MAKERERE UNIVERSITY

COLLEGE OF NATURAL SCIENCES

SCHOOL OF PHYSICAL SCIENCES

DEPARTMENT OF GEOLOGY AND PETROLEUM STUDIES

THE SEMLIKI BASIN FIELD STUDY PROJECT REPORT

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

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Submission Date: 13th June, 2026.

DECLARATION

I, **Kaweesi Paul,** hereby declare that this report is an original work and has never been submitted to any institution for any award.

Signed...

Date ....13th / June / 2026.......................................

THE PROJECT COORDINATOR, Dr Mutebi Denis

Signed...

Date....13th/June/2026..................................

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DEDICATION AND ACKNOWLEDGEMENT

I dedicate this work to the Almighty who through Him all things are possible. I also dedicate this work to my parents who continuously support me in all my endeavours, my lecturers for their selfless service to ensure that their students understand all the taught concepts and to all those who supported me along the journey.

My deep appreciation goes to the Department of Geology for organising this field trip to the Semliki basin thus availing an opportunity for the students to put classroom knowledge into practice.

I would also like to acknowledge the lecturers who accompanied us on this journey; Dr. Simon Echegu, Dr. Betty Nagudi, Dr. John Mary Kiberu and Dr. Mutebi Denis and the support for the guidance and support offered to us during the course of the trip and beyond. May the good Lord reward them abundantly!

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ABSTRACT

This study presents observations from a comprehensive field excursion conducted in the Semliki Basin, situated within the Albertine Graben of Western Uganda. The primary objective of the excursion was to gain a deeper understanding of the formation, sedimentary environment and petroleum potential of the basin. Throughout the fieldwork, various sites within the basin were studied, including locations such as Kichwamba, Kisegi hill quarry, Kisegi River, Kibuku road cut, and Sempaya hot springs. Through detailed fieldwork and data collection using GPS and geological tools, the students aimed to achieve several specific objectives. These objectives included identifying lithologies present in the Semliki basin, analyzing and correlating structural features observed within both the basement and sedimentary layers, assessing different elements of the petroleum system, and identifying various facies and depositional environments.

During the fieldwork, an extensive range of facies was logged and analyzed. These included fluvial, deltaic, and lacustrine sediments, all of which were significantly influenced by intensive tectonic activity within the basin. The sedimentary structures observed encompassed a diverse array, including cross-bedding, unconformities, faults and deformation bands. Of particular interest was the presence of hot springs within the area, indicating a notable geothermal gradient, which holds significant implications for source rock maturation and potential hydrocarbon generation. The integration of sedimentology, stratigraphy, and tectonics facilitated a comprehensive interpretation of the basin's geological history and provided valuable insights into its economic importance.

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

This report contains findings of a field study conducted in the Albertine Graben from June 31st, 2024, to July 10th, 2024, over the Kichwamba and Kibuku areas in the Semliki Basin to the south and east of the Lake Albert Basin. The field study is designed for students pursuing a Bachelor of Science in Petroleum Geoscience and Production who have completed their third year at the Department of Geology and Petroleum Studies, School of Physical Sciences, College of Natural Sciences, Makerere University. The fieldwork and excursion, conducted within the Albertine Basin, took place over 10 days from July 1st to July 10th (excluding travel days to and from the department). The focus areas for the study included Kichwamba, the Turaco wells, Sempaya hot springs, and the Semliki Basin. Throughout the field study, activities such as stratigraphic logging, geological analysis, and description were carried out, leading to interpretations of depositional environments and their history, paleo flow, basin and facies analysis, and other related concepts.

The study embraced some of the geological aspects including the East African Rift System, drainage and reversal, braided river environment, interpretation of petrophysical and geophysical data, depositional environments, and facies analysis.

1.2 STUDY AREA

1.2.1 Location

The study area, encompassing Kichwamba and the Semliki Basin, is located in the KarugutuNtoroko district of Southwestern Uganda. This region lies within the Albertine Graben, to the south and east of the Lake Albert Basin, and forms the northern part of the western arm of the East African Rift System (EARS). The Semliki Basin covers approximately 1,200 km², with 740 km² situated in the Ugandan portion of the Albertine Graben, and the remainder in the Democratic Republic of Congo. It is bordered to the southeast by the steep escarpments of the Rwenzori Mountains, to the north by Lake Albert, and to the west by the Lamia and Semliki rivers.

The Ugandan section of the Semliki Basin encompasses the southern part of the Lake Albert area and extends southward to the landward region south of the lake. This includes the eastern portion of the Semliki River floodplain and Lake Albert, referred to as the Semliki flats, as well as the nearby Toro plain an elevated escarpment area to the east of the floodplain. The region is bordered to the southeast by the steep escarpments of the Rwenzori Mountains, rising nearly 1,000 meters to the northernmost spur. The Toro plain's low-lying, undulating areas are separated from the

Semliki flats and the floodplains on the eastern banks of the Semliki River by the Kibuku and Makondo faults. The Semliki River forms the current border between Uganda and the Democratic Republic of Congo.

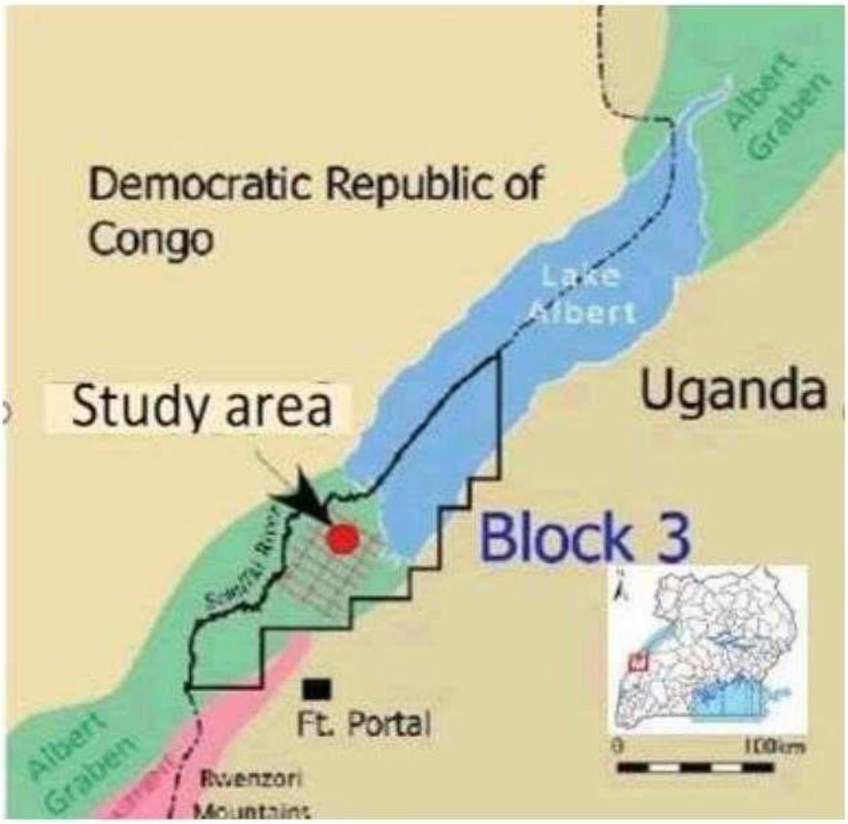


Figure 1: shows the location map of the semliki Basin (source, longdom org)

1.2.2 Accessibility

The area was accessed by road transport from Kampala to Ntoroko district using the KampalaMubende 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.

1.2.3 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.

The specific objectives include the following;

- 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 lithologies and the environment to identify different elements of a petroleum system.
- To identify the facies and depositional environments.

1.2.4 Geologic Setting of the Area

1.2.4.1 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).

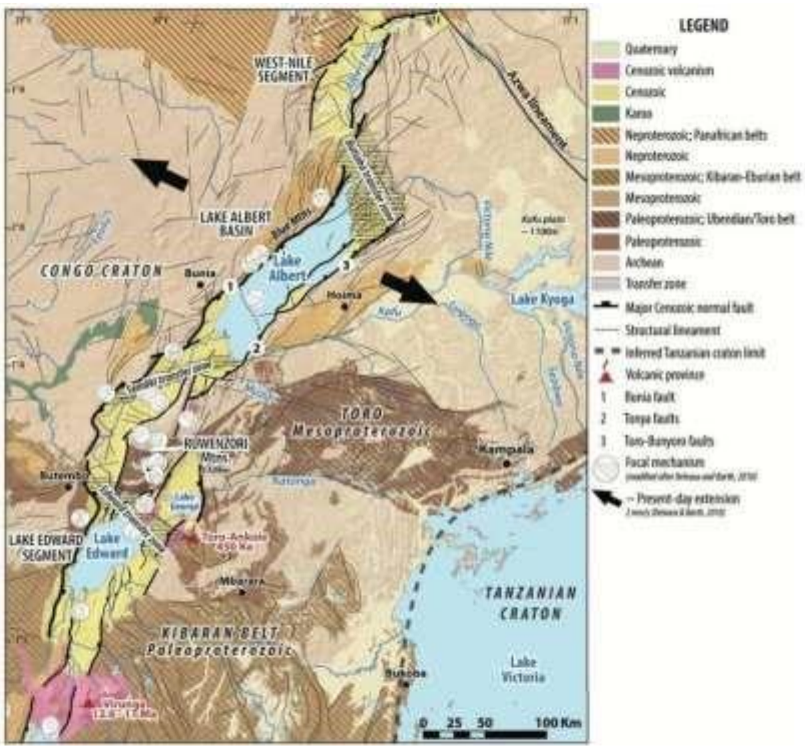


Figure 2: shows the Albertine Rift system. Geological and structure map of the Albertine Rift system from the Azwa lineament to the Virunga volcanic provice

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 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). Based on 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.

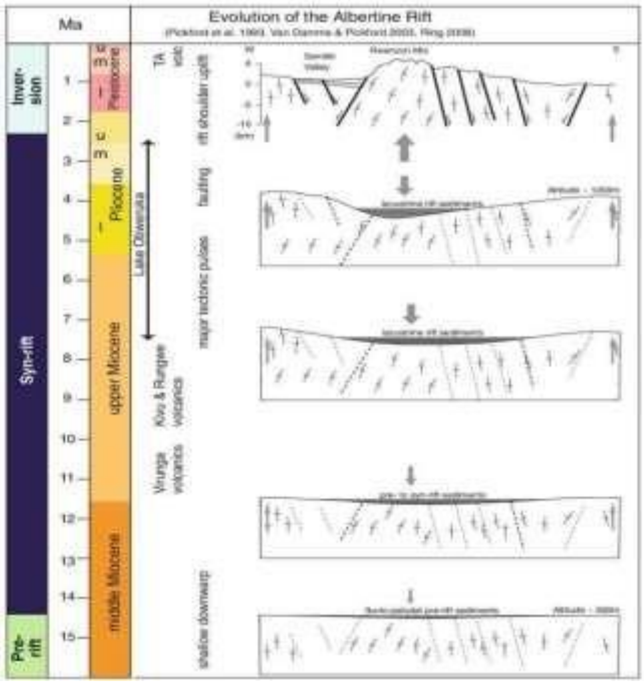


Figure 3:shows : Schematic evolution of the Albertine Rift Basin with major phases of tectonic and volcanic activity and indicated sedimentary evolution (modified after Pickford et al. 1993;

Van Damme and Pickford 2003; Ring 2008)

1.2.4.2 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.

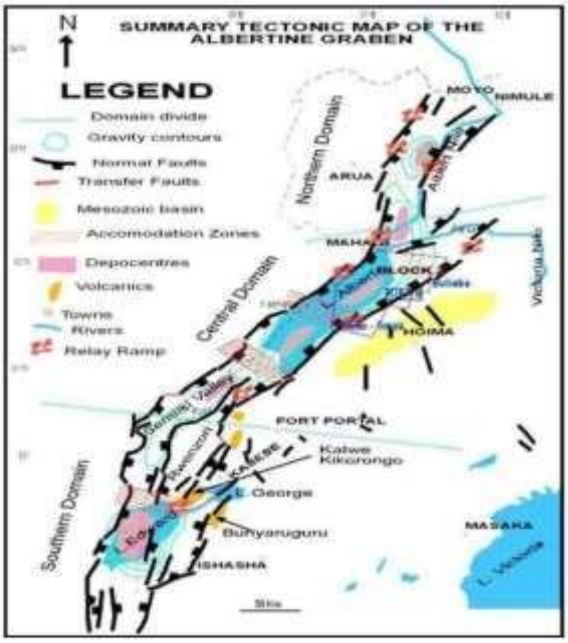


Figure 4: shows :Map showing the structural elements in the Albertine Graben (Dozith, 2012)

1.2.4.3 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. Several 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 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 PreCambrian 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).

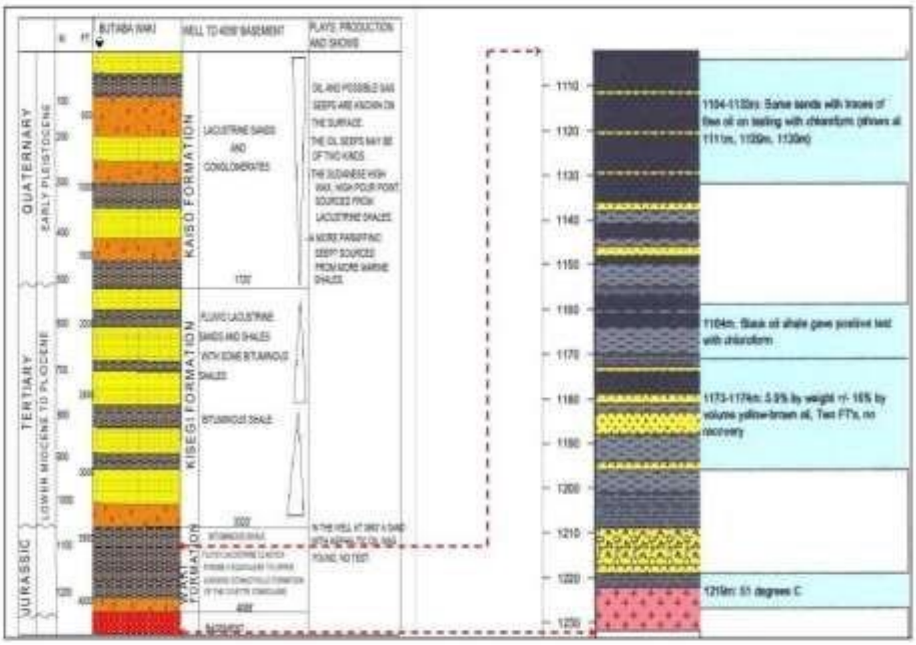
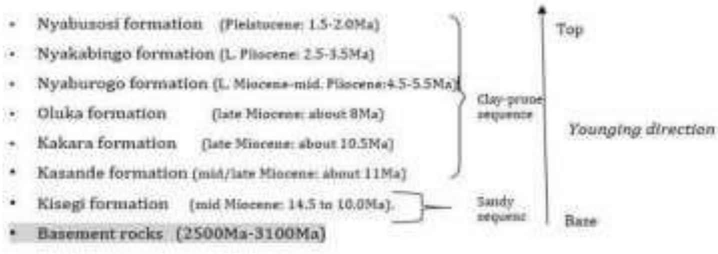


Figure 5: shows A section through the Waki-1B well demonstrating the stratigraphy of the Albertine Graben

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).



1.2.4.4 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. The 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 prerift 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.

1.2.4.5 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 km2 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 Southeast by a steep fault escarpment rising almost 1,000 m to this spur. It is also bordered on its western side by two major faults namely, the NNE- SSW trending Semliki fault and the NE-SW trending Bunya faults (Figure 7). These two separate the Congo escarpment and the basin.

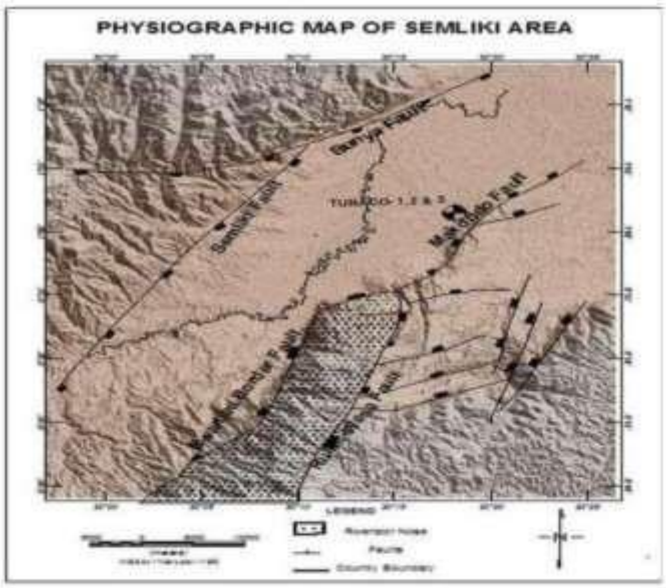


Figure 6: shows The physiography of the Semliki Basin

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 faultbounded 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 7: shows Topography of the Semliki plain cross section from East to West (Source; PEPD, 1995)

CHAPTER TWO: MATERIALS AND METHODS

In this chapter, the utilization of various equipment and materials, as outlined below, is detailed concerning their application in the field to accomplish diverse objectives. These objectives range from measuring bedding thickness and structural trends to gauging grain sizes and conducting facies analysis. The chapter elucidates the methodologies employed to achieve these aims, including the treatment of collected data.

Furthermore, the chapter provides insights into a visit to the Sempaya hot springs within the Albertine Graben, undertaken to investigate the potential influence of temperatures on hydrocarbon occurrence within the rift. This trip offers valuable information regarding the geological phenomena associated with thermal activity in the region and its potential implications for hydrocarbon exploration and development.

2.1 Materials

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 8:shows 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 9:shows 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 10: shows 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 11: shows 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 12: shows Spade and hoe

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

Figure 13: shows 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.

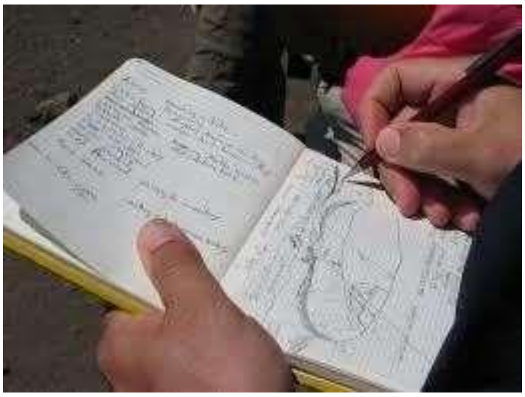


Figure 14: field notebook

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

Figure 16: shows 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

2.2.1 Desk study

The desk study phase involved a thorough examination of all available literature and geological maps pertaining to the Albertine area and the Semliki basin. This comprehensive review aimed to provide an overview of the study area and familiarize the team with the materials and equipment to be used during the field study.

