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Research Article

Effect of Reservoir Rock Properties on Hydrocarbon Accumulation in Sedimentary Basins

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Abstract

The sedimentary basins have unique geological characteristics and holds different types of sedimentary rocks, such as sandstones, shales, carbonates, and volcanic rocks. Reservoir rocks are the permeable, and porous sedimentary rock, usually composed of carbonates, and sandstones. In the laboratory, the chemical composition, porosity and permeability values of the reservoir rocks are determined using a representative sample that was collected from the study area.During field work, it was discovered that the following fault systems were dominate in the study area. These includes; east-west (E-W) trending faults, northeast-southwest (NE-SW) trending faults, and northwest-southeast (NW-SE) trending faults. A conventional petroleum system commonly includes a source rock, migration pathways, a reservoir rock, a seal, and a trap. Reservoir rocks are commonly porous and permeable sedimentary rocks such as sandstone and limestone.Porosity and permeability are fundamental physical properties of reservoir rocks.In the basin, there is the presence indicators for the potential of oil seeps in different sedimentary basins especially in the Ogaden and Abay basins such as Were Ilu, Mechale, Legehida, and Dengle Ber are few areas in the Abay basin where there are indications of oil seeps.

Keywords

Physical Properties, Reservoir Rocks, Hydrocarbon Formation, Sedimentary Basins, Ethiopia

1. Introduction

The sedimentary basins have unique geological characteristics and holds different types of sedimentary rocks, such as sandstones, shales, carbonates, and volcanic rocks. Reservoir rocks are permeable and porous sedimentary rock, usually composed of carbonates, and sandstones. The source rock in the Abay Basin is predominantly composed of organic-rich shales of the Upper Jurassic-Lower Cretaceous deposits shales were deposited in a deep marine environment and have the potential to generate significant amounts of oil and gas [1].

Seals are rock formations that form an impermeable barrier above the reservoir rock, preventing hydrocarbons from escaping [2, 4].

Trap structures in the Abay Basin may include both structural and stratigraphic traps, such as anticlines and fault blocks.

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The impermeable rock formations such as shale or evaporates act as seals preventing hydrocarbons from escaping [5, 6].

A conventional petroleum system commonly includes a source rock, migration pathways, a reservoir rock, a seal, and a trap. Reservoir rocks are commonly porous and permeable sedimentary rocks such as sandstone and limestone. Their physical properties determine the volume of pore space available for hydrocarbons and the ease with which fluids can flow [8]. Reservoir properties affect hydrocarbon storage and accumulation more directly than hydrocarbon generation.

Ethiopia's sedimentary basins offer significant potential for the extraction and exploitation of hydrocarbons and other minerals, including fuel, oil and geothermal energy [10]. A successful petroleum system depends on the interaction of geological elements and processes. An organic-rich source rock must contain suitable kerogen and attain appropriate thermal maturity to generate petroleum. Hydrocarbons must then be expelled and migrate through viable pathways into a reservoir with adequate porosity and permeability. A suitable trap and effective seal must retain the accumulation, while later geological events must not destroy it.

Therefore, the existence of a reservoir alone does not prove that a petroleum accumulation exists. Successful petroleum exploration requires integrated geological, geochemical, geophysical and basin-history evidence demonstrating source, generation, migration, accumulation, preservation and correct timing.

