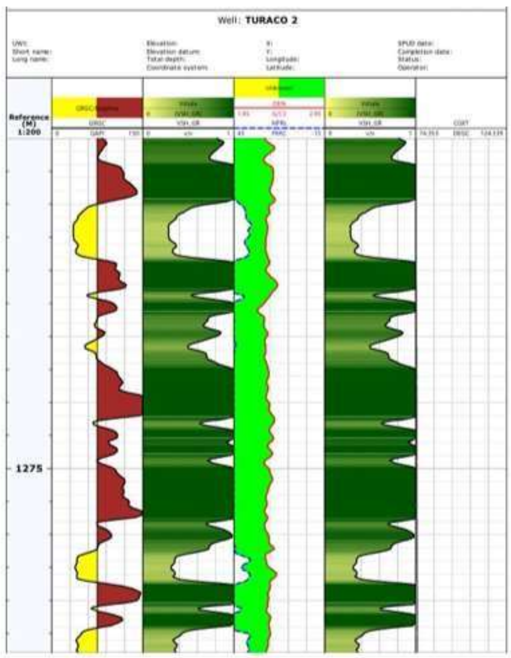
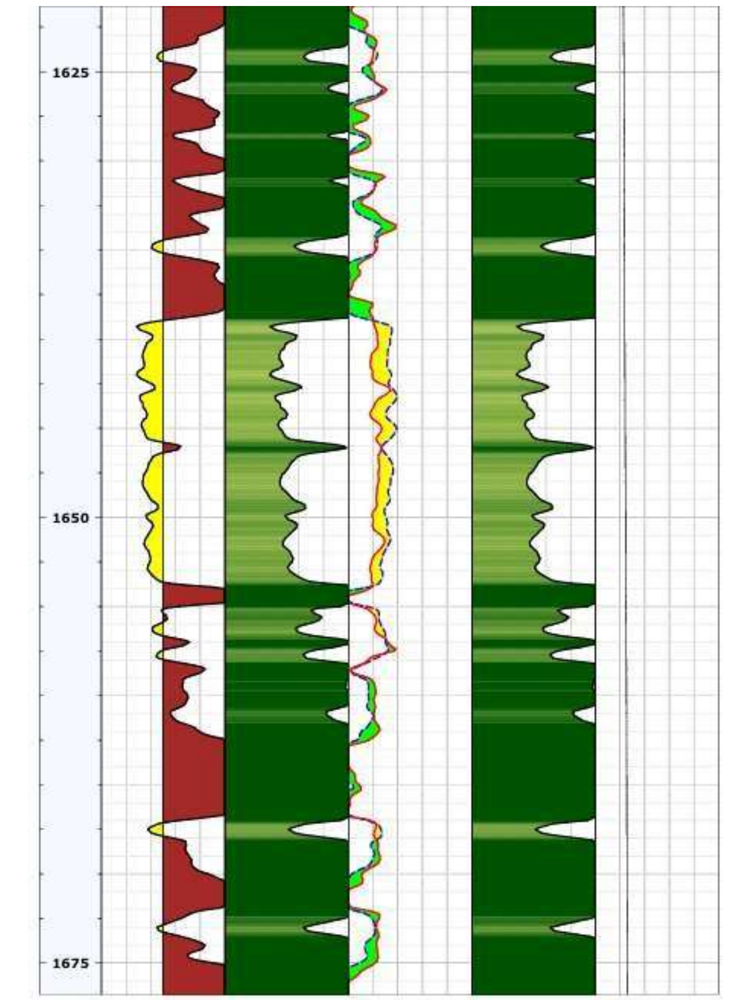


FIGURE 0-3 A SECTION OF A WIRELINE LOG FROM TURACO WELL 2



This section has an intercalation of clays and sandstones. The shale/clay layers are represented by the very high gamma ray values and low-density values. The sand layers are represented by the low gamma ray values and slightly higher density values. The V-shale also shows very high values in the zones with shales. Thus, a combination of V- shale and gamma log can be a good tool for identifying shale formations. The shale formations are also indicated by very high values of neutron logs. Gas bearing zones have also been identified by combing density and neutron logs. Gas zones are characterized by very low neutron values (negatives). The combination of the same logs has also been used to identify potential oil-bearing zones and water zones.