2.2.2 Structural measurements

During structural measurements, various structural features encountered in the field were carefully measured. Using a geologic compass, the team determined the dip and strike of structures such as joints, bedding, faults, and foliations, employing the right-hand rule. Additionally, parameters like bed thickness were measured using a Jacob's staff and tape measure. Detailed structural measurements obtained during this phase are provided in the Appendix.

2.2.3 Outcrop rock description

Rock descriptions were conducted to macroscopically characterize the properties of encountered rocks using the naked eye and a hand lens. Key properties described included rock name, grain size, colour, minerals present, and structural features.

2.2.4 Lithostratigraphic logging

Lithostratigraphic logging was performed systematically from bottom to top on fresh rock exposures. Contacts between different lithologies were identified based on variations in colour, grain size, structural orientation, and bed thickness. This information was used to construct sedimentary logs in the field using graph paper and Sedlog software to generate large-scale stratigraphic logs. These logs were then analysed and interpreted to extract valuable insights regarding the environment of deposition, sediment flow direction, and rock grading.

The logging procedure involved several steps:

- Cleaning the outcrops using a hoe to remove any vegetation or obstructions.
- Measuring the vertical thickness of the outcrop using a tape measure or Jacob's staff.
- Describing the outcrops based on sediment layers and rock properties.
- Using erosional contacts at the base of the log if the basement was not visible or clear.
- Constructing lithostratigraphic logs on graph paper, indicating structures and lithologies.

- Analyzing the logs to interpret the depositional environment and other rock properties to differentiate between rock types.

2.2.5 Determination of grain size and shape

During the determination of grain size and shape, observations were made on the clasts using a hand lens to estimate parameters such as sphericity, roundness, sorting, and cementation. These observations were conducted at exposures, road cuts, and outcrops to gain insights into the type of depositional environment and the prevailing conditions during deposition. The roundness and sphericity of the grains were particularly useful in identifying the type of transporting agent and estimating transportation distance. Additionally, they provided valuable information about sediment maturity, which is crucial for evaluating petroleum potential.

Grain size analysis revealed a range from very coarse sand to very fine sand. This analysis was facilitated using a grain size scale, allowing for the characterization of sediment grading within beds. Determining whether sediment coarsened upward or downward provided important clues about the deposition environment and the energy of the deposition agent.

2.2.6 Determination of paleocurrent flow direction

The determination of paleocurrent flow direction involved analyzing sedimentary structures such as cross-stratification, pebble imbrications, and current ripples. These structures provide valuable clues about the direction of ancient currents that deposited the sediments.

In particular, the dip direction of angular and tabular cross beds observed in sand layers was used to infer the paleocurrent direction of sediment transport. By examining the orientation of these sedimentary features, researchers were able to deduce the direction in which the sediments were transported by ancient currents.

Additionally, the asymmetrical nature of most observed ripples in flood plains provided further evidence. The shorter, steeper side of these ripples typically points downstream, aligning with the direction of flow of the currents responsible for their formation.

2.2.7 Interpretation of the depositional environment

The interpretation of the depositional environment relied on several key factors observed in the sedimentary rocks. These factors included the presence of specific minerals, grading within beds, grain sorting, and the types of structures present in the rocks.

For instance, the presence of minerals like gypsum, which had precipitated within joints found in sands and clays at the Kibuku road cut exposure, suggested phases of semi-aridity in the deposition environment. Variations in bed thicknesses across sediments indicated fluctuations in depositional conditions, potentially reflecting shifts between fluvial and lacustrine environments.

Furthermore, the grading observed within sedimentary beds provided valuable clues. Normal grading, where coarser sediments settle out faster than finer sediments, is characteristic of environments such as fluvial or lacustrine settings. Similarly, the presence of very fine-grained and well-sorted sandstones and clays suggested deposition in calm lacustrine environments.

2.2.8 Degree of metamorphism

In addition to interpreting depositional environments, the degree of metamorphism in basement rocks was analyzed. This analysis involved studying the foliation trends, which represent the planar orientation of minerals within the rocks. The direction of foliation provides insights into the direction of stress or pressure during metamorphism. For example, the presence of gneisses indicated high-grade metamorphism, while contact metamorphism was observed around intrusive rocks. Understanding the degree of metamorphism helped elucidate the distribution of rock types, mineral composition, and texture, thereby providing insights into the diagenetic history of the rocks.

CHAPTER THREE: LITHOLOGY AND STRATIGRAPHY

3.1. LITHOLOGY

The Semliki Basin's lithology comprises both basement rocks and sedimentary deposits. The basement lithology includes high-grade metamorphic rocks such as gneisses, indicative of significant tectonic and metamorphic activity. Overlying these basement rocks are sedimentary layers from the Miocene to recent periods, characterized by formations like Kisegi, Kasande, Kakara, Oluka, Nyaburongo, Nyakabingo, and Nyabusosi. These sediments are predominantly composed of conglomerates, sandstones, clays, and fine-grained lacustrine deposits, reflecting various depositional environments from fluvial to lacustrine settings. The sedimentary succession shows well-preserved fossiliferous layers, pointing to rich paleoenvironments and varied sedimentation conditions over time.

3.1.1 Basement lithology

The basement lithology of the Semliki Basin consists of rocks that belong to the Buganda-Toro system and is primarily composed of high-grade metamorphic rocks, such as gneisses, amphibolites, and quartzites, which reflect extensive tectonic and metamorphic processes. These basement rocks date back to the Proterozoic era and exhibit characteristics typical of deep crustal formation and deformation. The gneisses are often foliated, indicating significant directional stress, while other rocks show pronounced schistosity due to the alignment of platy minerals. Quartzites, formed from metamorphosed sandstones, are also present, showcasing the high temperatures and pressures during their formation. These ancient rocks, sometimes intruded by granitic bodies, form the foundational bedrock upon which younger sedimentary layers have been deposited, influencing the structural and geological framework of the Semliki Basin.

. Migmatite

The migmatite was located at Itojo (0191057,0094333 Elevation-1044m). It exhibits both solidstate and partial melting characteristics. Migmatites are associated to high-temperature metamorphic environments and commonly found in regions that have experienced intense geological processes such as mountain building or tectonic activity. The migmatite forms through the metamorphism of granites to form granite gneiss and subsequent partial melting. Therefore, migmatites have both metamorphic and igneous characteristics. The light-colored minerals, primarily quartz, melted first and make up the igneous component, while the dark minerals, with a schistose texture, represent the metamorphic component. The migmatite is characterized by folds, which are explained in the structures chapter.

Figure 17:shows showing migmatite

- **Amphibolites**

The amphibolite in the Semliki Basin is present as mafic intrusions with a dark grey to black colour. These rocks have a mineralogic composition that includes amphiboles, plagioclase, pyroxenes, and minor amounts of biotite and quartz. The outcrops are highly jointed and exhibit a porphyroblastic texture, with grain sizes ranging from fine to medium. The amphibolite originated from the metamorphism of diorite (dolerite dykes) that intruded the granite gneiss. The intrusion along lines of weakness caused shearing and foliation of the granite. Prominent foliation and brecciation of quartz veins are also observed in the amphibolites. A significant amphibolite intrusion was noted at a road cut exposure (coordinates: 1869069, 79373/1616m).

The contact between the basement rocks and the amphibolite intrusion is sharp, indicating that the intruding magma cooled rapidly, thus having minimal thermal impact on the surrounding basement rocks.

- **Granite gneisses**

Figure 18: showing a large highly jointed granite gneiss outcrop.

Granite gneisses are the most abundant rock type in the basement of the Semliki Basin, covering over 90% of the basement lithology. These rocks are primarily exposed in artificial outcrops created by human excavation during road construction, particularly along the northern nose of the Rwenzori Mountains (At Kichwamba; 0186953,0079664 Elevation-1604m) at an elevation of 670m. The granite gneisses are generally white-grey in colour, fine to mediumgrained, and composed of K- feldspars, quartz, and biotite minerals. Originating from granite, these rocks exhibit highgrade metamorphism, evidenced by the banding and foliation of minerals. The g n e i s s e s a r e h e a v i l y fractured, with some joints filled with quartz minerals from hydrothermal fluids during various tectonic episodes. The joints and foliations predominantly trend in the Northwest-Southeast direction, with joints dipping towards the Northeast. These granitic gneisses are highly jointed and fractured, making them potential reservoirs as the joints and fractures can serve as migration conduits for hydrocarbons.

- **Granites**

The granites found in the region exhibited characteristics of being massive, displaying colours ranging from pink to grey, with weathered sections appearing brown to grey due to the conversion of the feldspars to clay minerals. These granites were typically medium to coarse-grained and composed predominantly of K-feldspars, quartz, biotite, and muscovite minerals. However, the minerals within these granites appeared altered, likely due to the effects of active faulting and weathering in the area. The outcrops displayed extensive jointing and fracturing, indicative of significant geological activity and tectonic forces shaping the landscape.

3.1.2. Lithology and Stratigraphy of the sediments

Based on the colour and mineralogical characteristics of the sediments observed in the Semliki Basin, along with the geographical location of the basin, it is likely that the basement rocks in the Rwenzori Mountains and the surrounding escarpments serve as the primary source of these sediments. Given that the uplift of the mountains occurred more recently than the onset of rifting, it is plausible that the sediments originated from sources such as Lake Obweruka, which is present-day Lake Albert. These sediments were likely transported by rivers flowing from the mountains toward the basin, where they were subsequently deposited. The sedimentary deposits, which include sandstones, clays, silts, and conglomerates, overlay the basement rocks and are indicative of fluvial and lacustrine environments within the basin.

- **Sandstones**

Sandstones are the predominant sedimentary deposits in the Semliki Basin, exhibiting a wide range of sizes from very fine to very coarse grains. These sandstones typically overlie basal conglomerates and display colours varying from pale yellow to reddish brown. The yellow hue of the sands is attributed to iron oxide presence, a result of deposition in shallow water sub-aerial environments. The sandstones demonstrate variable sorting, ranging from well-sorted to poorly sorted, and extend laterally over significant distances with varying thicknesses, often intercalated with clay beds, conglomerates, and gypsum layers. Matrix-supported, the sandstones are cemented by reddish-brown iron minerals, forming laminations within some layers. Grain shapes vary from sub-angular to sub-rounded, with consolidation ranging from well to medium to loosely compacted. Predominant minerals include quartz, iron (III) oxides, clay minerals, and gypsum. The uniform size grading of many sand layers suggests deposition by a fluvial system, where different energy levels lead to the deposition of various grain sizes. Additionally, some layers exhibit fining-upward sequences, indicating fluctuations in energy levels. Conversely, coarsening-upward sand layers suggest changes in climate, variations in current energy, and seasonal shifts. Various structures observed within the sandstones include cross beds, laminations, tabular beds, joints, and gypsum-filled veins, highlighting the dynamic depositional environment. These sandstones possess qualities conducive to serving as reservoir rocks, with good sorting and less consolidation enhancing porosity and permeability, making them promising targets for hydrocarbon exploration.

Figure 19: showing a sandstone outcrop in the field.

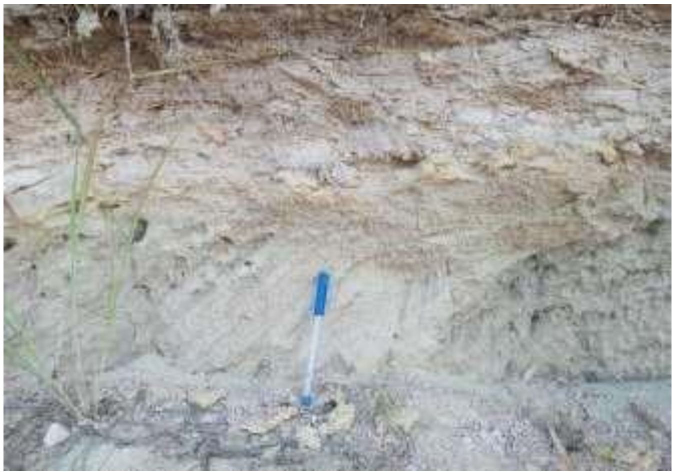
- **Conglomerates**

These conglomerates are characterized by poor sorting and a coarse-grained nature, composed of cobble and pebble-size particles ranging from 5-35mm in diameter, cemented with fine to coarse-grained sands. Their colours vary due to the presence of iron-rich minerals, and the beds exhibit discontinuous patterns with varying thicknesses. Small-scale conglomerate layers are often interspersed within sandstone and clay layers, indicating fluctuations in depositional conditions. Primarily matrix-supported by fine yellow sand, the conglomerates consist of angular to sub-angular grains of varying sizes and colours. The sub-angular nature of the cobbles and pebbles suggests relatively short transportation distances by the transporting agents. The clasts within the conglomerates predominantly comprise gneisses and quartzites, likely originating from the basement rocks.

Figure 20:showing a conglomerate exposure in the field.

- **Clay sediments**

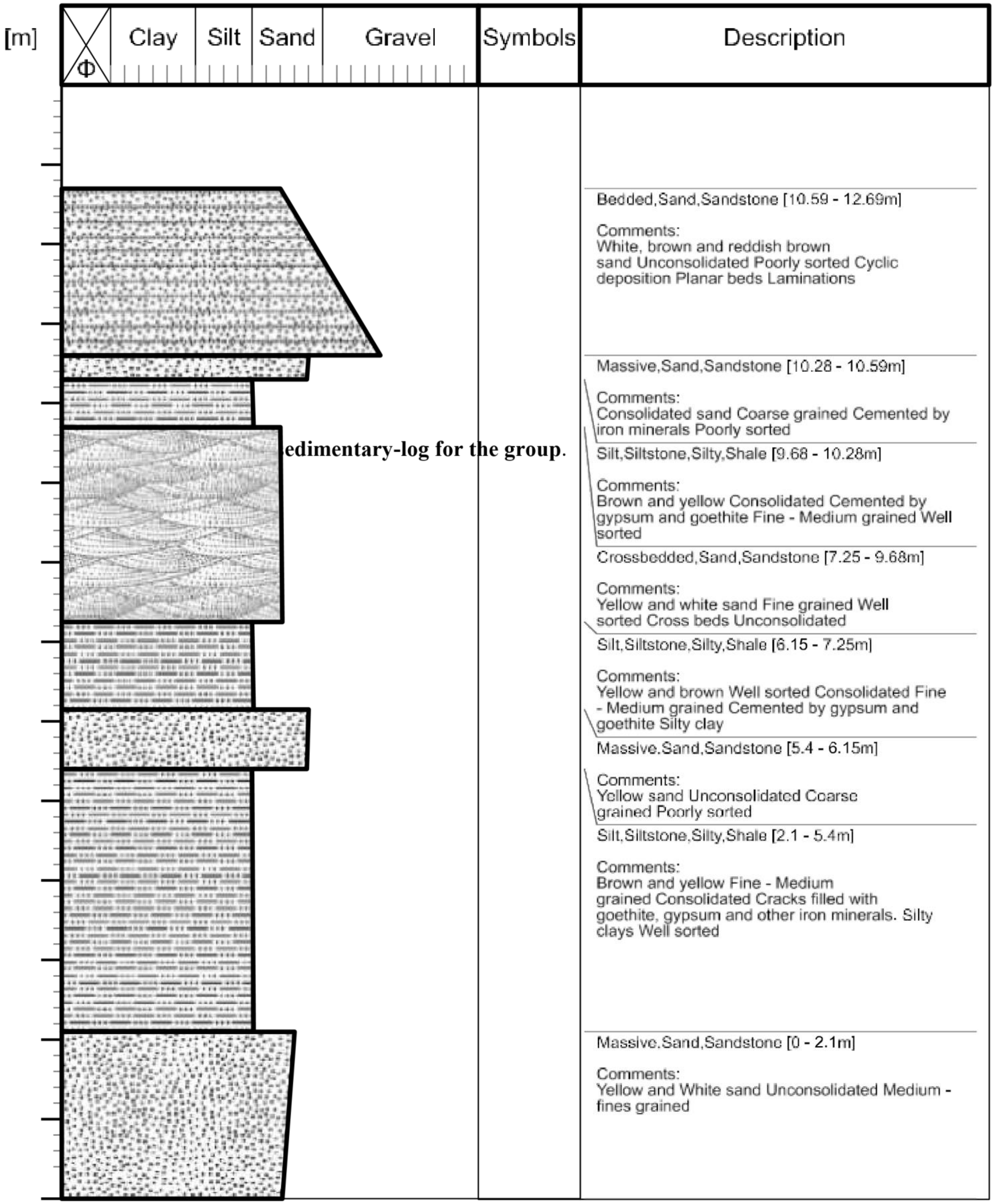
Clays are very fine grained sediment that exist in various colours. The clays observed in the area are mainly grey in colour and some are reddish brown. Some reddish brown clays are characterized by the presence of organic matter with potential to reach maturity and generate hydrocarbons. Thickness ranged from a few centimetres to tens of centimetres (about 5-20cm) but less thicker than the sands. Most of the clay layers encountered are found in intercalation with sand beds. This is due to cyclic deposition, owing to changes in climate patterns. Clays could have been deposited during periods of transgression when the waters were calm, whereas sands could have been deposited during periods of regression by high energy and dynamic waters. Clays could have also been deposited during periods of flooding when the rivers overflowed their banks, deposited silts and clays. Most of the clays are discontinuous and some clays are seen to terminate with in the sand beds. There were some occurrences of gypsum sheets within clay beds, which could possibly have resulted from precipitation of calcium sulphate-rich waters.



Silt.

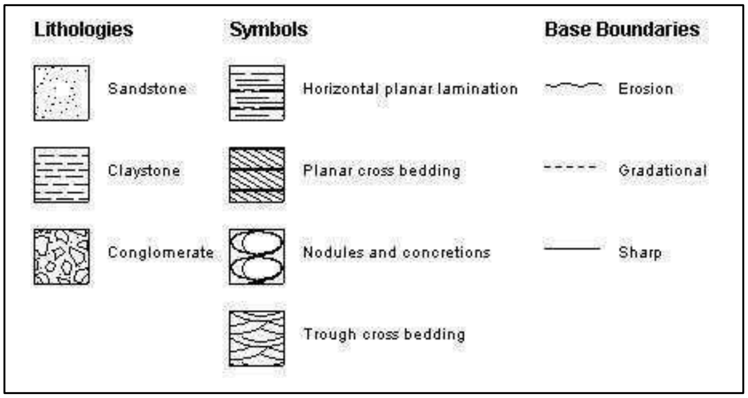
These are fine-grained sediments that appeared grey to white, with some yellow due to iron (III) oxide coating. They were well sorted and fine-grained, with thin, continuous beds showing low scale cyclicity.