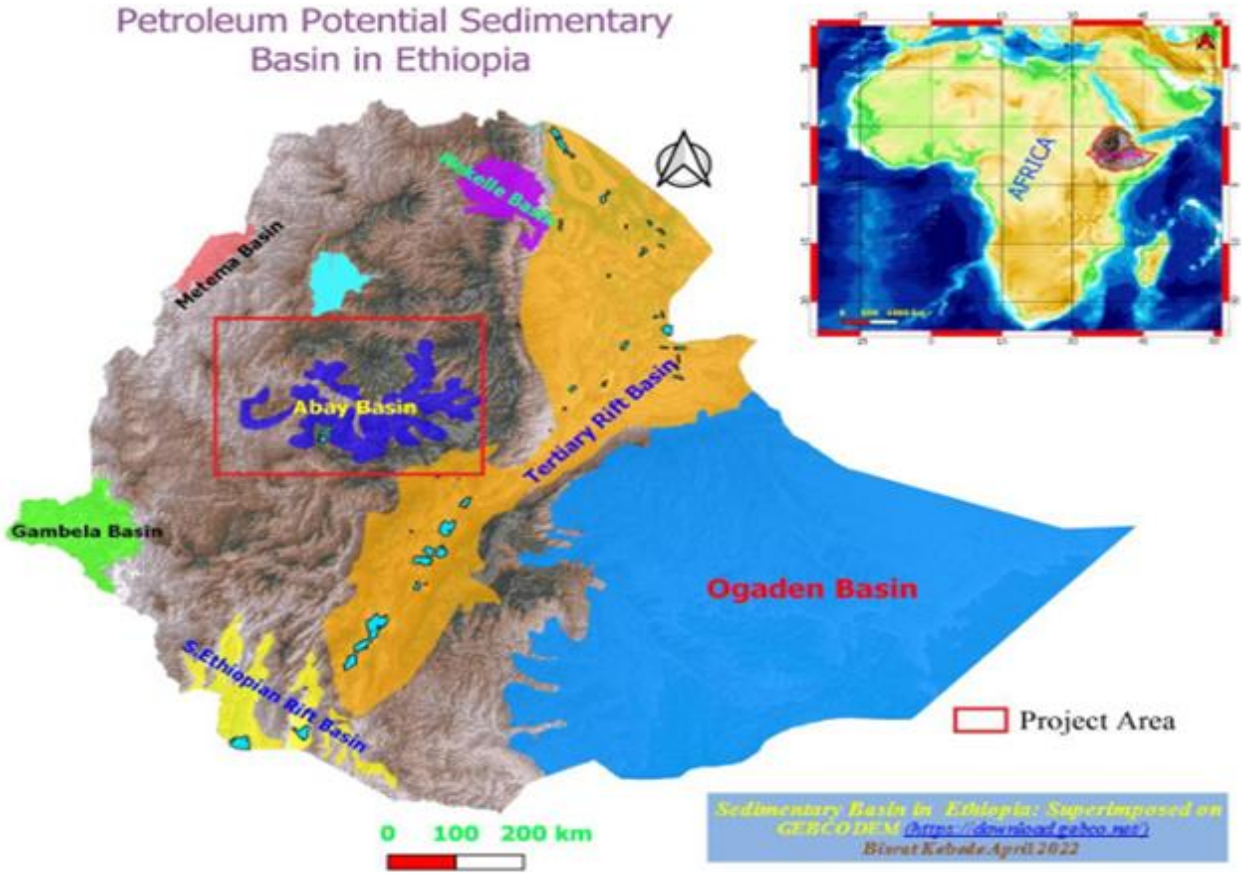

Figure 1. *Prospective Sedimentary Basin of Ethiopia.*

2. Geological Setting of the Basin

The study area is a section of the Ethiopian sedimentary basins, a semi-arid plateau area in the major parts of Ethiopia [3, 9]. The Basins have an extended history of sedimentation, with deposition occurring over the Paleozoic, Mesozoic, and Cenozoic eras. The Cretaceous higher reserve of sedimentary rocks in the basin are the reservoir rocks, which is bedded sandstone, limestone, and other carbonate, characterizes the reservoir rocks of the basin [10]. The structures framework like; faults, folds, joints, and other geological features are influence the movement and accumulation of hydrocarbons.

3. Methodology

3.1. Materials

Table 1. Field materials and their functions.

Equipment	Purposes
Geological hammer	Breaking and collecting representative fresh rock pieces
Hand lens (10x)	Examining grains, cements, pore related features, fractures, and weathering
Rock pick	General field examination and extraction of rock fragments
Shovel	Collecting of loose sediment or unconsolidated reservoir materials
Sampling bag	Containing of individual samples and preventing mixing
Sample labels	Giving each sample a unique identification number
Permanent waterproof marker	Writing sample IDs on bags, tags, and containers
Digital camera	Take photograph of the outcrop, sampling location, and sample before removal
Geographic Positioning System (GPS).	To record the sampling coordinates of the study area
Geological compass	Measuring strike and dip of bedding, joints, fractures, and other structures

3.2. Data Collection

The analysis is used to determine how the physical properties of reservoir rocks such as porosity, permeability, grain size, rock density, specific gravity, water absorption, influence hydrocarbon storage, migration, and accumulation. The following workflow below can be applied to the collected samples that take the study area and send to the laboratory analysis.

The main variables to collect:

Table 2. The physical properties of the reservoir rocks that shows their symbol and purposes.