Neutron- Density logs

Well logs are utilized to evaluate the porosity of a formation, with the density log (represented by the red line) measuring the formation's electron density, and the neutron porosity log (blue dashed line) detecting hydrogen concentration. When the density log shifts to the right and the neutron log to the left, it typically indicates a shale formation. A crossover, where the density log moves left and the neutron log shifts right, suggests the presence of gas-filled sand. If both logs closely follow each other, the formation is likely saturated with either oil or water. In the analyzed log section, the data points to a higher presence of gas than oil. This is evident from the lower neutron log values, which results from gas having a lower hydrogen content compared to oil or water, and the relatively higher readings on the density log. A significant separation between the two logs is a strong indicator of gas, while overlapping logs suggest oil or water saturation. The Turaco 2 well data indicates a predominance of gas over oil, which may not be economically attractive for companies primarily targeting oil production.

These logs can be used to calculate porosity using the following formula:

$$\Phi=\frac{\rho matrix-\rho density\ log}{\rho matrix-\rho fluid}$$

Where,

Φ=porosity

P matrix = the density of the matrix (g/cc)

P density log = the density read from the density log (g/cc) P

fluid = the density of the fluids (g/cc)

The Turaco-2 well returned average porosity values of 31%, 21%, 36%, 26%, and 22%. These values represent very high porosity, which indicates that the reservoirs in this region are of higher quality and have excellent potential for hydrocarbon storage and extraction.

Gamma ray logs

High gamma ray readings, typically shown as brown zones on logs, indicate shale formations due to their radioactive mineral content, such as potassium. Low gamma readings, marked in yellow, indicate clean sands or carbonates, as seen in the 1640–1655 ft interval. These low readings are characteristic of potential reservoir zones. Additionally, the presence of a reservoir can be suggested by negative readings or the formation of mud cakes as a result of interactions between reservoir rock and drilling fluids.

The gamma-ray log indicates that the Turaco well predominantly encountered shaly formations, as indicated by high gamma readings. This suggests the well likely penetrated the Kasande, Oluka, and Nyakabingo formations, which are known for their high shale and clay content within the Semliki Basin.

V Shale

The gamma-ray log is useful for estimating the shale volume within a formation. Low shale volumes indicate minimal shale content, suggesting higher porosity, which is favorable for the accumulation of hydrocarbons especially oil and water. The volume of shale can be calculated using the following formula;

$$Vshale = \frac{GRlog - GRmin}{GRmax - GRmin}$$

GRlog is the gamma-ray log reading at the point of interest,

GRmin is the gamma-ray reading for clean sand (minimum gamma-ray value), GRmax is the gamma-ray reading for shale (maximum gamma-ray value).

In summary, low Vshale values suggest higher porosity and potential hydrocarbon zones within the formation.

6.3.2. Results from the field visit to Turaco drilling

The Turaco well site, located on the hanging wall of the Makondo fault, has seen multiple drilling attempts over the years. The Turacos are three (Turaco 1, 2 and 3) were the second set of wells to be drilled in the Albertine Graben after the Butiaba-Waki well according to previous studies. The drilling history in the Albertine Graben began with the Butiaba-Waky well in 1937, spurred by surface oil seeps. Later, Turaco wells were drilled following seismic observations. Turaco-1, drilled by Heritage Oil in 2002 at coordinates (199706, 113822) was abandoned at 2.5 km due to collapse. Turaco-2, drilled in 2004 near Turaco-1 at coordinates (199740, 113753) to a depth of 2963 m, showed oil mixed with carbon dioxide. Subsequent 3D seismic surveys led to the drilling of Turaco-3 in 2004, 100 m from Turaco-2 at coordinates (199763, 113762) reaching 2980 m and encountering natural gas with carbon dioxide contamination. Another well at Kanywataba drilled to 2105 m, was dry with no hydrocarbon shows. The carbon dioxide contamination in the Turaco wells is possibly due to earlier volcanic activity and an over-mature source rock. The well was plugged, the project was abandoned, and the area was decommissioned. Turaco area still stands as an important hydrocarbon prospect within the Semliki Basin if exploration is heightened in future.