Figure 21: Showing Siltstones in the Semliki basin along the Kibuku road cut



edimentary-log for the group.

Legend.



3.3.1. Description of the Layers.

Layer 1 (Bottom): It is 2.1m thick, with grey to light yellow color. It is massive, well sorted, compacted and moderately hard. Sand grains are sub rounded. There occurs laminations probably due to the calm environment during the time of deposition.

Layer 2: It is 3.3m thick with coarse grains. Some brown color is evident due to the presence of iron minerals from oxidation weathering. It is well sorted with angular grains. Laminations occur probably due to a calm environment of deposition in the past. Cracks filled with geothite, gypsum and other iron minerals

Layer 3: It is 0.75m thick with medium sand grains. Ripples are evident. There occurs a brown colour probably due to iron minerals present. It is soft and well sorted.

Layer 4: It is 1.1m thick with fine sand that is compacted and hard. Ripples are present and well sorted sub rounded grains. The colour is grey to yellow with moderate weathering. The grains are cemented with gypsum and there occurs trough stratification.

Layer 5: It is 2.43m thick Clay dried forming cracks where the gypsum got precipitated. The grains are fine, well sorted and rounded. It is compacted and hard with a grey to brown colour.

Layer 6: it’s 0.6m thick sandstone with crossbedding.

Layer 7: It is 0.31m thick, with very coarse sand grains that are angular and poorly sorted. laminations are present in this layer.

Layer 8: it is a 2.1m thick, bedded sandstone with cyclic deposition, planar beds lamination.

3.4. Stratigraphy of the Sediments.

The Semliki basin consists of basement rocks and sedimentary deposits. Basement rocks include high-grade metamorphic rocks, gneisses, reflecting intense tectonic and metamorphic activities. Over this basement are deposited Miocene to Recent sedimentary formations such as Kisegi, Kasande, Kakara, Oluka, Nyaburongo, Nyakabingo, and Nyabusosi formations.

- The Kisegi Formation, identified by Pickford et al. in the Semliki area along the Kisegi River, consists of basal conglomerates overlying the crystalline basement. These conglomerates transition into thick, channeled, and cross-bedded sandstones with thin interbeds of tuff, reflecting dynamic depositional processes.
- The Kasande Formation, which overlies the Kisegi Formation, is characterized by dark brown to yellow-brown mudstones interbedded with yellow sandstones. It also includes grey to dark grey claystones and mudstones, reflecting a varied sedimentary composition (Joshua Lukaye, 2016).
- The Kakara Formation, defined by Pickford et al., consists mainly of clays and silts with ironstones and is typically observed in road cuts, though often dominated by sand. The contact with the underlying Kasande Formation is not visible in outcrops but is believed to be marked by the initial appearance of ironstones or ferruginous sandstones in the sequence.
- The Oruka Formation, exposed between the Nyaburongo and Kisegi rivers, begins with dark shales overlying a widespread conglomeratic ironstone containing large rounded quartz pebbles. It serves as a secondary reservoir and includes interbedded claystone, shales, siltstone, and sandstone.
- The Nyaburogo Formation is best observed in new road cut exposures, where basal shales rest on a faulted and eroded surface of the upper Oruka Formation, forming a micro-graben structure. Outcrops reveal thick claystone sequences interbedded with rusty brown to yellow-brown siltstones, pisolitic ironstones, and paleosols.
- The Nyakabingo Formation begins with a lacustrine shale base and features light grey to greenish-grey claystone, iron-stained siltstone, pebbly and coarse sandstones, and carbonate nodules. The overlying Nyabusosi Formation, seen near the Makondo Fault Zone, lacks a clear boundary with Nyakabingo and consists of alternating clays and silts throughout its exposures.

Conglomerates, sandstones, clays, and fine-grained lacustrine material make up the majority of these sediments, suggesting a wide range of distinct depositional settings from fluvial to lacustrine. Excellent preservation of the fossil-bearing units in the sedimentary succession is another sign of active paleoenvironments and changing sedimentation conditions over time.

The basement rocks in the Rwenzori Mountains and the nearby escarpments are probably the main source of the sediments found in the Semliki Basin, based on the color and mineralogical features of the sediments found there as well as the basin's position. The sediments may have come from places like Lake Obweruka, which is now Lake Albert, as the uplift of the highlands happened more recently than the start of rifting. Rivers from the highlands most likely carried these sediments to the basin, where they were deposited. The sedimentary deposits, which cover the basement rocks and are representative of the basin's lacustrine and riverine habitats, comprise sandstones, clays, and silts.

CHAPTER 4. BASIN AND FACIES ANALYSIS

Basin analysis is a geological technique that focuses on analyzing sediment fill to determine the basin's history, including facies, sedimentation processes, and sediment origin. Different forms of sediment deposition are indicated by sedimentary facies, which are visibly distinct types of sedimentary deposits. The study of sedimentary deposits to understand the depositional settings and processes that created them is known as facies analysis. Geologists can deduce historical conditions, sedimentation processes, and basin evolution by analyzing the physical, chemical, and biological properties of sedimentary rocks, such as grain size, composition, and sedimentary formations. In order to comprehend reservoir potential in petroleum exploration, this approach aids in forecasting the distribution and geometry of sedimentary rock bodies.

4.1. Integration of basin analysis concepts in interpretation of Semliki sedimentary basin

Long-term subsidence areas that provide room for sediment infill are known as sedimentary basins. In essence, basin analysis entails examining sediment fill to uncover the basin's past (sediment provenance, sedimentation processes, and facies).

4.1.1. Formation of the Semliki Basin.

The Semliki sedimentary basin is a single stretch of the half-graben rift, a geological formation with a fault on one side. A depressed block of land surrounded by parallel faults is known as a complete graben. Intracontinental rifting, which is reliant on strong heat flow and results in expansion, upward arching, and extension, is what created the Semliki sedimentary basin (McConnell, 1972). Passive and active rifting are the two types of rifting. The continental lithosphere fails due to tensional forces during passive rifting, allowing heated mantle rocks to enter the lithosphere. Volcanic activity and crustal dooming are merely incidental phenomena. Hence the resulting basin geometry, rates of subsidence or uplift, sedimentation and erosion, magmatism, etc. are surface expressions of processes operating at crustal and mantle levels. On the other hand, active rifting is linked to a thermal plume or sheet impinging on the base of the lithosphere. The lithosphere may thin due to conventional heating, heat transfer from magma production, or conductive heating from the mantle plume. Isostatic uplift results from relatively quick thinning of the continental lithosphere if heat fluxes from the asthenosphere are significant enough. Rifting may then be encouraged by tensional strains brought on by the uplift. The thinning lithosphere is severely fractured by the upwelling of the hot asthenospheric material, which is indicative of the presence of geysers, fumaroles, and hotsprings, such as Sempaya hotsprings.

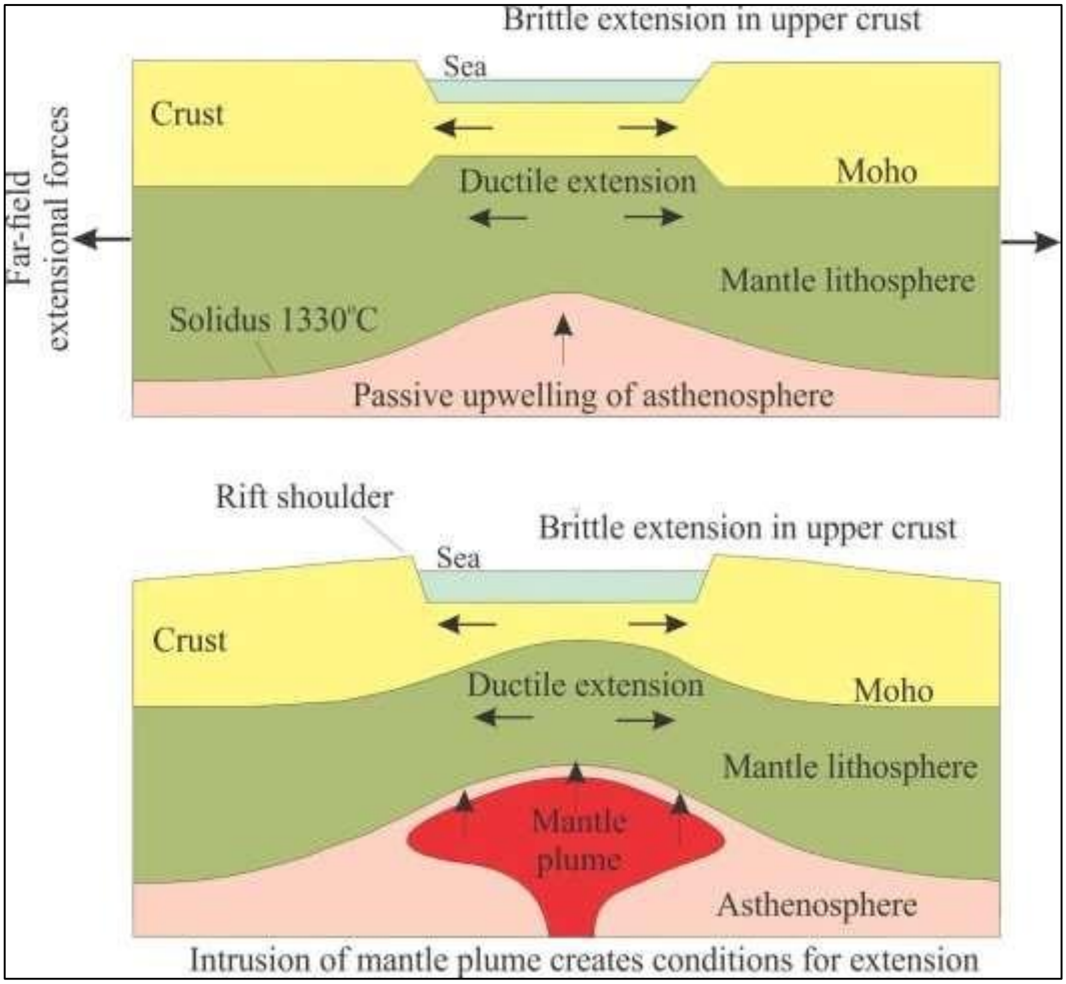


Figure 22: showing Passive rifting where mantle passively upwells in (isostatic) response to crustal stretching and thinning; Active rifting where the stretching is a consequence of a rising mantle plume. Modified from Allen and Allen, 2005

4.1.2. Basin Structure.

Structurally, the Semliki basin is a wedge-shaped (half graben) basin that is mostly composed of deposits from lacustrine, deltaic, and riverine sedimentary processes. Lithology and structures have been used to predict basin geometry. While reservoirs in shallow lacustrine and flexural sections as well as deep lacustrine zones formed sub-lacustrine sands or turbidites encased in mudstones or clays, source rocks primarily developed during the synrift in deeper portions. There may be deep sublacustrine "turbidite" sands among the fluvial-deltaic sediments directly on top of the basement.

Numerous pinch outs into deltaic sandstone formation (later cut by faults on the right side) and partially into lacustrine mudstone/clays may be seen in alluvial fan deposits deposited up to about 6 km. The lower most sediments immediately above the nonconformity are fluvialdeltaic. The basin fill is dominated by lacustrine mudstones/clays interbedded with fluvialdeltaic 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).

4.1.3. Basin Stratigraphy.

The Semliki Basin, part of the Albertine Graben in western Uganda, features a 3–6 km thick sequence of Cenozoic fluvial, deltaic, and lacustrine sediments. These rocks overlie Precambrian crystalline basement and are dominated by alternating sandstones, shales, silts, and clays. The basin contains seven major lithostratigraphic formations. The sedimentary fill of the Semliki Basin spans from the Paleogene or Early Miocene to the Pleistocene, generally divided into the following formations from oldest to youngest.

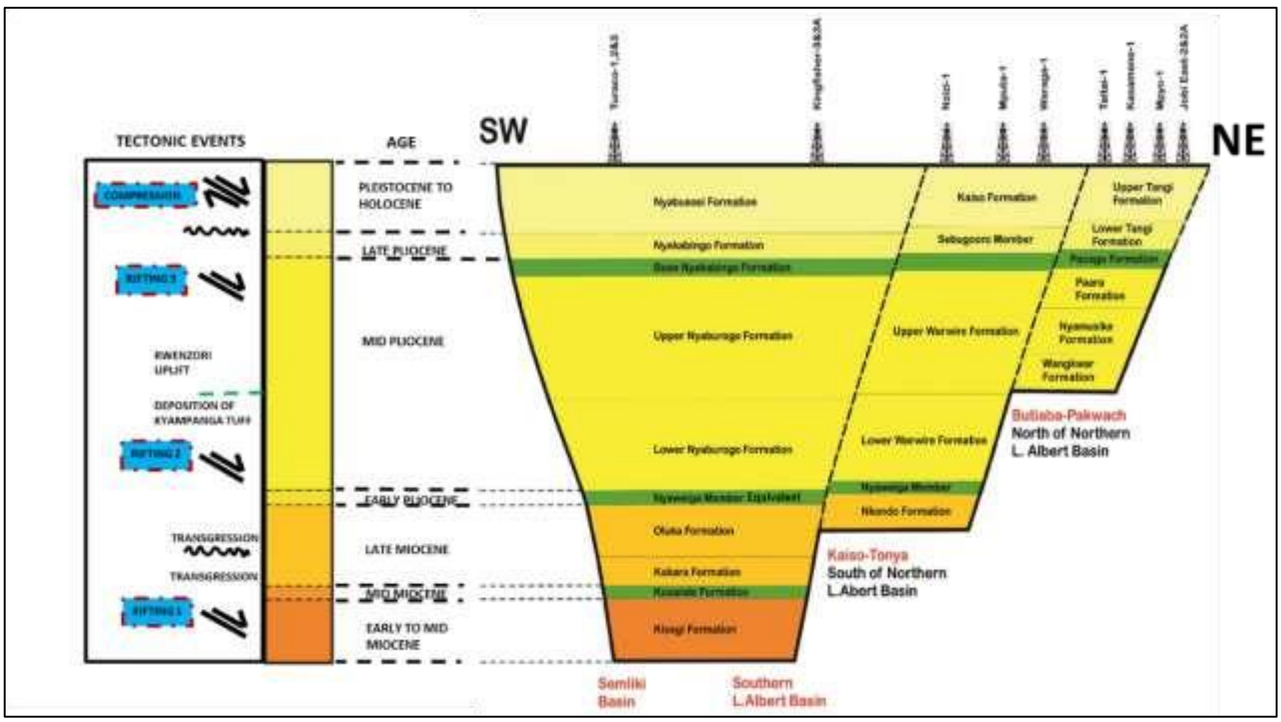


Figure 23: showing the Semliki basin and the tectonic events that influenced its development

Kisegi Formation.

The Kisegi Formation is considered the oldest formation in the Semliki Basin, lying directly on the basement complex of granite gneisses and Buganda-Toro metaquartzite. This contact is marked by a basal polymictic conglomerate. The basal conglomerates near the Kibuku seep transition into thick, friable, yellow, well-sorted, medium to fine-grained sandstone, comprising intercalations of conglomerates and low-angle cross-bedded sands. Gypsum veins and thin interbeds are common throughout the exposure. The upper part of this formation includes a cyclic sequence of sands and clays, suggesting formation in a combination of fluvial, deltaic, and lacustrine systems. The presence of gypsum and yellow sands indicates a semi-arid paleoenvironment with significant evaporation and oxidation. Hydrocarbon seeps in surface exposures of the basal stratotype at Kibuku show sandstones impregnated with waxy oil, likely due to a lacustrine source or biodegradation. The Kisegi Formation is estimated to be around 110m thick in its type section but much less than the 300m suggested by earlier studies.

Kasande Formation.

This formation, which serves as the source rock and seal and is situated above the Kisegi Formation, was given an informal name in 2002 by Heritage Oil & Gas plc in honor of Mr. Robert Kasande. It is distinguished by channelized sandstones that can be several meters thick and dark brown to yellowish-brown mudstones. The upper portion of the unit has thin black coaly shales. A transition from lacustrine to wet delta plain with fluvially produced marsh or swamp flora is indicated by the grey, dark grey, to reddish-brown claystones and mudstones found in these sections. The Formation has an estimated large lateral extension in the deeper western subsurface of Lake Albert and is 31 m thick in exposures and 115 m thick in the Turaco-3 well. The formation is characterized by thick clay and channelized sand sequences, which point to lacustrine conditions.

Kakara Formation.

Overlying the Kasande Formation is the Kakara Formation, which Pickford et al. (1993) examined and named. It is composed of sand-matrix conglomerates, brown to red pebbly and muddy sandstones interbedded with grey soft silty claystones, and intercalations of unconsolidated, yellowish-brown, poorly sorted, medium to coarse-grained sandstone. The formation was mostly deposited on a coastal plain, but neighboring channels' crevasse splay added coarse-ferruginous sandstones. The initial formation of ferruginous sandstones is thought to indicate interaction with the Kasande Formation. In Turaco-3, the Kakara Formation is 542 m thick, and irregular gammaray responses indicate shallowing upward sequences and coarsening. Exposures reveal a part that is primarily composed of sand, which is not typical of the formation in any other way.

Oluka Formation.

Named after Mr. John Oluka, this formation's base is exposed on the ridge between the Nyaburogo and Kisegi rivers. It consists of dark shales overlying well-developed widespread conglomeratic ironstone with large smooth, rounded quartz pebbles. The basal hypostratotype in the Turaco-3 well is defined by a thick shale unit marked by a rapid increase in gamma-ray and corresponding changes in SP, porosity, density, and sonic log responses. The formation comprises interbedded claystones, shales, siltstones, and sandstones. The formation is over 390 m thick in Turaco-3 and about 50 m thick in exposures, with a suggested age close to 7-8 Ma (Late Miocene).

Nyaburogo Formation.

Named after exposures in the Nyaburogo River valley, this formation consists of thick sequences of claystones with rusty brown to yellowish siltstones, pisolitic ironstones, paleosols, and fining upward sandstones at the top. The formation indicates deposition in regimes of humid tropical climates. It consists of a lower arenaceous sequence with stacked fluvial-channel sandstones that fine upwards into more clayey sequences. The Nyaburugo Formation's stratotype is proposed in the Turaco-1 well at an apparent log break at 1,492 m.

Nyakabingo Formation.

Named after exposures in the Nyakabingo river valley, this formation's type section is defined in the Turaco-1 well and is 207 m thick. It consists of repetitive coarsening-upward cycles, with exposures showing light grey to light greenish-grey claystones, iron-stained siltstones, pebbly and coarse sands/sandstones, and carbonate nodules. The formation indicates late Pliocene age in outcrops based on mollusc associations, suggesting flood plain and/or lagoonal deposition.

Nyabusosi Formation.