Variables	Units	Purposes
Depth	m	Compare reservoir properties with burial depth
Lithology	-	Identify sandstone, limestone, shale and etc
Grain size	mm	Evaluate pore geometry and sorting
Porosity (Φ)	%	Estimate pore/storage capacity
Permeability (K)	mD	Evaluate fluid flow capacity
Water absorption (Sw)	%	Estimate water filled pore space
Specific gravity (γ)	-	Determine the density of the rocks

The high porosity generally provides more pore volume for storing fluids, while high permeability generally indicates better connected flow pathways. However, porosity alone does not guarantee good reservoir performance. The cementation, compaction, clay content, fractures, and digenesis can strongly modify the permeability and porosity of the reservoir rocks.

3.3. Sample Collection

The reservoir rock samples are collected from the basin, which are important to determine the physical properties of the reservoir rocks.

To gather the samples and take the regular data from the study area. The representative samples are sending to the laboratory, and determine the quality of reservoir rock properties that includes; porosity, permeability, and the chemical composition. The fifteen better reservoir rock samples have been taken from different place of sedimentary (Abay Basin) outcrops. The samples were prepared for three different analyses: The all samples were used to measure the rocks porosity and permeability, and these samples were used to assess their chemical composition.

Table 3. *The measurement locations of collected samples, measuring of dykes, strike and dip direction of the study area during field work.*

No.	Sample code	Reading					
		Easting (º)	Northing (º)	Strike (º)	Dip (º)	Altitude (m)	Depth (m)
1	SS_1	0547392	1214515	N15E	N65	2044	2
2	SS_2	0547392	1214515	N15E	N65	2044	2
3	SS_3	0547160	1226551	N5E	N60	2150	1
4	SS_4	0547090	1276725	N50E	N20	1860	1
5	SS_5	0547100	1276720	N40E	N10	1865	2
6	SS_6	0547120	1276715	N35E	N15	1867	1
7	SS_7	0547130	1276710	N20E	N10	1870	1
8	SS_8	0547140	1276055	N15E	N5	1875	2
9	SS_9	0547395	1214625	N10E	N10	2050	1
10	SS_{10}	0547310	1214530	N5E	N15	2055	2
11	SS_{11}	0547155	1214550	N10E	N20	2145	1
12	SS_{12}	0547170	1214580	N20E	N30	2155	1
13	SS_{13}	0547365	1214600	N15E	N25	2165	2
14	SS_{14}	0547150	1276155	N15E	N5	1880	1
15	SS_{15}	0547170	1276250	N10E	N10	1885	2

3.4. Laboratory Analysis

The method is important to determine chemical compositions, the porosity, and the permeability values of the reservoir rocks, which are primarily composed of silica (SiO_2) with smaller amounts of aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3). These results will be considered the physical properties of the upper sandstone reservoir rocks of the basin.

Table 4. *The physical properties of Upper Sandstone reservoir rocks.*

No.	Description	Samples code														
		SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9	SS_{10}	SS_{11}	SS_{12}	SS_{13}	SS_{14}	SS_{15}
1	Unit weight rock (g/cc)	1.62	1.70	1.65	1.71	1.65	1.72	1.80	1.61	1.75	1.65	1.71	1.76	1.68	1.72	1.76
2	Specific gravity	1.90	1.89	1.85	1.88	1.92	1.89	1.88	1.79	1.75	1.80	1.86	1.91	1.93	1.84	1.82

No.	Description	Samples code														
		SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8	SS_9	SS_{10}	SS_{11}	SS_{12}	SS_{13}	SS_{14}	SS_{15}
3	Water absorption (%)	20.98	23.02	21.85	22.10	21.00	22.05	23.15	21.5	22.35	20.50	20.65	23.10	21.25	23.001	22.25
4	Porosity (%)	32.31	34.35	33.25	302.6	34.40	32.50	35.00	33.25	34.35	32.60	34.45	32.50	35.00	32.35	33.25

3.4.1. Porosity (Φ) Determination

The sandstone reservoir rocks have a porosity value that ranges from 10% to 40% [7]. Although there are a number of direct and indirect methods for estimating reservoir porosity, the direct method is used in this project to determine the porosity value.

Table 5. Porosity quality based on porosity range [7].

Porosity range (%)	Porosity quality
0 - 5	Negligible
5 - 10	Poor
10 - 15	Fair
15 – 20	Good
20 – 25	Very good (maximum carbonate reservoir rocks
10 – 40	Very good (in sandstone reservoir rocks)

A. Direct methods

In this method, the analysis of the physical properties of the sandstone rocks that are on the top, such as the bulk unit weight values, porosity value, specific gravity value, water absorption value, etc., is to be done.

Table 6. The porosity value of the Upper Sandstone reservoir rock.