6.4. RESULTS FROM THE STUDY OF GEOPHYSICAL METHODS FOR GEOTHERMAL EXPANSION

We visited the the Sempaya hotsrings. The Sempaya hot springs, located in Semliki National Park within the Albertine Graben, are a remarkable natural phenomenon. Situated approximately 40km from the border with the Democratic Republic of Congo (DRC), these hot springs are an intriguing feature of the landscape. The hot springs are a result of geothermal activity within the East African Rift System, where the Earth's crust is being pulled apart, allowing geothermal energy to reach the surface. The bubbling springs and mud pots are evidence of this underground heat, which can also influence the maturation of hydrocarbons.

Figure 9: The female and make Sempaya hotsprings

According to Vincent (2016), a combined Magnetotelluric (MT) and Time-Domain Electromagnetic (TDEM) survey was conducted in the Buranga geothermal field. In addition, soil- gas and gas-flux measurements, including radon gas analysis, were performed to identify hidden faults connected to the reservoir and to trace concealed permeable structures in the area. Helium isotope ratios ($^3He/^4He$) from the Buranga site were also measured to detect any deep mantle signatures. The results showed elevated ratios, suggesting the presence of deep permeability and potentially deeper, high-temperature fluid reservoirs.

Magnetotelluric (MT) Method and TEM Soundings:

The Magnetotelluric (MT) method is a passive, frequency-domain electromagnetic sounding technique that measures the Earth's natural electric (telluric) and magnetic field responses to determine the resistivity structure of the subsurface. The electromagnetic (EM) signals used in MT are primarily generated by distant lightning strikes (frequencies above 1 Hz) and electric currents in the ionosphere (frequencies below 1 Hz) (Isaiah T., 2010).

In recent geophysical investigations, the MT method has been employed for deep subsurface exploration, reaching depths of up to 15 km, while the TEM method has been used to correct for telluric shifts in MT data. Between 2014 and 2017, a total of 108 MT and 94 TEM soundings were carried out in the Buranga area. The sedimentary basin at Buranga is characterized by high conductivity, attributed to clay-rich minerals compacted within the sediments (Bahati et al., 2016).

Aeromagnetic survey

According to (Bahati et al. 2016), Aeromagnetic survey conducted in 1980s by the Department of Geology and Survey Mines in Uganda revealed two distinct areas of high and low magnetization. The low magnetic susceptibility was interpreted as the probable areas of geothermal interest due to reduced magnetization as a result of thermal activities.

Seismic survey

A joint seismic study by BGR (German Geological Survey) and DGSM was carried out in 2007. The inversion tomography of the huge seismic data set indicated low P-wave velocity anomalies in the subsurface located south of the hot springs at 10 km depth. The reduced velocity anomalies were interpreted as high temperature anomalies inferred to be hot actively degassing magmatic intrusions which could be the heat source for the hot springs (Bahati et al. 2016). Seismic reflection data was also used to indicate location of major faults and areas of structural complexity such as fault intersections, where fracture density would likely be greatest.