This formation, which was initially called by Pickford et al. (1993) after locations in the Nyabusosi river valley, is mostly composed of alternating silts and clays interspersed with characteristic ironstone horizons. It is composed of the ironstone-free Makondo member at the base, the ironstone-covered Behanga member on top, and the ironstone-free Kagusa member at the summit. With coastal to near-shore lacustrine deposition conditions and notable lake-level variations, the formation is thought to be late Pleistocene in age.

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

In essence, facies are rock entities that can be distinguished from one another by certain observable traits, such as their general appearance and their textural, structural, and compositional qualities. These differences result from the various conditions that exist throughout the creation, transportation, and deposition of sediment. Fossil material (biofacies) or lithology (***lithofacies***) can be used to classify sedimentary facies. Whereas ***biofacies*** are distinguished by their fossil richness, lithofacies are defined by petrological features such grain size, mineralogy, and sedimentary architecture. By connecting historical rock formations to current depositional conditions, facies analysis enables geologists to create depositional models for ancient rocks. A particular area of the earth's surface where sediments build up under particular physical, chemical, and biological circumstances is known as a depositional habitat.

Both clastic and non-clastic sediments that were generated in a range of environments, such as lacustrine, deltaic, and fluvial settings, dominate the Semliki Basin's depositional framework. Situated in the western arm of the vast East African Rift System, the basin is an intricate geological formation. It is a rift basin with a half-graben structure, where a fault borders one side. Conglomerates, sandstones, siltstones, mudstones, and clay are among the several lithologies seen during the logging operation along the Kibuku roadcut. These differences in sediment types are a reflection of the basin's many habitats and depositional processes.

Lithofacies

Lithofacies classification is based on the lithology of the sediments. Four distinct lithofacies were identified in the field: sandstones, conglomerates, silts, and clays.

- **Sandstone;** The sandstones varry from poorly sorted to well sorted, with grain sizes ranging from fine to coarse. Their colours include white, grey, yellow, pink, and brown. The presence of gypsum indicates a semi-arid paleoenvironment, whereas the brown color indicates iron (III) oxide precipitation, indicating an oxidation environment. Paleocurrent flow direction may be inferred from the sands' angular and tangential strata, which are mostly dipping in the NW-SE direction.
- **Clays;** The clays range in color from dark green to brown and grey, and they are extremely fine-grained. While some clay deposits were discontinuous, others were durable and continuous. Beds range in thickness from a few centimeters to up to two meters. Blocky and massive clay beds suggest a low-energy lacustrine depositional environment, especially in the Kasande formation.

- **Silt;** These fine-grained sediments appear grey to white, with some yellow due to iron (III) oxide coating. They are well sorted and fine-grained, with thin, continuous beds showing low-scale cyclicity.
- **Conglomerates;** The conglomerates are poorly sorted, mostly brown due to iron-rich minerals, with a matrix-supported fabric of coarse sands and pebbles and cobbles. They form the contact between the basement and the sediments.

Biofacies.

A stratigraphic unit's biofacies are areas where the fossilized flora and animals are very different from those found elsewhere in the unit. Fossil assemblages are used to describe them. Biofacies in the Semliki Basin are remnants of preserved plants or animals. Fish bones, bivalves, and white oyster shells were discovered in Makondo, suggesting a freshwater lacustrine habitat. Plant roots, fossil wood, gastropods, and snail shells were among the other biofacies found in the Kisegi River channel.

4.3. Depositional Environments Summary.

Fossils provide critical clues about the depositional environment, as specific fossil occurrences are characteristic of particular environments and depth ranges. The Semliki Basin features clayey facies, fine to coarse sand facies, and conglomeratic facies.

Fluvial System; Fining-upwards sequences, point bar deposits at the Kisegi river channel, floodplain deposits of fine sediments, cross beds, meander channels in the coarse sands of the Kisegi formation, and water fossils like bivalves are used to explain these deposits. Local paleocurrent directions can be inferred from structures like as ripples and cross-beds. Sand and clay intercalations reveal shifts in the energy and environmental parameters of the depositional process. In floodplains, rivers deposit coarser materials during higher energy circumstances and clays and finer sands during low-energy or flood episodes.

Lacustrine Environment; A lacustrine depositional environment is indicated by thick clay layers and blocky sand layers. A delta may have served as a transitional zone during the change from fluvial to lacustrine. In certain areas of the Kibuku roadcut, coarsening ascending sequences suggest a deltaic environment.

Semi-arid Conditions; The presence of red sands and gypsum, associated with clays and sands, suggests semi-arid conditions. Gypsum results from high evaporation rates, and red sands result from iron oxide oxidation.

Therefore, the depositional environments in the Semliki Basin encompass fluvial, lacustrine, and deltaic systems.

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 24:Shows an anticlinal fold, Plunge 390SW.

Figure 25: : Shows a Synclinal fold, Plunge 280Sw.

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.

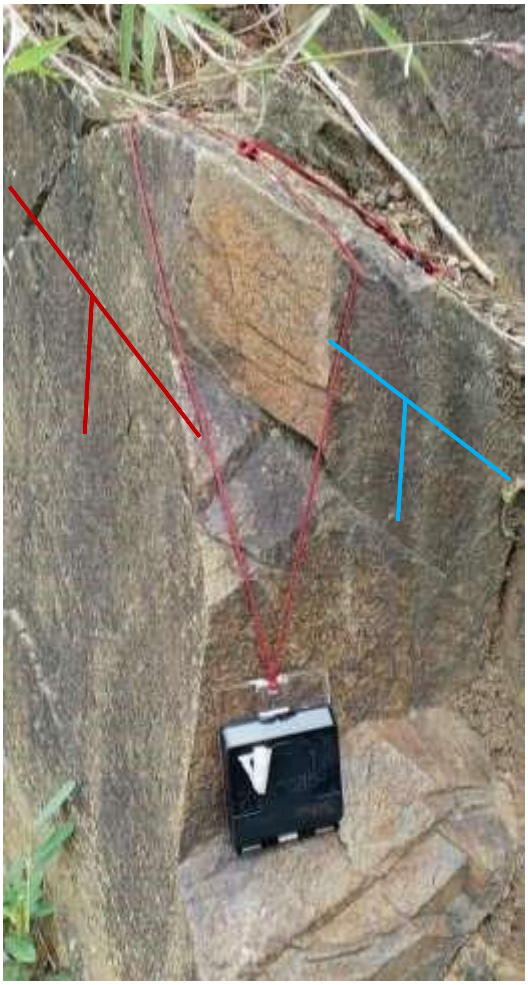


Figure 26: Shows are highly Jointed rock outcrop with various joint sets.

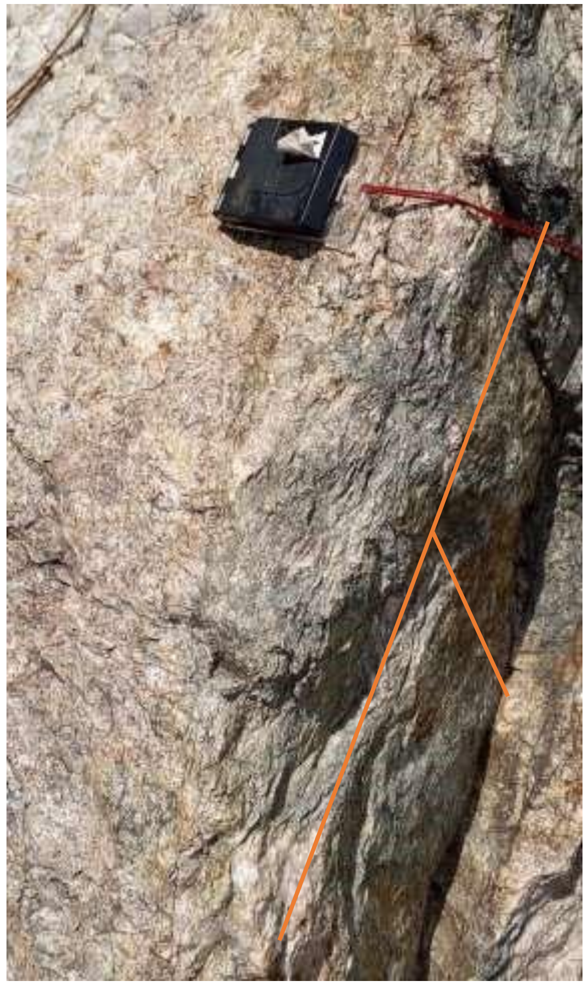


Figure 27: Shows a rock outcrop with exfoliated surface contributing to the jointing.

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.

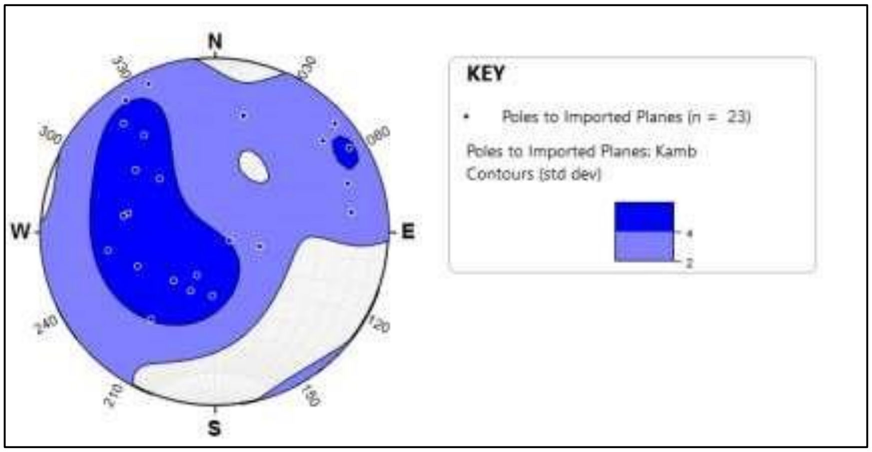


Figure 28:showing sreogram of joints

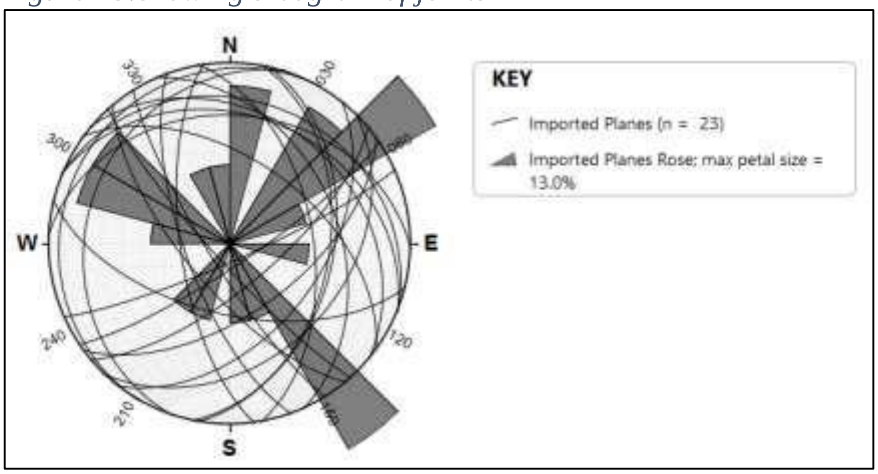


Figure 29:showing rose diagram of joints

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.

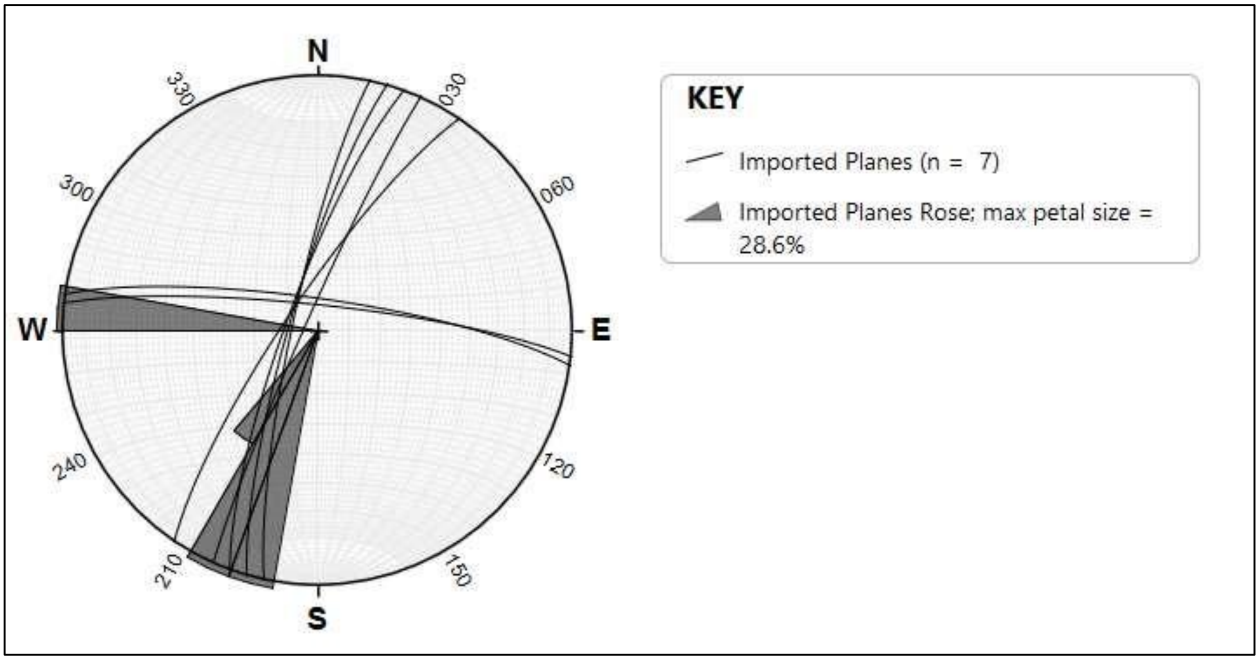


Figure 30:showing a red diagram of joints

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 31: Shows a highly foliated rock outcrop with felsic minerals aligning in a certain direction

5.2.4. Faults.

Figure 32:Shows a fine grained originally dolerite dyk

In geology, a fault is a planar fracture or discontinuity in a volume of rock across which there has been significant displacement as a result of rock-mass movements. A fault is formed in the Earth's crust as a brittle response to stress.

Generally, the movement of the tectonic plates provides the stress, and rocks at the surface break in response to this.

The type of faults in the Semliki basin are dip-slip normal faults resulting from tensional forces that affected the area. They are oriented in the NE-SW direction and include both large scale faults and minor faults. The trend of faults in the Semliki basin is consistent with the general trend of faults in the Albertine rift.

The major faults include the Makondo fault between the Semliki flats and the Toro plains. The Semliki basin is bordered to the South-east by a steep fault escarpment rising up to 1,000m to the northernmost spur of the Rwenzori Mountains. The normal faults in the Semliki basin are conjugate in nature, that is to say, they have similar magnitudes of dip but opposing directions and thus able to form the graben architecture. The NE-SW trending Kichwamba normal fault with a Western dip, controlled the escarpment (exposed by roadcut) along which several measurements of structures in basement rocks presented herein were made. It was also observed that the major faults manifested in form of discontinuous faults that are shorter and somewhat off the overall orientation. These faults influence drainage because the brecciated and weathered rocks along faults are easily removed by water to form seasonal streams gullies. These faults influence drainage because the brecciated and weathered rocks along faults are easily removed by water to form seasonal streams gullies.

Figure 33: Showing the Kichwamba fault

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.

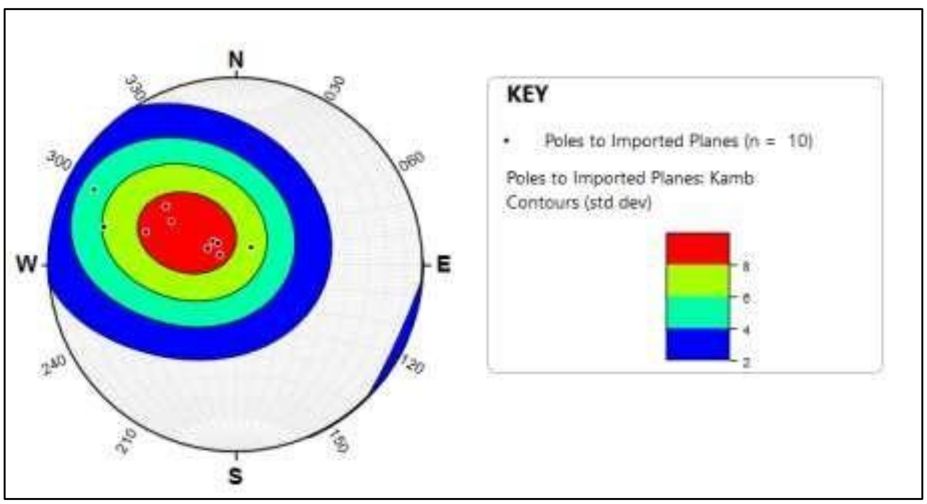


Figure 34:showing stereogram of beddings

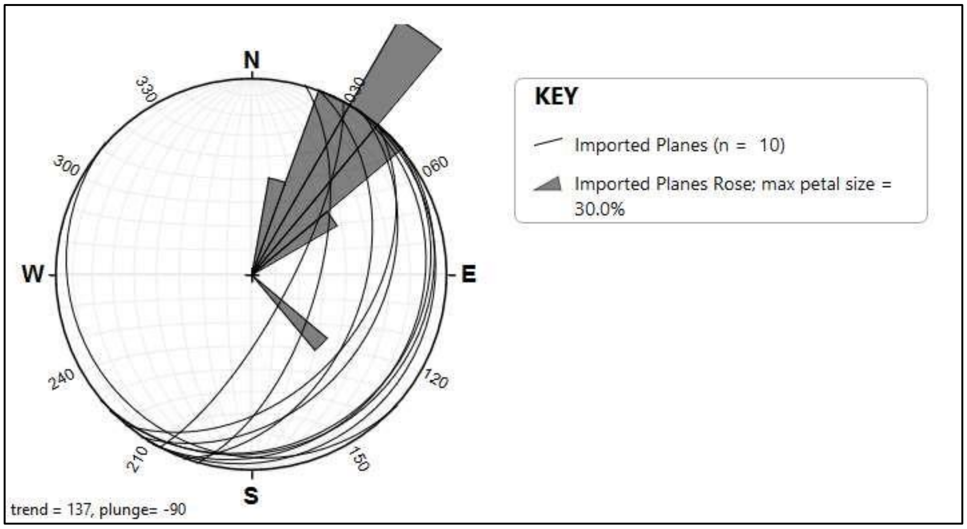


Figure 35:showing rose diagram of beds

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.