No.	Sample Codes	Porosity value (%)
1	SS1	32.31
2	SS2	34.35
3	SS3	33.25
4	SS4	32.60
5	SS5	34.40
6	SS6	32.50
7	SS7	35.00
8	SS8	33.25
9	SS9	34.35
10	SS10	32.60
11	SS11	34.45
12	SS12	32.50
13	SS13	35.00
14	SS14	32.35
15	SS15	33.25

3.4.2. Permeability (K) Estimation

The shortage of the laboratory, we could be evaluate the permeability value of the upper sandstone rocks were by using the mathematical correlation of porosity and permeability [7]. The tasks are conducting by using the indirect method to calculate the permeability value of the rocks.

Table 7. Reservoir permeability classification [7].

Permeability Value (mD)	Classification
1 – 10	Poor
10 – 100	Fair
100 - 100	Good
>1000	Excellent

B. Indirect Methods

The application of empirical correlations can yield rapid estimates of permeability for initial examination when direct or laboratory methods are not available to collect permeability data. The following formula represents the relationship between permeability and porosity [7].

$$K = 19.17 * e0.14 *\Phi \quad (1)$$

Where K is Permeability and Φ is Porosity of the reservoir rocks.

Table 8. The permeability values of the Upper Sandstone rocks (correlation).

No.	Sample Codes	K = 19.17* e0.14*Φ	
		Porosity value (%)	Permeability value (mD)
1	SS1	32.31	1766
2	SS2	34.35	2350
3	SS3	33.25	2015
4	SS4	32.60	1840
5	SS5	34.40	2367
6	SS6	32.50	1814
7	SS7	35.00	2574
8	SS8	33.25	2015
9	SS9	34.35	2350
10	SS10	32.60	1840
11	SS11	34.45	2384
12	SS12	32.50	1814
13	SS13	35.00	2574
14	SS14	32.35	1776
15	SS15	33.25	2015

Porosity and permeability are fundamental physical properties of reservoir rocks. Porosity controls the amount of pore space available to store formation fluids, while permeability describes how easily fluids can move through interconnected pores and fractures. Therefore, they are strongly influence hydrocarbon migration, accumulation, storage, and production.

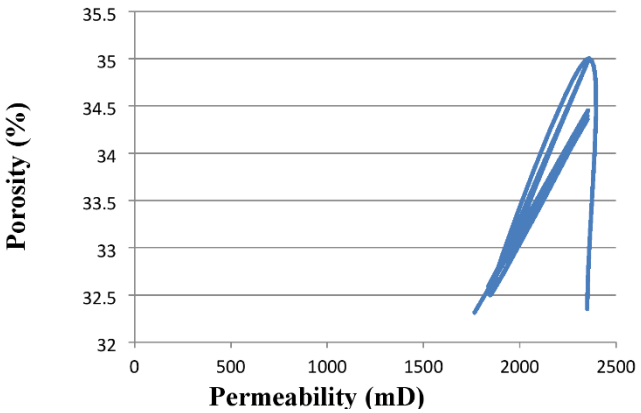

Figure 2. Porosity vs Permeability graph (Correlation).

The resulting structural map is a crucial tool for understanding the geological context of the region, identifying potential hazards and opportunities and informing decision- making and planning activities.

The following processes are used to generate the structural map of the study area:

Step 1. Take the (x, y) coordinate reading of the area by using GPS

Step 2. Measure the strike and the dip direction and obtain the values of the structures

Step 3. Measure the joint space values of the structures

Step 4. Insert all the known and collected values into the system and analysis by using

ArcGIS version 10 application

Step 5. Label the structures such as faults, lineaments, lakes, towns, dykes and water bodies by different color in the system

Step 6. Finally by using the ArcGIS system we can prepare the structural map at a scale of 1:50,000.

For analysis and the creation of the map layout, the Geographic Information System (ArcGIS® version 10) of the ESRI was used.

The areas of engineering structural map are created by ArcGIS 10 ® which is used to create the maps at a scale of 1:50,000.

4. Results and Discussion

The reservoir characteristic of the basin is the physical characteristics of the Upper Cretaceous Amba Aradam deposit (Upper Sandstone) rock.

Compared to the sandstone rocks, the limestone reservoir rocks in the study area cover a greater surface area. The physical characteristics of the sandstone reservoir rocks include their texture, colour, grain size, shape, and roundness. The following chemical analysis of reservoir rocks, the research area's upper sandstone rock frequently has light white colour and fine to medium-to-coarse grains with major and minor elements like SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, MnO, K_2O, P_2O_5, TiO_2, and H_2O.