CHAPTER 7.0: DISCUSSION

7.1 FACIES AND DEPOSITIONAL ENVIRONMENTS

Sedimentation in the Semliki Basin is composed of both clastic and non-clastic deposits that accumulated under lacustrine, deltaic, and fluvial conditions. The basin lies within the western arm of the East African Rift System and is characterized by a complex geological setting. Structurally, it is a rift basin with a half-graben geometry, mainly controlled by faulting along one margin. Lithological evidence from the Kibuku roadcut shows different rock units, including sandstones, siltstones, mudstones, and clay. These rock types reflect the influence of varying depositional processes and environmental conditions within the basin.

Lacustrine deposits are common across the Semliki Basin and are mainly made up of claystones and siltstones, with sandstone interbeds. The occurrence of freshwater invertebrate fossils, including molluscs, together with evaporite minerals such as gypsum, supports the interpretation of deposition in a lake environment. Lacustrine settings are generally associated with low-energy conditions, allowing fine-grained sediments to settle and accumulate. Gypsum, being an evaporite mineral, points to semi-arid conditions and high evaporation rates, suggesting intervals when lakes or rivers experienced drying. The change from fluvial to lacustrine settings commonly involves deltaic deposition, which forms a transition zone where river-transported sediments are deposited before entering the lake.

Deltaic conditions in the Semliki Basin are interpreted from the presence of fine-grained sedimentary materials, including mud diapirs, fine sands, and silts, as well as sandstone units showing coarsening-upward trends. These sedimentary patterns suggest variations in sediment input and depositional energy through time. The occurrence of both fining-upward and coarsening-upward sequences in the sandstones indicates alternating periods of transgression and regression. During transgression, rising water levels allow finer sediments to be deposited over coarser materials, producing a fining-upward succession. In contrast, regression results in the deposition of coarser sediments over finer ones, creating a coarsening-upward sequence.

Fluvial deposits in the Semliki Basin are represented by thick sandstone beds ranging from coarse- to fine-grained textures and commonly displaying fining-upward sequences. These deposits indicate high-energy depositional environments such as meandering river systems, alluvial plains, floodplains, point bars, and overbank areas. Although their thickness varies, fluvial sediments generally form laterally continuous sandstone bodies. The presence of angular coarse-grained conglomerates further suggests rapid transportation and deposition under high-energy conditions. The distribution and orientation of both fluvial and deltaic deposits were controlled by factors such as climate, water discharge, sediment supply, basin gradient, tectonic activity, and basin geometry.

Deformational features such as faults and joints within the sedimentary successions show that the Semliki Basin was tectonically active during sediment deposition. Tectonic activity plays an important role in sedimentation by creating accommodation space for sediment accumulation and by influencing sediment transport and depositional patterns. Evidence of tectonism in the area is further supported by the formation of the Rwenzori Mountains, together with the faulting and fracturing observed throughout the basin.

7.2 SUMMARY OF THE GEOLOGICAL HISTORY OF THE SEMLIKI BASIN

The Semliki Basin forms part of the Albertine Graben and has been influenced by major tectonic and sedimentary processes related to the East African Rift Valley system. The basin is underlain by Precambrian high-grade metamorphic and igneous rocks and has undergone several tectonic events that created favorable conditions for the accumulation of thick sedimentary successions. The development of rift shoulders and increased subsidence promoted rapid sedimentation, allowing continental and lacustrine sediments to fill the half-graben under relatively less active tectonic conditions.

Most sediments in the Semliki Basin were derived from the surrounding highlands, escarpments, and areas near present-day Lake Albert. These deposits include sands, clays, silts, and conglomerates, which accumulated in cyclic patterns controlled by climatic and seasonal variations. The basin’s depositional systems evolved from fluvial to lacustrine environments, with river systems contributing significantly to sediment accumulation. Stratigraphically, the basin consists of a basal conglomerate at the base, followed by sand-rich units and capped by clay-rich deposits. Later tectonic activity caused mineral remobilization, leading to the formation of quartz veins within the basement rocks.