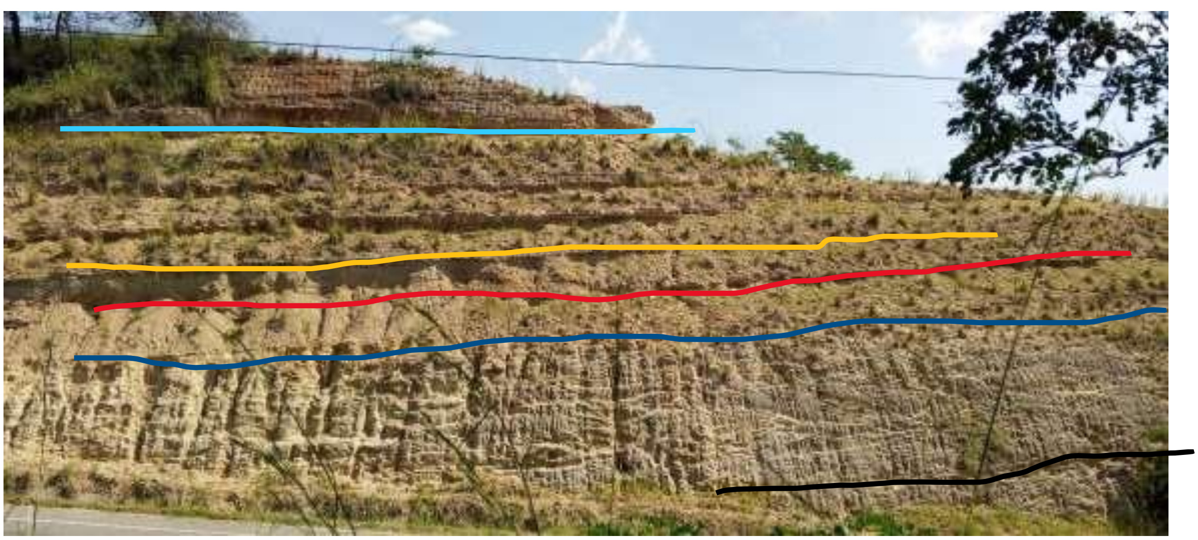


Figure 36: showing plannar bedding

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.

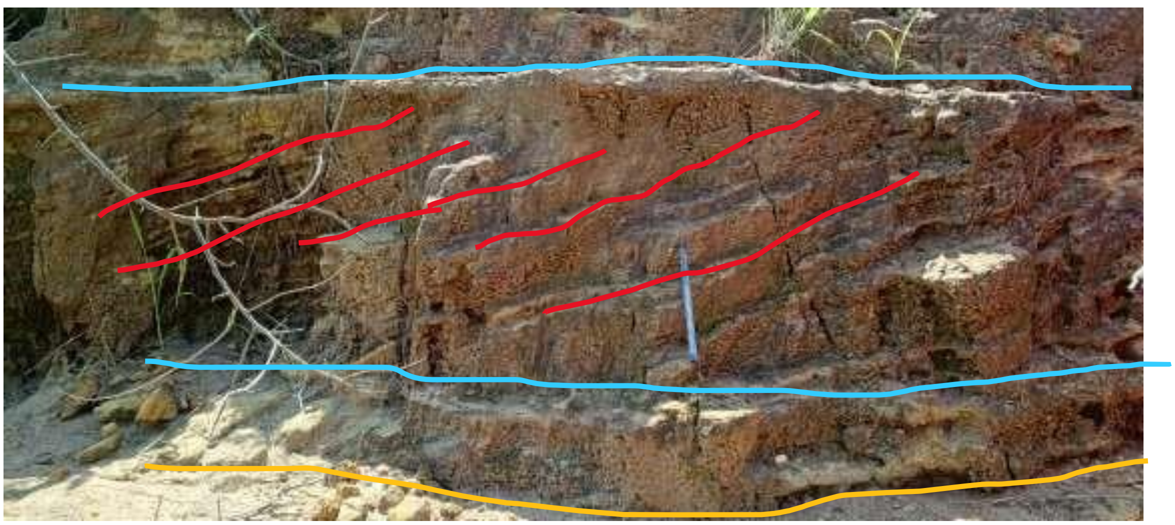


Figure 37:showing cross beddings

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.

Figure 38: showing laminations in clays

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 polygonshaped 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.

Figure 39: 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.

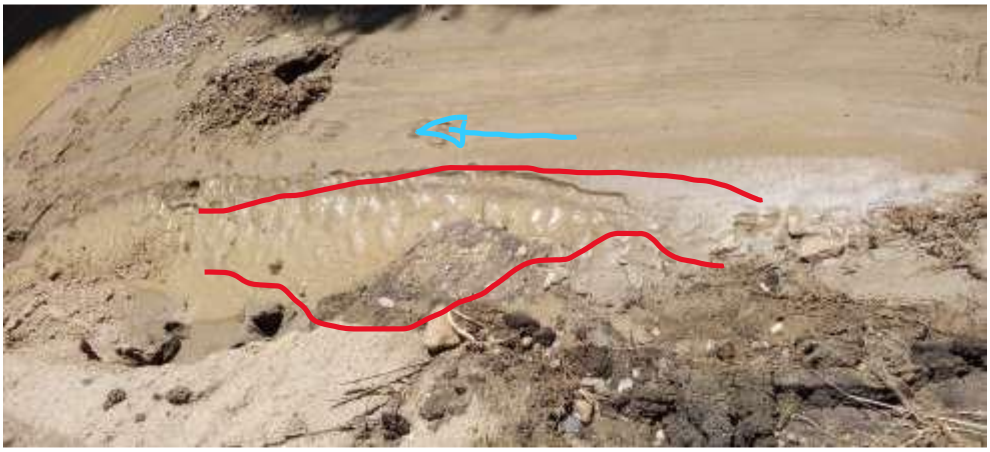


Figure 40:showing ripples

6.0. Geophysics And Geothermal Exploration Of The Semliki Sedimentary Basin.

6.1. Introduction.

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.

6.2. 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.

6.2.1. Gravity data interpretation for Semliki Basin.

Understanding underlying geological features is greatly aided by gravity survey techniques that make use of the Bouguer anomaly. The Bouguer anomaly is computed by adjusting the measured gravity values for the survey area's topographic relief, elevation, and latitude. This adjustment makes it possible to read the gravity data more clearly by eliminating the gravitational effects brought on by variables other than underlying geology. Negative Bouguer anomalies point to regions of lesser density, such as sedimentary basins or empty spaces, whereas positive anomalies show regions of higher-density rocks, such as igneous intrusions or mineral deposits. Geophysicists can better comprehend the geological history of the examined area, discover possible mineral or hydrocarbon reserves, and delineate subsurface structures by examining these anomalies.

A Bouguer anomaly map of the gravity data of the Semliki basin was generated using Geosoft Montaj software.

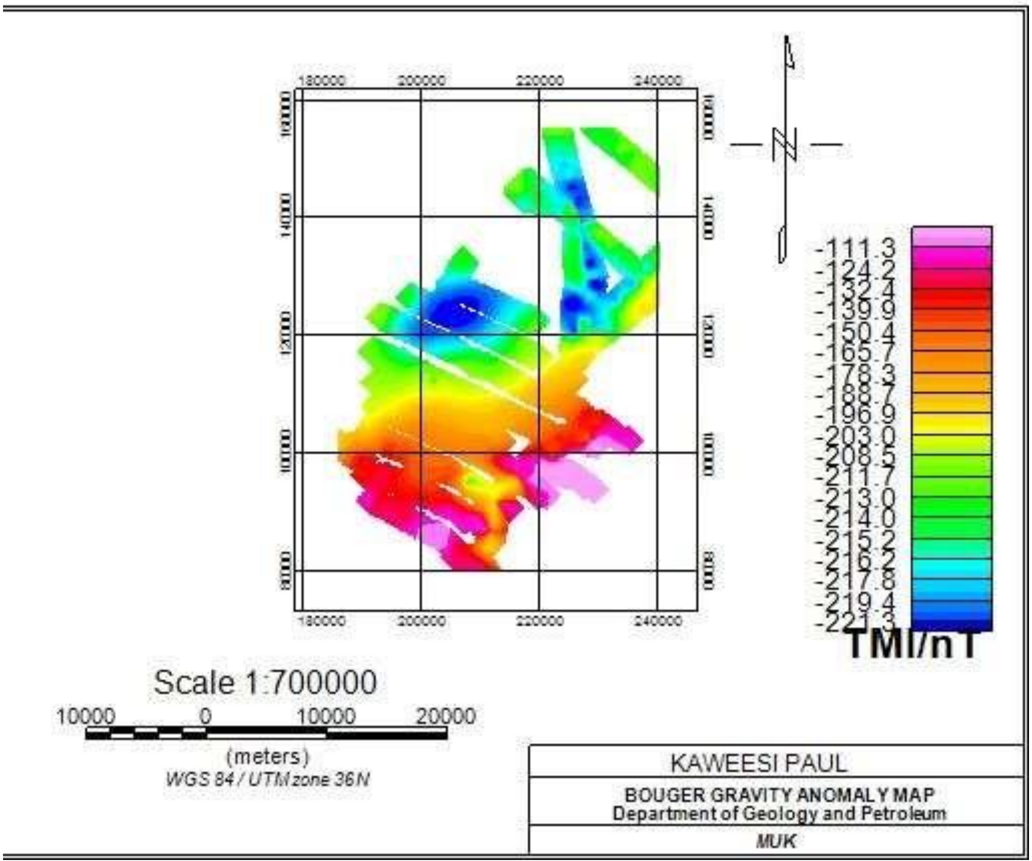


Figure 41: showing the Bouguer anomaly map generated using the geosoft software

As a result, Semliki's northeastern (usually northern) portion is deeper than the basin's southern portion. This indicates that the deeper areas had more sediment accumulation than the shallower areas. As a result, the Semliki basin is asymmetrical, with the deeper portions located on the northern portion more precisely, the northeastern portion, which is on the DRC side. Because the side with the principal controlling fault is usually deeper than the opposing side, this layout is typical of half grabens. The typical gravity anomaly values in the center of the Semliki basin suggest that the sediment thickness is likewise average. The gravity anomaly exhibits smaller negative values (-111 mgals to -203 mgal) in the southern portion of the basin. In comparison to other areas of the Semliki basin, this section is the shallowest.

Because different areas of the Semliki basin have varying silt deposit thicknesses, the gravity anomaly varies throughout the basin. In contrast to the deeper portions of the basin, where the basement rocks that would yield high values are deeply buried by the thick sediment accumulation, the areas with less negative values have the thinnest sediments, making the basement rocks that produce high gravity anomaly values relatively close. Low gravity anomaly findings indicate low density rocks, which are undoubtedly sediments with potential hydrocarbon accumulations or entrapments. The variety in depths (accommodation space) in the various basin sections caused the variability in sediment accumulation thickness.

6.2.2. Magnetic Data Interpretation of the Semliki Basin

Geophysical techniques called magnetic surveys are used to find differences in the magnetic susceptibility of underlying rocks that result in anomalies in the Earth's magnetic field. These surveys provide vital information about the composition and structure of the Earth's crust by assisting in the determination of the geometry, depth, and magnetic characteristics of rock formations. On maps, magnetic anomalies deviations from the local magnetic field are usually displayed to draw attention to subsurface features.

The quantity of magnetic material and its distance from the sensor both affect how strong the observed magnetic signal is. The strongest magnetic responses are produced by basic igneous rocks, weak signals are produced by sedimentary rocks, and intermediate readings are produced by acidic gneisses and metamorphic rocks. Geosoft Oasis Montaj software was used to evaluate magnetic data for the research region, facilitating geological and resource exploration and helping to identify underlying structures.

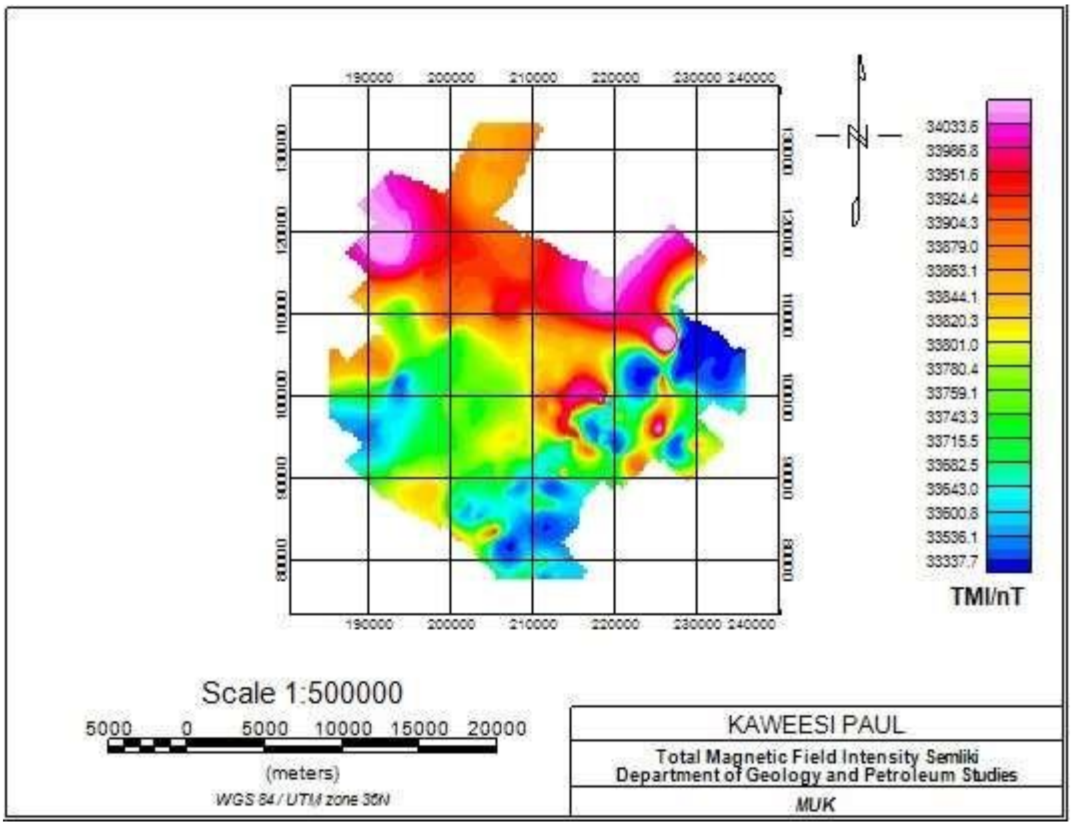


Figure 42: showing the magnetic field map generated using the geosoft softwar

The northern portion of the Semliki Basin exhibits strong magnetic field intensities (pink to yellow) on the magnetic anomaly map, with values ranging from 33844.1 to 34033.6 nT, suggesting the existence of igneous basement rocks with high magnetic susceptibility. The high gradients that surround these regions indicate that the magnetic sources are close to the surface, most likely indicating the basin's edge. On the other hand, the southern region has low magnetic intensities (green to blue, ranging from 33643.0 to 33337.7 nT), which correspond to sedimentary rocks with low remnant magnetization. The sudden change in magnetic susceptibility or magnetite content required to produce the observed magnetic anomalies may be caused by the enormous transition from sedimentary to igneous rocks.

The magnetic interpretation is predicated on the following presumptions:

- Rocks that produce anomalies are magnetized in the earth's field and are magnetically homogenous.
- The rock masses that cause anomalies have an unlimited deep extension, a level surface, and vertical sides

- Contrasts in magnetic susceptibility cause anomalies of considerable amplitude and wide areal extent (topographic relief of a magnetic rock unit typically creates relatively small amplitudes of anomalies).
- There is very little remnant magnetization in the direction of the earth's field.

6.3. Seismic Surveys.

According to Mondol and Bjørlykke (2010), seismic investigation is unquestionably the most significant of all geophysical exploration techniques, mainly due to its ability to identify both large-scale and small-scale subsurface structures. By examining the return of sound waves that have passed through the earth, seismic techniques aid in predicting the forms and physical characteristics of the Earth's underlying layers. In order to obtain important information about the composition and structure beneath the surface, a seismic pulse is created from a source at or close to the Earth's surface. The amplitudes and travel times of the waves are then recorded as they reflect or refract off various subsurface layers.

Numerous variables, including sedimentary facies and structural traits, can be identified by interpreting the acquired seismic data. Seismic data interpretation in the Semliki Basin study depended on information obtained by ExxonMobil from the Gulf of Mexico and the basin in the Albertine Graben. Analyzing the sedimentary facies found in these two locations' subsurface was the main goal.