The laboratory study found that the porosity values of the rocks in the Abay basin's Sandstone reservoir range from 32.31 to 35.00% (Table 8). The findings indicate that the upper sandstone rocks have good reservoir characteristics for the formation of hydrocarbons, with permeability values ranging from 1766 to 2574 mD (Table 8). Were Ilu, Mechale, Legehida, and Dengle Ber are a few locations in the Abay Basin where there are signs of possible oil spills.

4.1. Field Description of the Reservoir Rocks of the Basin

My project work focused on the effects of physical properties of reservoir rocks, such as their porosity and permeability values. The measurements will provide crucial information regarding the rocks in the Sandstone reservoir's suitability for hydrocarbon exploration and production. The project's efforts would increase our understanding of the hydrocarbon resource potential of the basin.

The amount of sand in upper sandstone rock determines its porosity and permeability, which in turn determines its reservoir rock capacity. Quartz grains, which are almost as big as sand or silica cement, make up the majority of the best sandstone reservoirs. This suggests that the Sandstone rock in the basin might be a great reservoir rock for the buildup of hydrocarbons.



Figure 3. *The carbonate reservoir rocks, light grey, fine to medium grained taken from the study area.*



Figure 4. *The Sandstone reservoir rocks, pink color, fine to medium grained taken from the study area.*

The physical properties of the sandstone reservoir rocks have a moderate to high porosity because they contain few fragmented particles and well-packaged quartz grains. Based on the laboratory result, the porosity and permeability value can be found between 32.31-35.00%, and 1766-2574 mD respectively. The Ethiopian Construction Design and Supervision Works Corporation and the Geological Survey of Ethiopia's Geochemical Laboratory conducted these tests.

In the study area, the upper sandstone rock formation is primarily light white and grey in color. Both the size and form of the grains and the arrangement of the framework grains of detrital components define the texture of the upper sandstone rocks in the Basin.



Figure 5. *The coarse sandstone reservoir rock of the Abay basin.*



Figure 6. *The carbonate reservoir rocks, brown color, fine to medium grained taken from the study area.*

4.2. Physical Properties of Reservoir Rocks

The sandstone reservoir rocks have a porosity value that ranges from 10% to 40%, and the permeability value is found between 1766 mD and 2574 mD. Although there are a number of direct and indirect methods for estimating reservoir porosity, and the permeability value. The direct method is used in this project to determine the porosity value.

In this method, the analysis of the physical properties of the sandstone rocks that are on the top, such as the porosity value

is to be done. The application of empirical correlations can yield rapid estimates of permeability for initial examination when direct or laboratory methods are not available to collect permeability data.

4.3. Chemical Composition of Reservoir Rocks

Determining the chemical composition of the reservoir rocks in the Abay Basin is important as it helps to identify the types and proportions of minerals and elements present.

To determine the chemical composition of the reservoir rocks, representative samples were collected from the study area.

The following chemical analysis of reservoir rocks, the research area's upper sandstone rock frequently has light white color and fine to medium-to-coarse grains with major and minor elements like SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, and MnO, K_2O, P_2O_5, TiO_2 respectively and also composed of volatiles(H_2O).

Table 9. Chemical properties of reservoir rocks taken from the laboratory.

No.	Sample codes	Composition of upper sandstone											Weight of samples
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_3O_5	TiO_2	H_2O	(Kgs)
1	SS_1	65.40	15.58	4.12	1.52	0.60	1.76	2.20	0.08	0.14	0.21	1.57	1.3
2	SS_2	65.58	16.50	4.25	1.40	0.45	1.50	2.25	0.09	0.25	0.24	1.50	1.3
3	SS_3	68.10	15.50	2.50	0.50	0.15	1.50	2.35	0.005	0.20	0.30	1.60	1.3
4	SS_4	66.55	14.70	3.50	1.15	0.12	1.35	2.05	0.075	0.17	0.25	1.70	1.3
5	SS_5	64.80	15.68	5.15	0.75	0.025	1.10	2.50	0.05	0.13	0.12	1.80	1.3
6	SS_6	69.25	13.90	2.50	0.55	0.012	1.005	1.90	0.025	0.11	0.34	1.68	1.3
7	SS_7	66.50	14.25	3.40	1.12	0.10	1.11	1.95	0.07	0.18	0.22	1.75	1.3
8	SS_8	65.80	17.50	2.75	0.95	0.05	1.00	2.05	0.09	0.16	0.19	1.80	1.3
9	SS_9	66.70	14.75	3.15	1.15	0.01	0.75	2.25	0.01	0.12	0.18	1.65	1.3
10	SS_{10}	65.90	15.55	2.15	0.55	0.005	0.55	1.99	0.04	0.19	0.20	1.70	1.3
11	SS_{11}	66.50	13.55	2.45	1.05	0.05	0.45	1.85	0.05	0.15	0.18	1.60	1.3
12	SS_{12}	63.85	15.55	3.25	0.85	0.025	0.65	2.00	0.01	0.18	0.25	1.75	1.3
13	SS_{13}	65.65	13.67	3.005	1.15	0.05	0.50	1.95	0.06	0.20	0.15	1.68	1.3
14	SS_{14}	64.75	14.85	2.95	0.65	0.005	0.55	1.75	0.05	0.14	0.19	1.80	1.3
15	SS_{15}	62.90	14.65	4.10	0.70	0.05	0.60	2.10	0.02	0.16	0.20	1.85	1.3