The Kisegi Formation, which is the oldest formation in the basin, consists of a basal conglomerate grading into yellow sandstone with gypsum veins. This suggests deposition in fluvial, deltaic, and lacustrine environments under semi-arid climatic conditions. The Kasande Formation is composed of dark mudstones and coaly shales, indicating a shift from lacustrine conditions to a wet delta plain setting. The Kakara Formation contains poorly sorted sandstones and ferruginous layers, suggesting deposition on a coastal plain influenced by nearby channels. The Oluka Formation is made up of dark shales and conglomeratic ironstone, pointing to lacustrine and nearshore mudflat environments.

The Nyaburugo Formation consists of claystones with ironstone concretions and fining-upward sandstones, reflecting fluvial channel deposition under humid tropical conditions. The Nyakabingo Formation contains coarsening-upward cycles with light grey claystones and iron-stained siltstones, which are typical of floodplain and lagoonal environments. Finally, the Nyabusosi Formation is characterized by alternating clays and silts with distinct ironstone horizons, suggesting coastal to nearshore lacustrine environments affected by significant lake-level changes.

In general, the geology of the Semliki Basin reflects a complex relationship between tectonic activity and sedimentary processes. These processes produced diverse sedimentary sequences that provide important evidence about the basin’s past environments and geological evolution.

7.3 HYDROCARBON PETROLEUM POTENTIAL OF THE SEMLIKI BASIN

The study area shows several characteristics of a potentially effective petroleum system. These components are important for the generation, migration, accumulation, and trapping of hydrocarbons. Evidence from surface geological mapping, seismic interpretation, and well data indicates that the key elements required for a working hydrocarbon system are present in the Semliki Basin. The widespread lacustrine clays in the basin could develop into good source rocks if subjected to sufficient burial and high temperatures over time. The dark grey colour of some clay units suggests the presence of organic matter, which is necessary for hydrocarbon generation. However, the clay deposits in the area are not sufficiently thick to form very good source rocks.

The Semliki Basin contains moderately to well-sorted sandstones with grain sizes ranging from medium to very coarse. This suggests that the sandstones may have good porosity and permeability, making them potential hydrocarbon reservoir rocks. The sediments are also underlain by basement rocks such as granitic gneisses, which are highly fractured and jointed. These fractures and joints may provide migration pathways for accumulated hydrocarbons. In addition, the rapid discharge of water at the Sempaya hot springs, estimated at about 10–15 litres per second, indicates high permeability in the subsurface rocks. However, reservoir quality is reduced by secondary minerals such as gypsum and iron oxides, which fill fractures and decrease porosity. Intense weathering has also caused reservoir compartmentalization, reducing communication between productive zones and potentially creating production challenges.

Both structural and stratigraphic traps occur in the study area. Seismic data from the Semliki Basin revealed numerous small tilted fault blocks, apparent rollover structures, and anticlinal features related to listric fault block rotation. Unconformities observed in the study area may also provide stratigraphic traps or combined structural and stratigraphic traps. Positive flower structures, such as those observed at Turaco, are considered important exploration targets for hydrocarbon trapping in the Semliki Basin.

Potential top seals in the Semliki Basin are provided by impermeable lacustrine claystones interbedded with sandstones, as well as fine-grained lacustrine successions overlying sandstone reservoirs. Clay beds approximately 20 metres thick could act as regional seals by preventing hydrocarbons from escaping from reservoir units. However, the presence of oil seeps suggests that some intervals are poorly sealed. Geological structures such as rollover anticlines, unconformities, tilted faults, and gypsum-filled joints and fractures may also act as hydrocarbon traps.

In the study area, the Kasande clays may provide sealing capacity for the underlying Kisegi Formation. However, these clay units are not thick enough to serve as highly effective seal rocks. Shales associated with transgressive systems tracts can also act as seals for underlying lowstand systems tracts. The presence of oil seeps, such as the Kibuku oil seep, indicates that some sealing intervals are inadequate.