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

Random Line 1

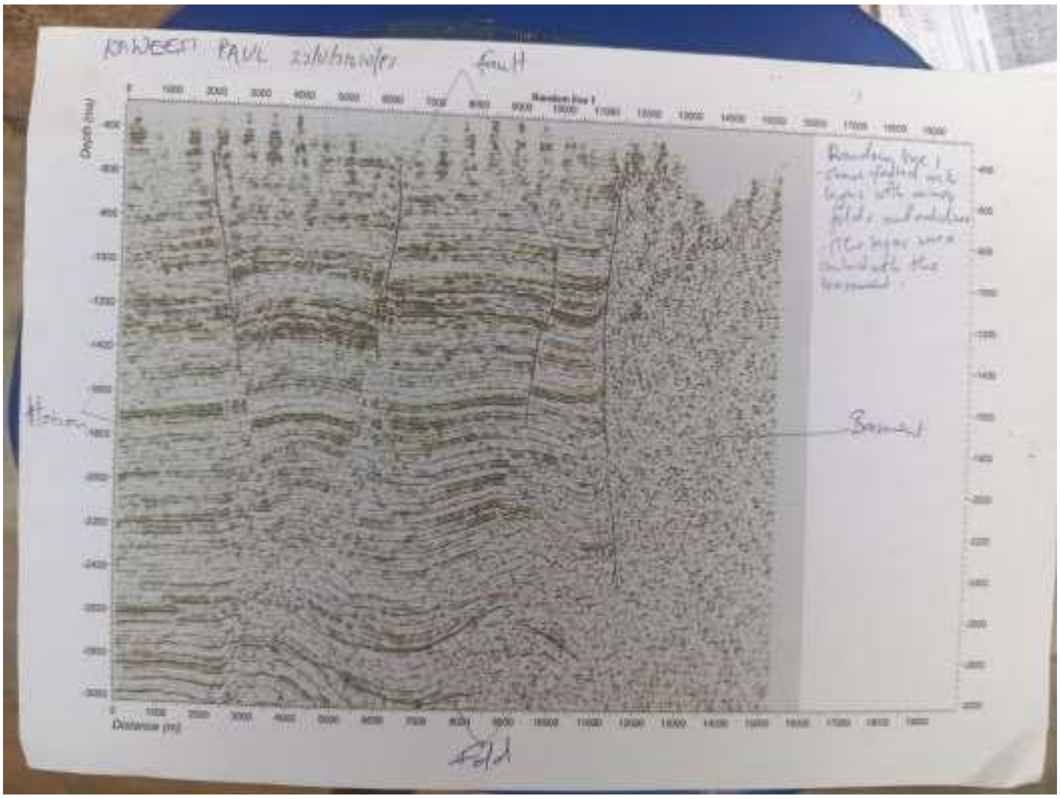


Figure 43: showing random line 1

Random Line 2

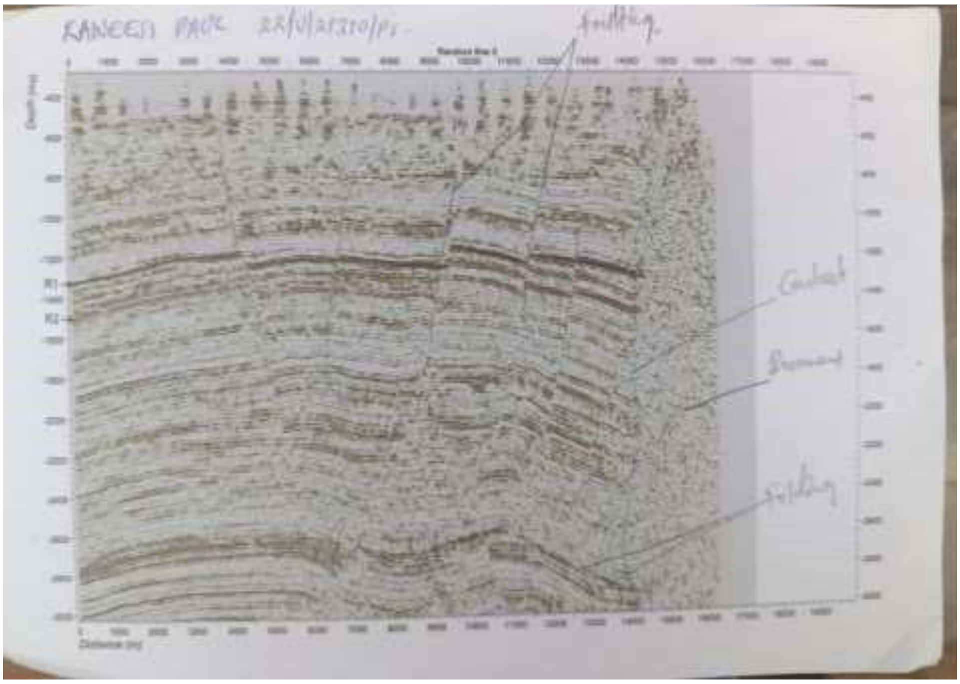


Figure 44: Showing Random line 2

Random line 3

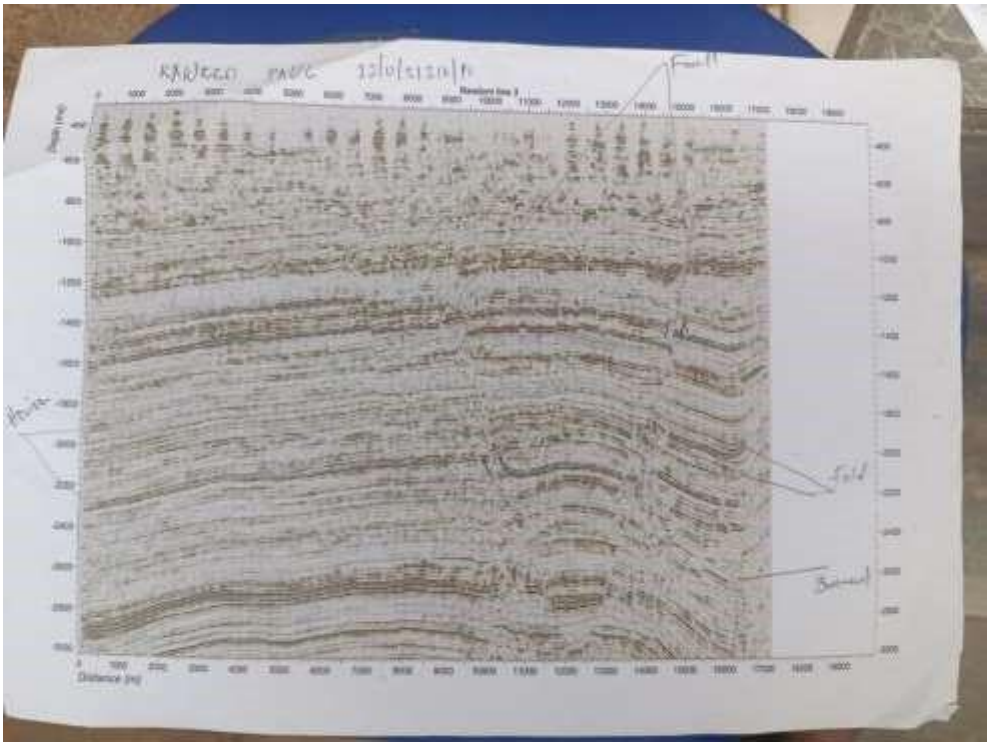
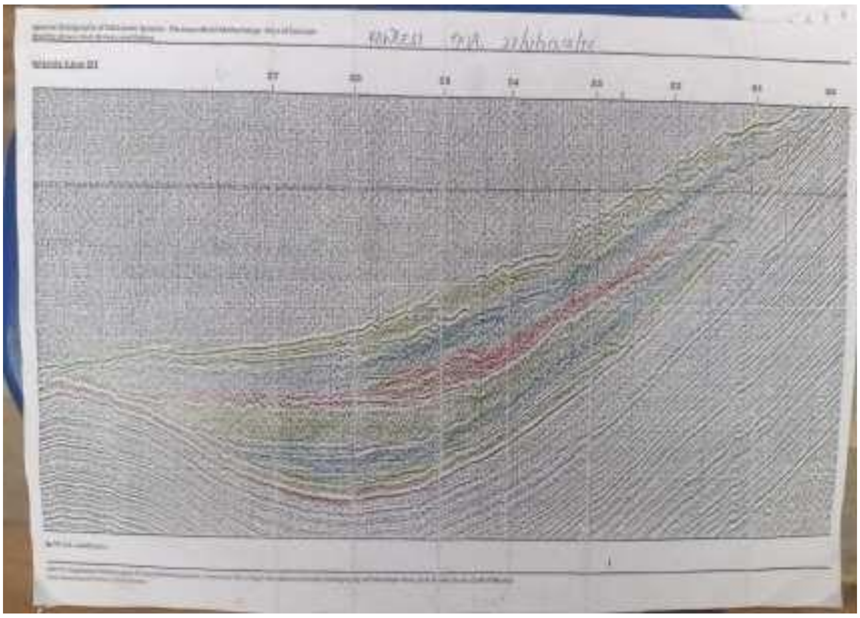


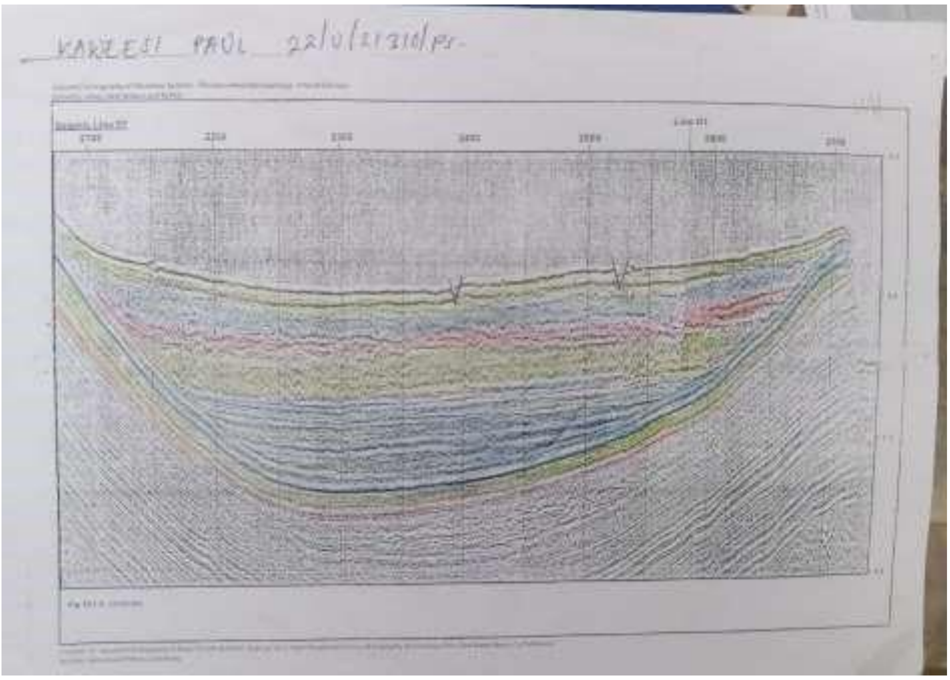
Figure 45: showing Random line 3

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.

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

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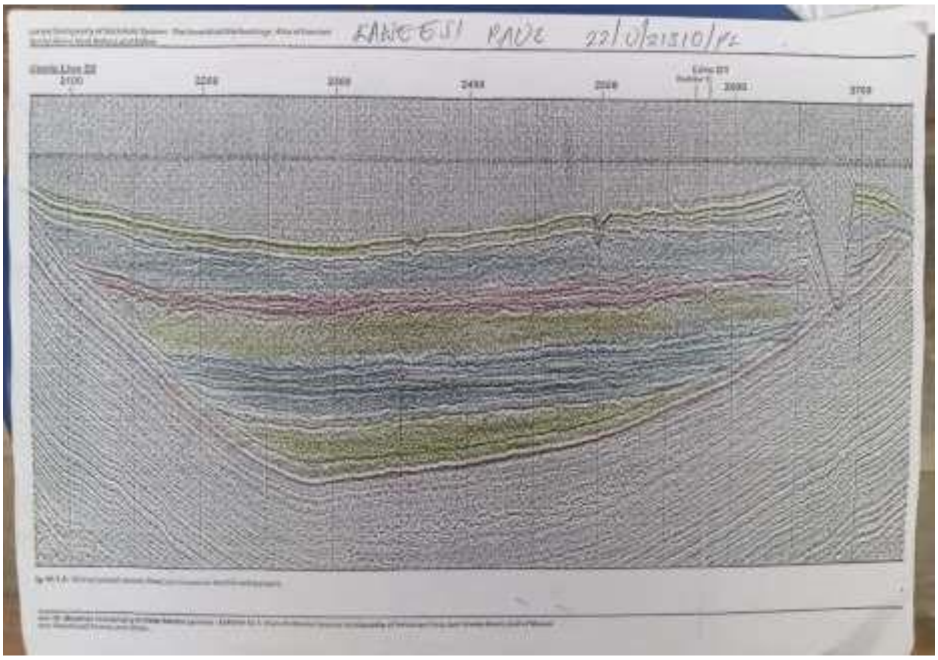
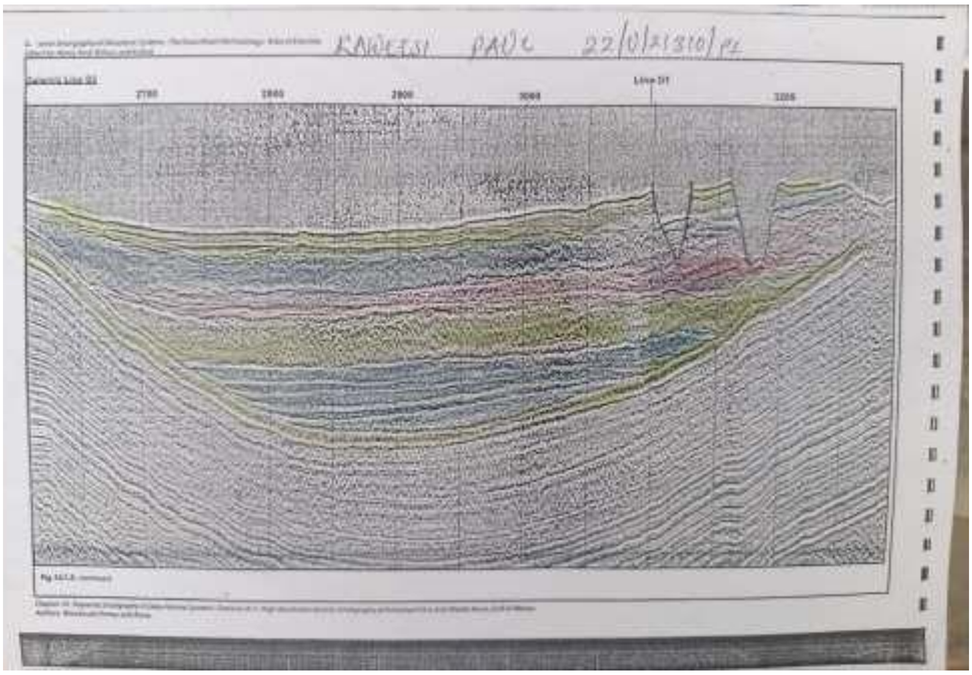
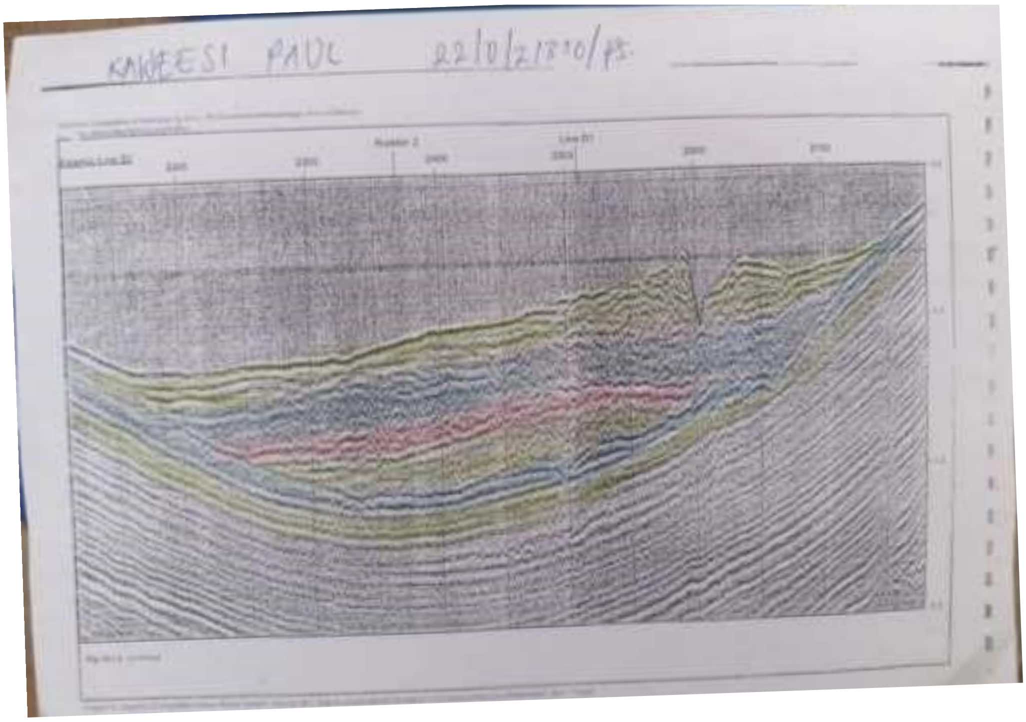
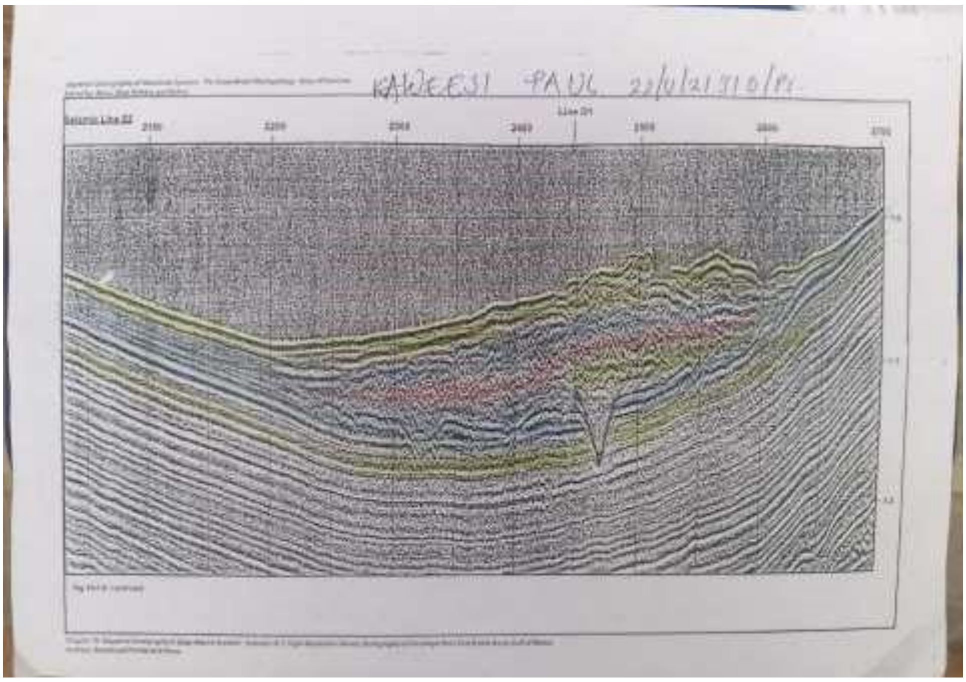
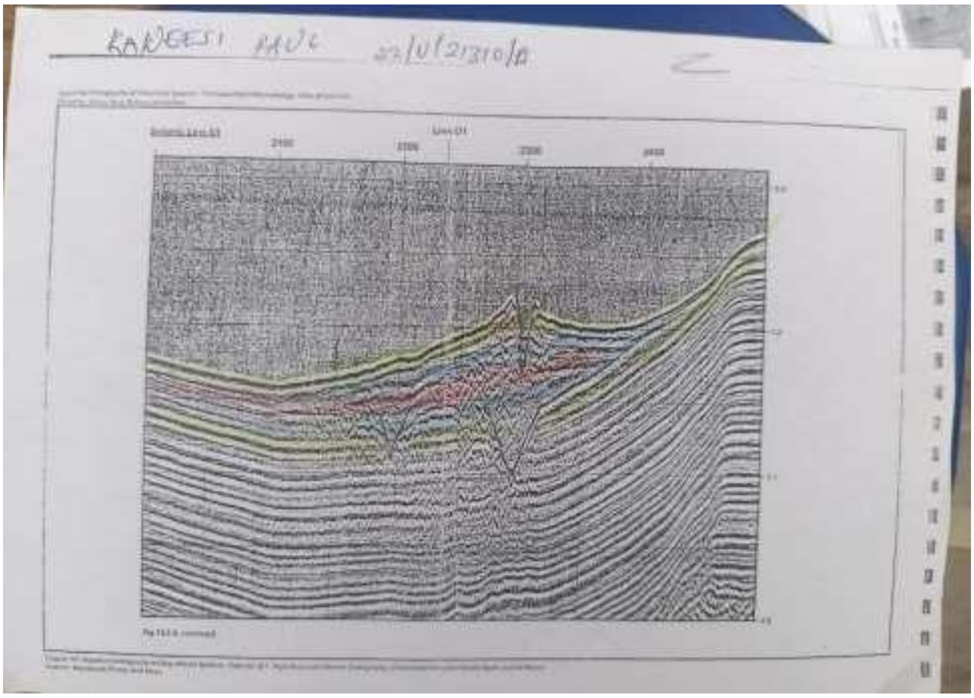





KAWEESI PAUL 22/U/21310/PS


KAWEESI PAUL 22/U/21310/PS



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.