4.4. Factors Controlling Reservoir Rock Properties

Grain size and sorting: the well-sorted sediments can preserve substantial intergranular pore space. Poorly sorted sediments contain smaller grains that fill spaces between larger grains, commonly reducing porosity. The grain shape and packing arrangement affects the amount of void space. Compaction during burial rearranges grains and generally reduces porosity. Compaction has its own effects on reservoir properties like; increasing burial stress can deform grains, close pores, and reduce pore volume. In cementation, the minerals such as quartz, calcite, and clay may precipitate in pores and reduce available pore space, as well as in the dissolution process; the removal of soluble minerals can create secondary pores and sometimes increase porosity. Fracturing and clay content have also their geologic effects for the reservoir properties create additional voids and flow pathways, particularly important in low-matrix-porosity rocks and may occupy pore space and can also produce very small pore throats, strongly affecting permeability respectively.

4.5. Effects of Porosity and Permeability on Hydrocarbons

Higher effective porosity and higher permeability, generally increases the volume of pore space available for oil and

gas storage, which provides better pathways for hydrocarbon migration and reservoir flow. The low-permeability rocks can act as seals and restrict hydrocarbon escape. Compaction and cementation also commonly reduce porosity and permeability with burial but dissolution and fracturing may create or improve secondary pore space and flow pathways. The more connected pore volume can increase the amount of hydrocarbon a reservoir can contain, for comparable geometry and saturation. Compaction and Cementation are commonly reduces porosity as grains rearrange and pore spaces collapse and minerals precipitated in pore spaces can reduce available pore volume. Migration is the permeable pathways that help hydrocarbons move from source rocks toward reservoir rocks.

4.6. Effects on Hydrocarbon Formation and Accumulation

4.6.1. Hydrocarbon Generation and Expulsion

Hydrocarbons are generated mainly in organic-rich source rocks during burial and thermal maturation. The Porosity and permeability of the source and surrounding rocks influence whether generated fluids can occupy pore spaces and escape from the source interval. Low permeability can delay expulsion, while fractures or overpressure can provide additional migration pathways.

4.6.2. Primary Migration

Primary migration is movement of hydrocarbons from source-rock pore systems into adjacent carrier beds or reservoir pathways. The very small pores and low permeability typical of many source rocks mean that pressure, buoyancy, capillary forces, compaction flow, and fractures can be important.

4.6.3. Secondary Migration

Secondary migration occurs after hydrocarbons enter more permeable carrier rocks. Higher permeability and connected pore networks generally facilitate movement over geological distances. Buoyancy tends to drive hydrocarbons upward relative to formation water, while capillary forces and bedding architecture influence the actual pathway.

4.6.4. Hydrocarbon Accumulation

A reservoir must provide sufficient connected pore volume to store hydrocarbons and sufficient permeability to allow migration into and movement within the accumulation. A trap commonly combines a reservoir rock with a seal that has extremely low permeability, preventing further upward escape.

4.6.5. Reservoir Pressure and Production

Permeability strongly affects well productivity. High permeability usually allows fluids to reach a well more easily, whereas low permeability may require stimulation, horizontal wells, or other engineering approaches. Porosity influences the volume of fluids in place, but production depends on connectivity, pressure, saturation, fluid properties, and relative permeability as well.