The high temperatures in the Semliki Basin, as shown by the presence of hot springs, may have supported the maturation of organic matter into hydrocarbons. Proper timing is important in a petroleum system because reservoir rocks, traps, and seals must form before hydrocarbon generation and migration begin. Although the Albertine Graben is among the youngest rift basins with Cenozoic sediments, it has high petroleum potential, with estimated recoverable reserves of about 1.4 billion barrels of crude oil. A high geothermal gradient is believed to have accelerated thermal maturity within a relatively short geological time.

7.4 EFFECT OF HIGH TEMPERATURE ON HYDROCARBONS

Elevated temperatures in the Semliki Basin, particularly around the Sempaya hot springs in the Buranga geothermal field, can strongly affect hydrocarbon maturation through hydrothermal heating. Temperatures at the Sempaya hot springs range between 95°C and 100°C. If rocks with low thermal conductivity are present, they may retain enough heat to promote hydrocarbon maturation. However, temperatures above the oil window range of about 60°C to 120°C may cause thermal cracking, converting oil into gaseous hydrocarbons such as methane and carbon dioxide. This process can produce hydrocarbons with higher API gravity. Excessive heat may also lead to coking, where hydrocarbons are altered into carbon or coke.

7.5 EFFECT OF STRUCTURES ON HYDROCARBONS

The Semliki Basin contains important geological structures such as faults, bedding planes, and joints, all of which influence hydrocarbon migration and accumulation. Faults and joints formed as a result of intense tectonic activity and represent secondary structures affecting the basin sediments. Faults may act as migration pathways, allowing hydrocarbons to move from source rocks into reservoir units and possibly to the surface as oil seeps. They may also form structural traps where they are juxtaposed against impermeable sealing rocks.

Similarly, joints within both basement rocks and sedimentary units can serve as conduits for hydrocarbon migration. Where these joints are filled with impermeable minerals such as gypsum or quartz, they may act as barriers or traps that restrict hydrocarbon movement. Unconformities within the sedimentary succession can also create stratigraphic traps, helping hydrocarbons to accumulate. A significant nonconformity occurs between the sedimentary rocks and the underlying basement rocks.

CHAPTER 8: CONCLUSION AND RECOMMENDATIONS

8.1 CONCLUSION

The Semliki Basin was formed through tectonic processes and has continued to undergo structural modification due to ongoing tectonic activity. These tectonic processes have strongly influenced the rocks and sediments within the area. They have also produced structural traps that may host hydrocarbons. Major faults extending from the basement into the overlying sedimentary units provide effective trapping mechanisms, while folding in both sedimentary and basement rocks may create anticlinal traps. Furthermore, the high geothermal gradient associated with tectonic activity explains the presence of mature source rocks in the Albertine Graben, despite the relatively young age of the sediments.

Facies analysis of the study area indicates the presence of lacustrine, fluvial, and marginal lacustrine or deltaic paleodepositional environments. The basement rocks show evidence of high-grade metamorphism, including migmatites, shearing, foliation, and foliated gneisses. Geophysical studies have also identified a major nonconformity at the boundary between the basement and the overlying sediments. This boundary is important for age dating and confirms the presence of young Miocene sediments.

In conclusion, the geology of the Semliki Basin is largely controlled by tectonism, which has greatly influenced the development of the petroleum system and its hydrocarbon potential. The basin contains the essential components required for petroleum accumulation and therefore has promising petroleum potential.

8.2 RECOMMENDATION

Field studies are very important because they allow students and lecturers to observe geological features directly and apply geological principles in real-world settings. Therefore, it is recommended that the department organize more field studies. In addition, seismic surveys of the basin should be included in field programs to improve participants' understanding of the subsurface geology, rather than relying only on outcrop observations.

The department should also improve its collaboration with oil and gas companies operating in Uganda. Such companies can support student fieldwork by providing funding, technical expertise, human resources, and logistical assistance.

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