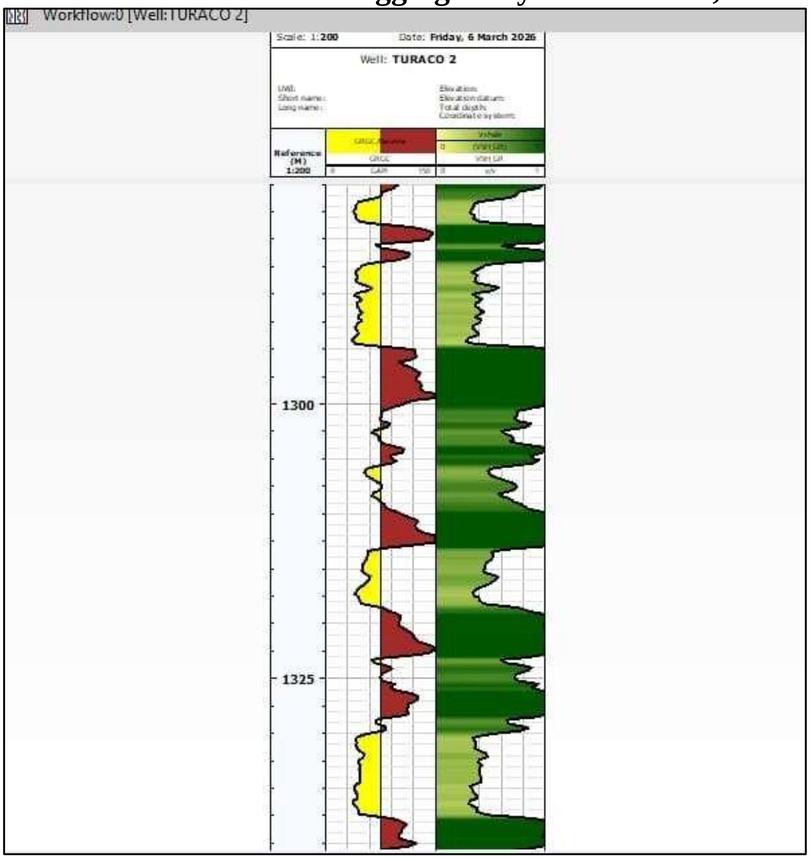
In the Gulf of Mexico seismic section, two main sedimentary facies are identified. One facies has stronger and more continuous reflections, likely representing sandy deposits, while the other has weaker and thinner reflections, likely representing shale or clay. The lens-shaped body suggests an intraslope 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.

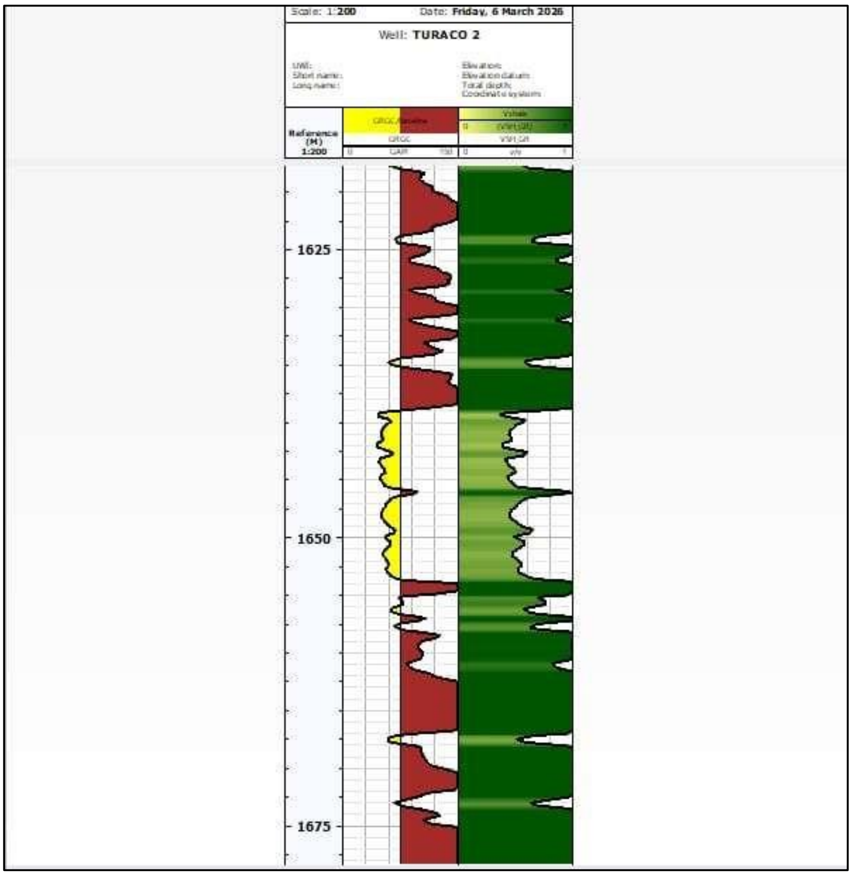
Generally, the seismic sections show structurally and stratigraphically controlled basins. The Semliki section is mainly controlled by faulting and folding, while the Gulf of Mexico section shows deep-water fan deposition and facies changes. Both sections are important for petroleum interpretation because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

6.4. Petrophysics for Formation evaluation.

Petrophysics involves the study of the physical and chemical properties of rocks and their interactions with the fluids they contain. The primary goal of petrophysical well log analysis is to convert well log data into key reservoir properties such as porosity, permeability, and hydrocarbon saturation. In this study, formation evaluation was carried out using density, neutron, and gamma ray logs. Additionally, the volume of shale (V-shale) was calculated to estimate the shale content within the formations.

6.4.1. Results of Wireline logging study for Turaco 1, 2 & 3.





- **Gamma Ray Log.**

Shales, which contain a variety of radioactive minerals, including potassium, are indicated by high gamma ray readings. On the logs, these high readings are indicated by brown color zones. On the other hand, clean sands and carbonates are indicated by low gamma values, which are indicated by yellow color zones. For instance, low gamma measurements between 1640 and 1655 feet indicate the existence of clean sands.

Because they include radioactive minerals, shales have high gamma ray readings, whereas sands have low gamma readings because they don't contain radioactive materials. A negative reading or mud cakes that develop as a result of the interaction of drilling and reservoir fluids are common indicators of the existence of a reservoir.

The high gamma values from the gamma-ray log clearly show that the Turaco well encountered mostly shaly strata. This implies that the well probably reached the Kasande, Oluka, and Nyakabingo formations, which are known to have substantial shale and clay contents in the Semliki Basin.

- **V-Shale.**

The volume of shale in a formation can be determined using the gamma-ray log. Low volumes suggest that there is less shale in the formation, making it more porous and conducive to the presence of hydrocarbons, particularly water and oil. The V-shale log is obtained from the Techlog software using the in-built calibration and can also be calculated manually from the equation;

$$\mathbf{V_{shale}} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$$

Where;

GR_{log}**;** is the gamma-ray log reading at the point of interest,

GR_{max}**;** is the gamma-ray reading for shale (maximum gamma-ray value),

GR_{min}**;** is the gamma-ray reading for clean sand (minimum gamma-ray value). In summary, low Vshale values suggest higher porosity and potential hydrocarbon zones within the formation and high Vshale values are indicative of an organic matter rich source rock from which hydrocarbons can be generated.

- **Neutron-density Logs.**

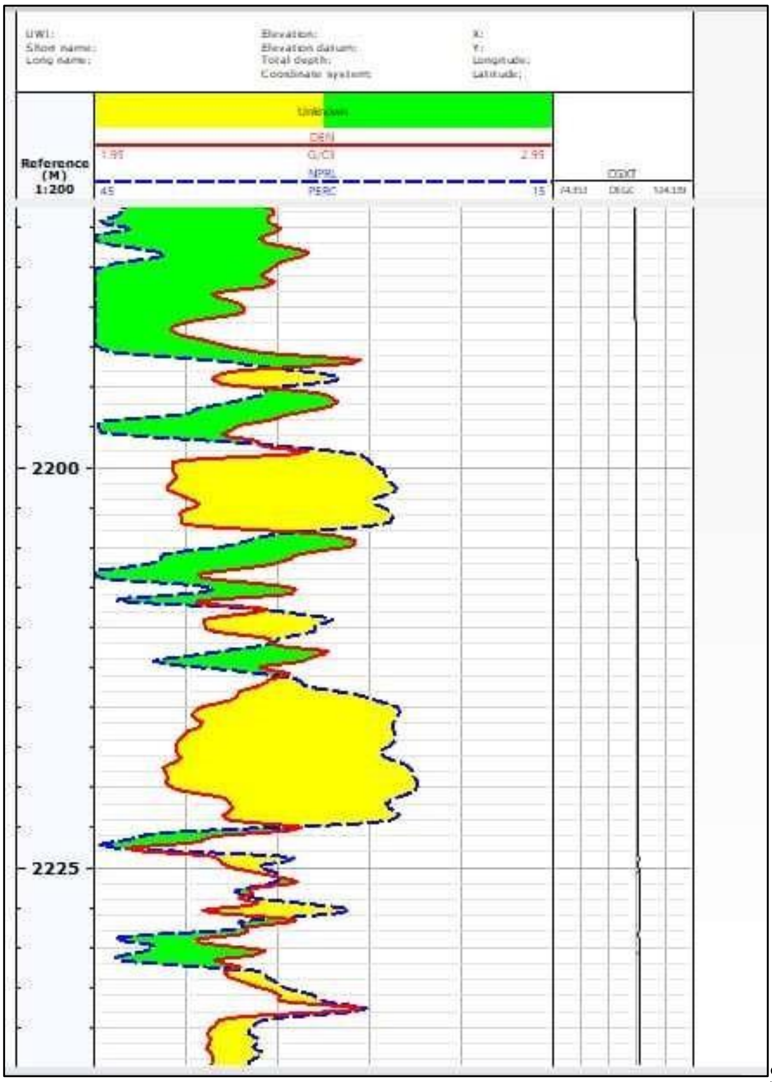


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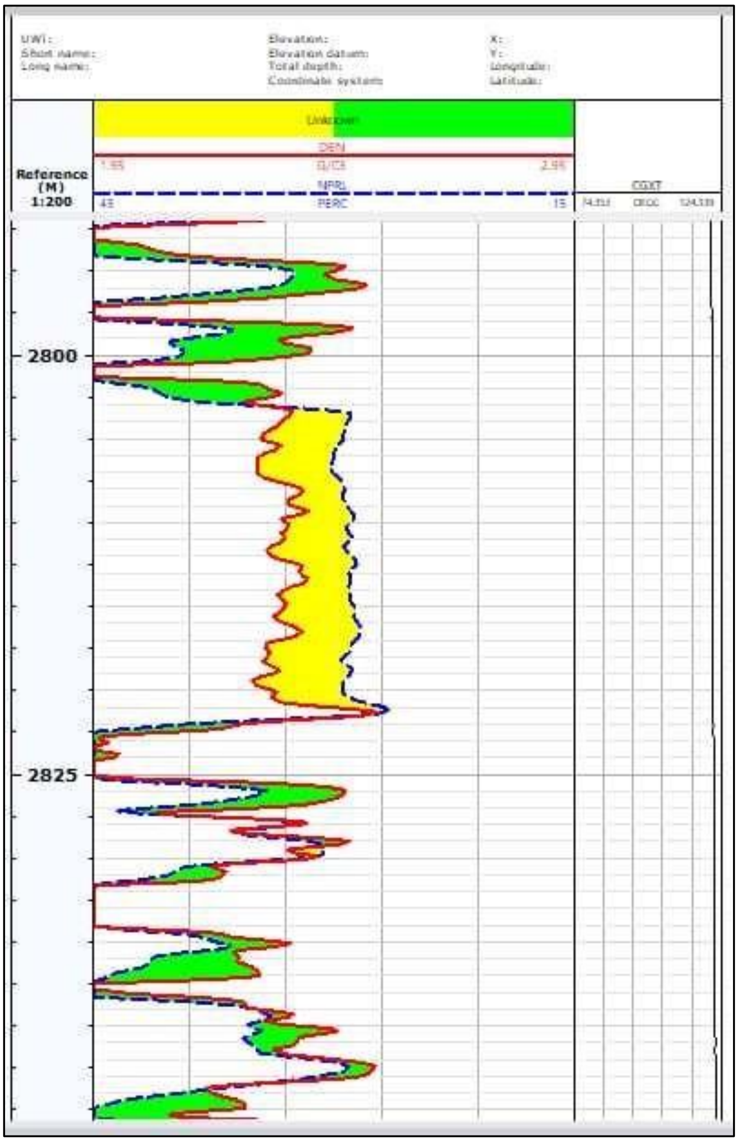
Figure 46:shows Neutron density log

The logs are used to measure the porosity of the formation, with the density log (red line) measuring the electron density of the formation, and the neutron porosity log (blue dashed line) measuring the hydrogen concentration. When the density log is to the right and the neutron log to the left, the formation is shale.

If the logs cross over with the density log on the left and the neutron log on the right, this indicates an oil and gas-filled sand. When the two logs track each other, the formation is either a wet sand or oil sand. The observed log section suggests that the formation contains more gas than oil. Low neutron log readings indicate the presence of gas due to its low hydrogen concentration compared to oil or water. Thus, a wide separation of the two logs signifies gas presence, while superimposed logs indicate oil or water. The Turaco 2 well data shows more gas than oil, which may not be economical for companies primarily interested in oil extraction. The high amounts of gas present can be attributed to type of organic matter origin and thermal cracking attribute to increased temperatures.

From the figure above, the depth interval 2200 to 2225m, is generally a gas zone from the large size of the crossover and the sharp decrease in the density values and the decrease in the neutron values while from the figure below an oil zone is observed at the interval 2800 to 2825m due to the small crossover.



6.5. Results from the field visit to Turaco drilling Site.

Over the years, numerous drilling attempts have been made at the Turaco well site, which is situated on the Makondo fault's hanging wall. According to earlier research, the three Turacos (Turaco 1, 2, and 3) were the second group of wells dug in the Albertine Graben following the

Butiaba-Waki well. Driven by surface oil seeps, the Butiaba-Waky well in 1937 marked the beginning of drilling in the Albertine Graben. After seismic investigations, Turaco wells were later drilled.

- Turaco 1 (199706,113822); started September 2002 to January 2003, while in march 2003, drilling was suspended due to loss of drilling pipes probably caused by differential pipe sticking in shales. Depths upto 2.5km were drilled to a target of a Kisegi sandstone which was expected to be a potential reservoir.
- Turaco 2 (199740,113753); This was drilled about 10 metres from Turaco 1 to a depth of about 2.962km. This well was started in 2002 with oil shales but was not tested, and it was found that the oil was mixed with carbon dioxide.
- Turaco 3 (199763,113762); Drilled 200 metres apart from Traco 2 and was found to contain hydrocarbons which were contaminated by carbon dioxide probably generate due to thermal cracking of the hydrocarbons in the presence of oxygen to generate high amount of carbon dioxide.

6.6. Results from the study of methods for geothermal exploration.

Situated in the Albertine Graben's Semliki National Park, the Sempaya hot springs are an amazing natural occurrence. These hot springs are an interesting aspect of the terrain, located about 40 kilometers from the Democratic Republic of the Congo (DRC) border. The East African Rift System, where the Earth's crust is being torn apart to allow geothermal energy to reach the surface, is the source of the hot springs. This subterranean heat, which can also affect the maturation of hydrocarbons, is demonstrated by the bubbling springs and mud pots.

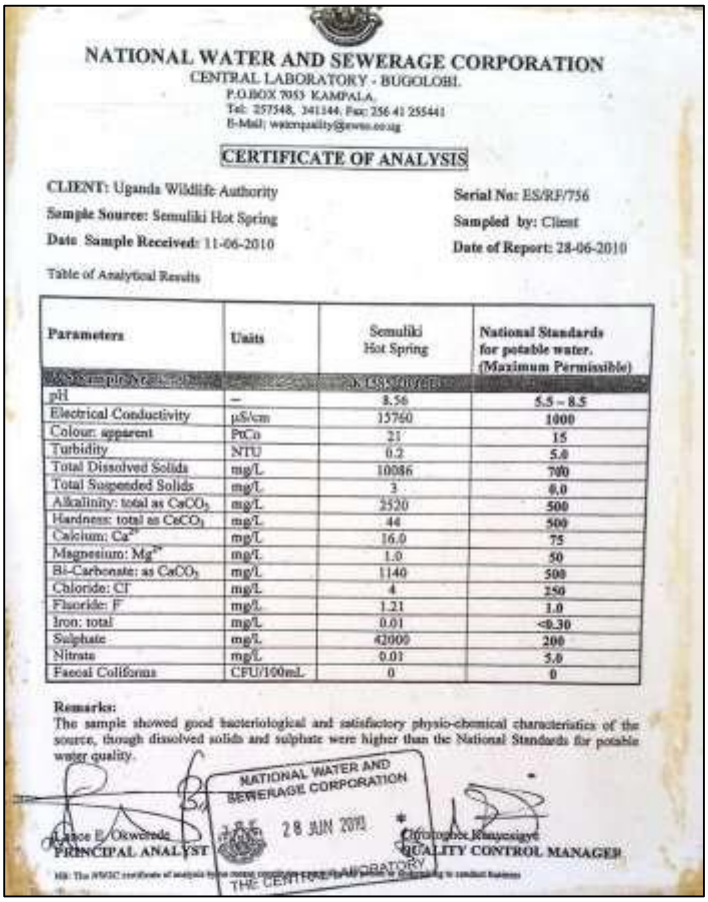
The Geothermal System consists of a heat source, reservoir (where water/steam collects), and fluid pathways. The indicators of a geothermal system include; fumaroles, geysers, travertine deposits and hotsprings which were observed in the study area (male and female Hotspring).