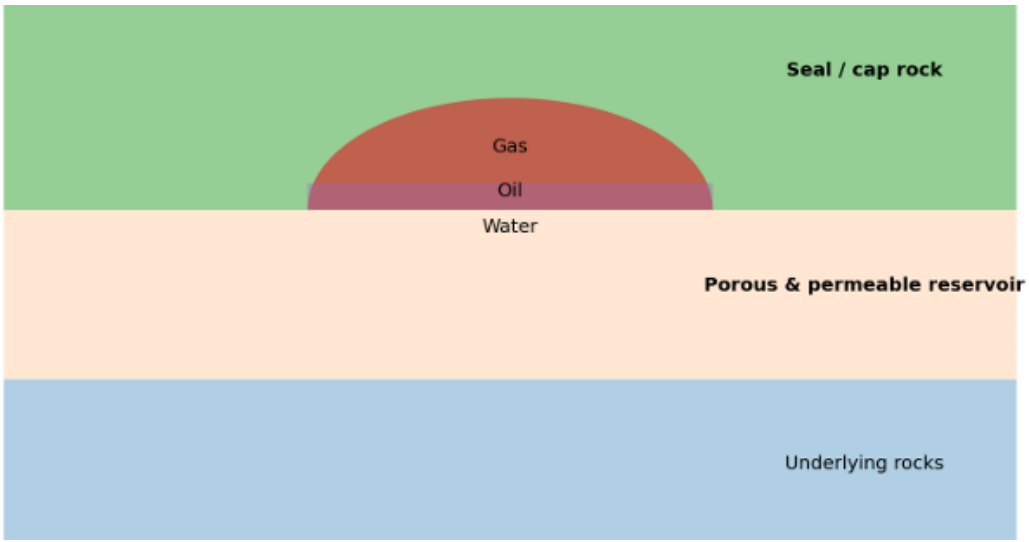

Figure 7. *Hydrocarbon accumulation in the reservoir trap.*

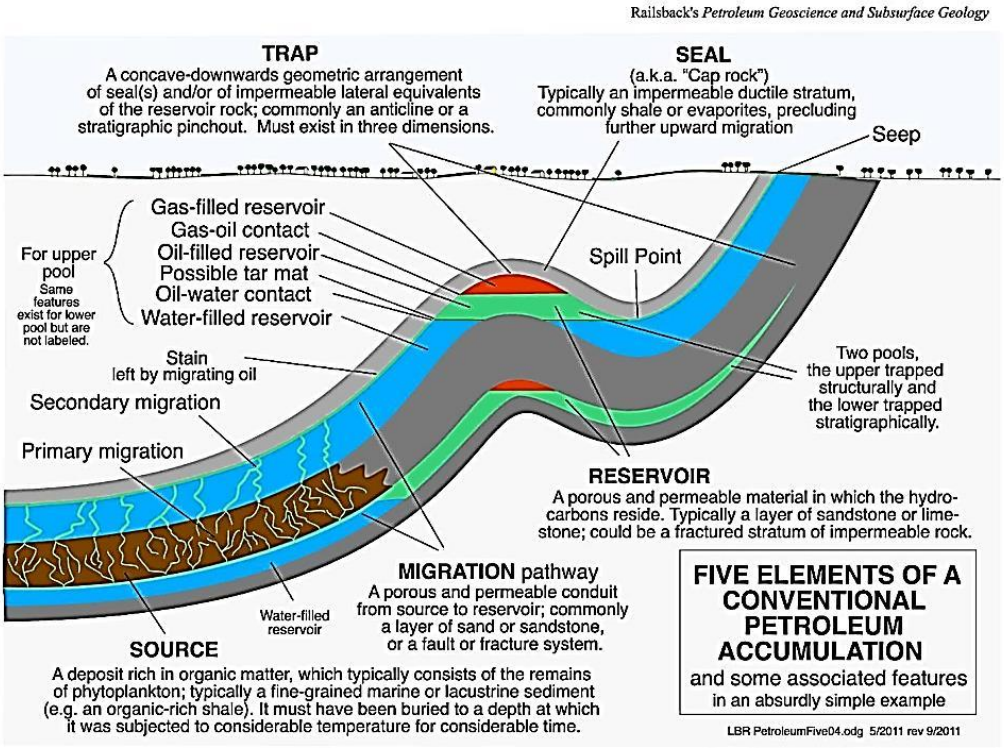

Figure 8. *Conceptual cross-section showing source rocks, migration pathways, reservoir rocks, seals and hydrocarbon traps.*

The source rock generates hydrocarbons after sufficient burial and heating. Oil and gas move through permeable rocks, fractures or faults and may accumulate in a porous reservoir beneath an impermeable seal. A suitable trap and correct timing are necessary for a commercially significant accumulation to form.