Figure 47: showing the female and male sempaya hotspring

Geothermal exploration in the Semliki Basin relies on an integrated, phased approach combining surface studies, geophysical surveys, and exploratory drilling to map the region's fault-controlled geothermal systems. Sempaya Hot Springs (with temperatures >100^{0}C) act as the primary guide for identifying subsurface heat sources and structural conduits.

The main exploration methods used in the basin include:

- **Geological & Structural Mapping:** Field geologists map stratigraphy, fault lines, and fracture zones, focusing on the boundary faults of the East African Rift System that allow deep meteoric water to circulate and get superheated. And during field mapping exercise, important geothermal features can be identified for example; alteration zones that include, Argillic, illitic, propylitic, and thermometamorphile zones.
- **Geochemical Analysis:** Scientists sample fluid and gas emissions (such as the sulfur-rich waters at Sempaya) to determine the chemical composition through geochemistry studies and estimate deep reservoir temperatures through geothermometry. The source of ions in the hotsprings were attributed to, WRI (water rock interactions), Calcium carbonate, Carbon dioxide of magmatic origin and H_2S also from magma. Some geochemical analysis has been carried out by the National Water and Sewerage Corporation as shown below.



NATIONAL WATER AND SEWERAGE CORPORATION
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CERTIFICATE OF ANALYSIS

CLIENT: Uganda Wildlife Authority
Sample Source: Semuliki Hot Spring
Date Sample Received: 11-06-2010

Serial No: ES/RF/756
Sampled by: Client
Date of Report: 28-06-2010

Table of Analytical Results

Parameters	**Units**	Semuliki Hot Spring	**National Standards for potable water. (Maximum Permissible)**
[illegible]	[illegible]	[illegible]	
pH	–	8.56	5.5 – 8.5
Electrical Conductivity	µS/cm	15760	1000
Colour: apparent	PtCo	21	15
Turbidity	NTU	0.2	5.0
Total Dissolved Solids	mg/L	10086	700
Total Suspended Solids	mg/L	3	0.0
Alkalinity: total as $CaCO_3$	mg/L	2520	500
Hardness: total as $CaCO_3$	mg/L	44	500
Calcium: Ca^{2+}	mg/L	16.0	75
Magnesium: Mg^{2+}	mg/L	1.0	50
Bi-Carbonate: as $CaCO_3$	mg/L	1140	500
Chloride: Cl^-	mg/L	4	250
Fluoride: F^-	mg/L	1.21	1.0
Iron: total	mg/L	0.01	<0.30
Sulphate	mg/L	42000	200
Nitrate	mg/L	0.01	5.0
Faecal Coliforms	CFU/100mL	0	0

Remarks:
The sample showed good bacteriological and satisfactory physio-chemical characteristics of the source, though dissolved solids and sulphate were higher than the National Standards for potable water quality.

NATIONAL WATER AND SEWERAGE CORPORATION
28 JUN 2010
THE CENTRAL LABORATORY

Lance E. Okwerede
PRINCIPAL ANALYST

Christopher Kanyesigye
QUALITY CONTROL MANAGER

- **Geophysical Surveys:** Magnetotelluric (MT) and transient electromagnetism (TDEM) methods measure electrical conductivity to map deep, sub-vertical fault networks and potential clay caps. Additionally, gravity and magnetic surveys identify basin depocenters and basement structures.

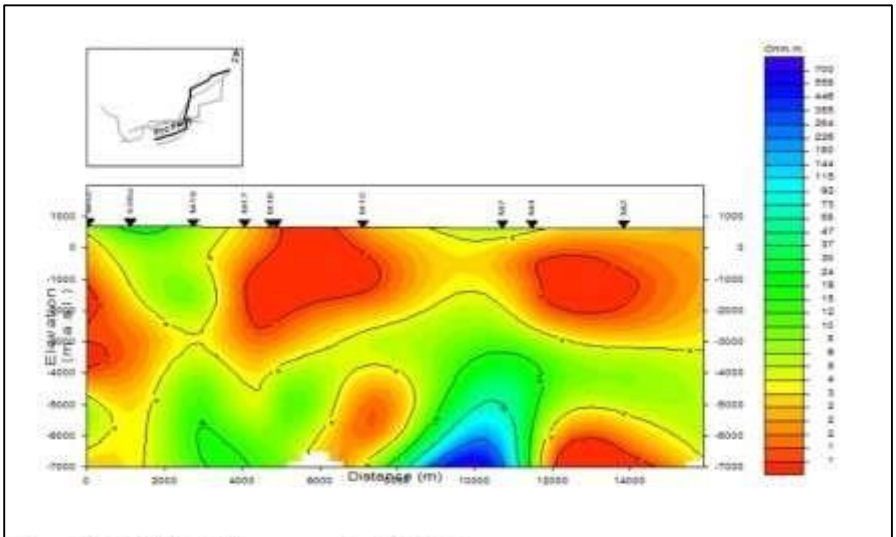

Figure 3.2: MT Resistivity cross-section SW-NE

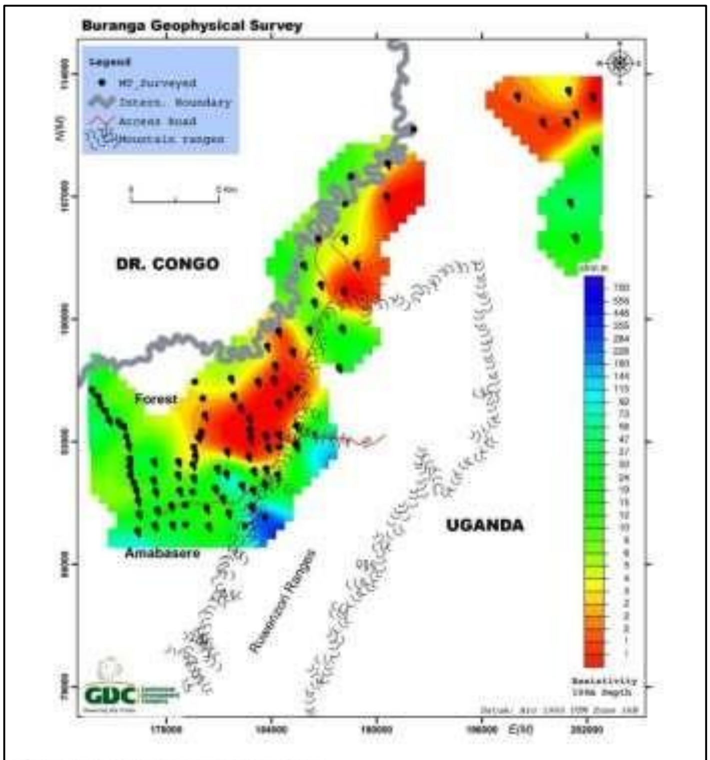

Figure 3.3: Resistivity map at 100 m depth.

- **Temperature Gradient Drilling:** Shallow temperature gradient holes (TGH) are drilled to measure the local thermal gradient (which can exceed (67^0C/km) in the basin) and confirm shallow heat flow before committing to expensive deep drilling. Some geothermal exploration wells drilled in the past were present these could have been drilled to establish the temperature gradients.

Figure 48: showing geothermal exploration well

CHAPTER SEVEN: DISCUSSION

7.1. FACIES AND DEPOSITIONAL ENVIRONMENT

In the Semliki Basin, the depositional framework is dominated by both clastic and non-clastic sediments formed in a variety of environments, including lacustrine, deltaic, and fluvial settings. The basin, located within the western arm of the great East African Rift System, represents a complex geological structure. It is a rift basin characterized by a half-graben structure, where one side is bounded by a fault. The diverse lithologies observed during the logging process along the Kibuku roadcut include conglomerates, sandstones, siltstones, mudstones and clay. These variations in sediment types reflect the different depositional processes and environments within the basin.

Fluvial environments in the Semliki Basin are characterized by thick sand beds with grains ranging from coarse to fine, often showing a fining upward sequence. These sediments are indicative of high-energy depositional settings, such as meandering rivers, alluvial plains, floodplains, point bars, and overbank deposits. The fluvial deposits vary in thickness and form laterally consistent sandstones. The presence of angular and coarse-grained conglomerates further suggests deposition in a high-energy environment, where sediments are rapidly transported and deposited. The distribution and orientation of fluvial and deltaic deposits are controlled by factors such as climate, water discharge, sediment load, slope, tectonics, and the geometry of the basin.

Lacustrine sediments are widespread throughout the Semliki Basin, dominated by claystones and siltstones interbedded with sandstones. The presence of invertebrate fossils, such as freshwater molluscs, and the occurrence of evaporites like gypsum, confirm the interpretation of a lacustrine environment. Lacustrine settings typically involve calm water conditions that allow fine sediments to settle and accumulate. The presence of gypsum, an evaporite mineral, indicates semi-arid conditions with high rates of evaporation, suggesting periods when the lakes or rivers were drying out. The transition from fluvial to lacustrine environments often involves deltaic deposition, acting as an intermediary zone where sediment from rivers is deposited before reaching the lake.

Deltaic environments in the Semliki Basin are inferred from the presence of fine sediment loads, such as mud diapirs, fine sand, and silts, often exhibiting a coarsening upward sequence in sandstones. These sequences indicate changes in sediment supply and energy conditions over time. The occurrence of both fining upward and coarsening upward sequences within the sandstone beds suggests periods of transgression and regression, respectively. During transgressions, when sea levels rise, fine sediments are deposited over coarser ones, leading to a fining upward sequence. Conversely, during regressions, when sea levels fall, coarse sediments are deposited over finer ones, resulting in a coarsening upward sequence.

The presence of deformational structures, such as joints and faults, within the sedimentary sequences indicates that the Semliki Basin was a tectonically active environment during sediment deposition. Tectonic activity can influence sedimentation by creating accommodation space for sediments to accumulate and by affecting sediment transport and deposition patterns. The tectonic activity in the area is evidenced by the development of the Rwenzori Mountains and the associated faulting and fracturing observed in the basin.

In summary, the Semliki Basin exhibits a complex depositional history characterized by fluvial, deltaic, and lacustrine environments. The diverse lithologies and sedimentary structures observed in the basin reflect the varying conditions of sediment transport and deposition over time. Facies analysis of these sediments provides valuable insights into the paleo-environmental conditions and depositional processes that shaped the basin, allowing for the prediction of sedimentary rock distribution and the identification of potential petroleum plays. The sedimentary sequences in the Semliki Basin suggest a viable petroleum system with excellent potential for reservoirs and top seals, as well as indications of mature source rocks, seals, traps, and hydrocarbon migration pathways.

7.2. Summary of the geological history of semliki basin.

The Semliki Basin, part of the Albertine Graben, has been shaped by significant tectonic and sedimentary processes associated with the East African Rift Valley system. This basin, characterized by high-grade metamorphic and igneous rocks of the Pre-Cambrian age, experienced multiple tectonic episodes that created conditions for substantial sediment accumulation. The formation of the main rift shoulders and increased subsidence led to rapid sedimentation, filling the half-graben with continental and lacustrine sediments in a more tectonically relaxed environment.

Sediments in the Semliki Basin are primarily derived from surrounding highlands, escarpments, and the area around present-day Lake Albert. These sediments, including sands, clays, silts, and conglomerates, were deposited in cyclic sequences due to variations in climate and seasons. The depositional systems in the basin transitioned from fluvial to lacustrine environments, with fluvial systems contributing significantly to the sediment accumulation.

The stratigraphy of the basin reveals a sequence starting with a basal conglomerate, overlain by sand-prone layers, and topped by clay-prone layers. Later tectonic events led to mineral remobilization, resulting in the formation of quartz veins within the basement rocks.

The Kisegi Formation, the oldest in the basin, features a basal conglomerate transitioning to yellow sandstone with gypsum veins, indicating fluvial, deltaic, and lacustrine deposition in a semi-arid climate. The Kasande Formation, characterized by dark mudstones and coaly shales, suggests a transition from lacustrine conditions to a wet delta plain. The Kakara Formation, with poorly sorted sandstones and ferruginous layers, was deposited on a coastal plain with contributions from nearby channels. The Oluka Formation consists of dark shales with conglomeratic ironstone, indicative of lacustrine and nearshore mudflat environments.

Further, the Nyaburugo Formation comprises claystones with ironstone concretions and fining-upward sandstones, reflecting fluvial channel deposition in humid tropical climates. The Nyakabingo Formation exhibits coarsening-upward cycles with light grey claystones and iron-stained siltstones, typical of floodplain and lagoonal environments. Lastly, the Nyabusosi Formation, with alternating clays and silts and distinctive ironstone horizons, suggests coastal to near-shore lacustrine environments with significant lake-level fluctuations.

Overall, the geology of the Semliki Basin is a complex interplay of tectonic and sedimentary processes, resulting in diverse sedimentary sequences that provide valuable insights into the past environmental conditions and geological history of the region.

7.3. Hydrocarbon potential of the semliki basin

Evaluating the hydrocarbon potential of the Semliki Basin involves analyzing the quality, thickness, and lateral extent of different facies that represent source rocks, reservoir rocks, and cap rocks. These elements are crucial for generating, accumulating, and trapping hydrocarbons. Based on surface geological mapping data, seismic data, and well data, it is evident that the essential components for a successful hydrocarbon system are present in the Semliki Basin.

- **Source Rocks**

Evidence of oil generation in the Semliki Basin is supported by the Kibuku oil seep, characterized by dark, paraffin-smelling sands observed at the base of the Kisegi Formation at the sediment-basement contact. This oil seep indicates the presence of a regionally mature source rock. The extensive lacustrine clays in the area, which are potential source rocks, could become prolific given sufficient time for burial and increased temperatures. The dark grey colour of some clays suggests a high organic matter content, which is essential for petroleum formation. Additionally, the basin's sedimentary section, varying from 4 to 6 kilometres in thickness, provides adequate temperature and pressure for organic matter to reach maturity and generate hydrocarbons.

- **Reservoir Rocks**

The Semliki Basin contains sandstones with grain sizes ranging from medium to very coarse. These sandstones are moderately to well sorted, indicating high porosity and permeability, which are essential properties for good hydrocarbon reservoirs. The sediments overlie highly fractured and jointed basement rocks, providing potential migration pathways for petroleum and enhancing reservoir quality. The high flow rate of water in the Sempaya hot springs (about 10-15 litres per second) also suggests high permeability in subsurface rocks. However, the intercalation of sand and clay layers within the sediments could lead to reservoir compartmentalization, reducing reservoir quality by limiting communication between different reservoir compartments.

- **Traps and Seals**

In the Semliki Basin, potential top seals are provided by impermeable lacustrine claystones interbedded with sandstones and fine-grained lacustrine sequences overlying sandstones. The presence of 20-meter-thick clay beds could act as regional seals, preventing petroleum from escaping the reservoir. However, the presence of oil seeps indicates intervals that are inadequately sealed. Various geological structures observed in the area, such as rollover anticlines, unconformities (both mapped and identified on seismic data), tilted faults, and gypsum-filled joints and fractures, could serve as potential traps for hydrocarbons.

- **Maturation**

High temperatures in the Semliki Basin, as evidenced by hot springs, can facilitate the conversion of organic matter to hydrocarbons and promote their maturation. The geothermal gradient in the basin is sufficient to drive the maturation process, ensuring that organic matter reaches the oil window and generates hydrocarbons.

Conclusion

The Semliki Basin exhibits significant hydrocarbon potential due to the presence of essential elements for a hydrocarbon system: mature source rocks, high-quality reservoir rocks, effective traps, and seals. The geological and geophysical data indicate a viable petroleum system with the potential for hydrocarbon generation, accumulation, and preservation. However, further exploration and detailed analysis are required to fully understand the basin's hydrocarbon potential and address challenges such as reservoir compartmentalization and seal integrity.

7.4. Effect of high temperature on hydrocarbons

High temperatures in the Semliki Basin, exemplified by the Sempaya hot springs in the Buranga geothermal field, can significantly influence the maturation of hydrocarbons through hydrothermal heating. The temperatures at the Sempaya hot springs range from 95°C to 100°C. If low-conductivity rocks are present, they can retain enough heat to facilitate the maturation process. However, if temperatures rise above the oil window range (60°C-120°C), thermal cracking can occur, transforming oil into gaseous hydrocarbons such as carbon dioxide and methane, which results in high API gravity oils. Intense heat can also cause hydrocarbons to undergo coking, producing carbon or coke.

7.5. Effect of structures on hydrocarbons

The Semliki Basin features several major geological structures, including faults, beddings, and joints, which significantly influence the migration and accumulation of hydrocarbons. Faults and joints, formed due to high tectonic activity, are secondary structures impacting the basin's sediments. Faults can serve as migration pathways, facilitating the movement of hydrocarbons from source rocks to reservoirs and potentially leading to surface oil seeps. They can also act as structural traps for hydrocarbons when juxtaposed against sealing materials. Similarly, joints within both basement rocks and sediments can provide migration pathways for hydrocarbons. If these joints are filled with impermeable materials like gypsum or quartz, they can act as traps, preventing hydrocarbon movement. Additionally, unconformities within the sediments can create stratigraphic traps, further aiding in hydrocarbon accumulation. A notable nonconformity exists between the sediments and the underlying base

CHAPTER EIGHT: CONCLUSION AND RECOMMENDATION

8.1. Conclusion

The Semliki Basin, shaped by tectonism, has undergone further structural modifications due to ongoing tectonic activity, impacting the rocks and sediments within the area. These tectonic processes have created structural traps with the potential to accumulate hydrocarbons. Extensive faulting from the basement through to the sediments acts as a trapping mechanism and observed folding within both the sediments and basement rocks can form anticlinal traps. The high geothermal gradient, a result of tectonic activity, explains the presence of mature source rocks within the Albertine Graben despite the relatively young sediments.

Facies studies in the area have identified lacustrine, fluvial, and marginal lacustrine/deltaic paleo-depositional environments. The basement rocks exhibit high-grade metamorphism, indicated by migmatites, shearing, foliation, and mineral banding in the gneisses. Geophysical studies have also confirmed a non-conformity at the basement-sediment contact, crucial for age dating, indicating the presence of young Miocene sediments.

In summary, the geology of the Semliki Basin is predominantly influenced by tectonism, which significantly affects the petroleum system and its potential. The basin shows promising potential for petroleum accumulation, with essential elements of the petroleum system present.

8.2. Recommendations

Field studies are essential for students and lecturers to physically appreciate geology and apply geological principles to understand nature. Therefore, I recommend that the department organize more field studies. Additionally, incorporating seismic surveys of the basin into the field program would enhance participants' understanding of the area's geology beyond just analyzing outcrops.

To improve efficiency, students should be given exercises a semester before the field study, particularly logging and geophysics seismic exercises. This approach would save time and facilitate a better understanding of the field.

Furthermore, the department should strengthen collaboration with oil and gas companies operating in Uganda. These companies can provide valuable support for students' field trips in terms of funding, human resources, and logistical support.

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