4.6.6. Effective Source Rocks

A source rock is a sedimentary rock containing organic matter that can generate oil or natural gas when subjected to suitable burial, temperature, and pressure conditions. The common source rocks include organic-rich shale, mudstone, and some carbonate rocks. The organic matter is commonly derived from algae, plankton, and terrestrial plants. The source rock must contain suitable organic matter and reach sufficient thermal maturity to generate hydrocarbons.

4.6.7. Organic Richness

Organic richness refers to the quantity of organic carbon present in a rock. It is commonly evaluated using total organic carbon (TOC), expressed as a percentage by weight. TOC is measured using laboratory geochemical analysis. Higher TOC can indicate greater hydrocarbon-generating potential, depending on organic-matter quality and maturity. The source-rock richness is assessed together with kerogen type and thermal maturity.

4.6.8. Kerogen Type

Kerogen is the insoluble organic matter in sedimentary rocks from which hydrocarbons can form during burial and heating.

1) Type I: Commonly algal; generally has high oil-generating potential.
2) Type II: Commonly associated with marine organic matter; can generate oil and gas.
3) Type III: Commonly derived from terrestrial plant material; tends to favor gas generation.
4) Type IV: Highly oxidized or inert organic matter; generally has very low hydrocarbon-generating potential.

4.6.9. Thermal Maturity

Thermal maturity describes the degree to which organic matter has been altered by geological heating during burial.

1) Immature source rocks have not generated significant thermogenic hydrocarbons.
2) Mature source rocks may generate and expel oil or gas.
3) More advanced maturity commonly favors gas generation, although the outcome depends on organic-matter type and geological history. Maturity can be assessed using vitrinite reflectance, Rock-Eval pyrolysis, and other geochemical indicators.

4.6.10. Generation Timing

Generation timing concerns when a source rock generated and expelled hydrocarbons during the basin's geological history. Burial progressively increases temperature and pressure. Hydrocarbon generation begins when suitable maturity conditions are reached. Generation and expulsion must be evaluated

relative to the development of traps and migration routes.

4.6.11. Migration of Hydrocarbons

Migration is the movement of oil and natural gas from source rocks toward reservoir rocks. Primary migration: Hydrocarbon expulsion from the source rock. Secondary migration: Movement through permeable carrier beds, faults, fractures, or connected pore networks. Buoyancy, pressure differences, and capillary forces influence migration.

4.6.12. Structural Trap

A petroleum trap is a geological configuration that permits hydrocarbons to accumulate and remain in a reservoir beneath a seal. The principal trap types are structural, stratigraphic and combination traps.

A. Structural trap

The structural trap is formed by deformation such as folding or faulting. An anticline may create a dome-shaped reservoir beneath a seal.

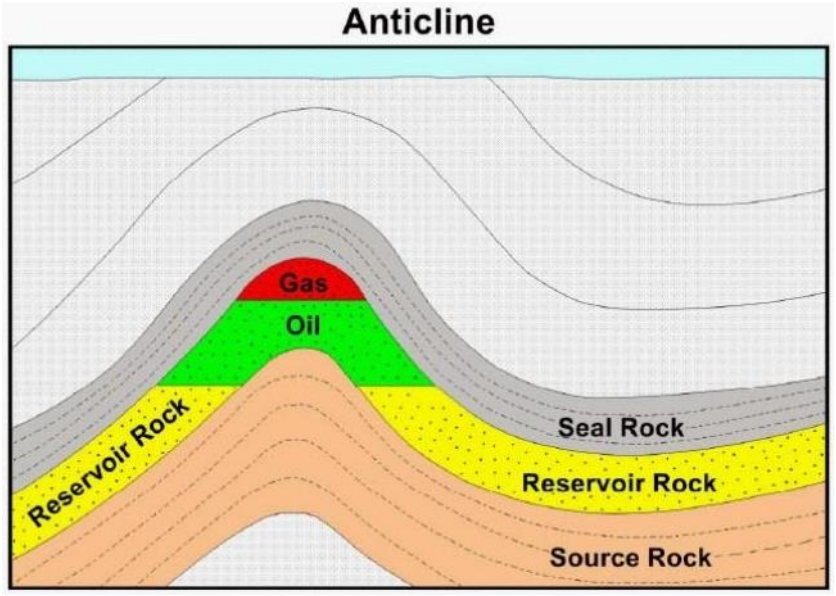

Figure 9. *The structural trap on petroleum configurations.*

B. Stratigraphic trap

The trap is also formed by changes in rock properties or geometry, such as a sandstone pinch-out, unconformity or reef.

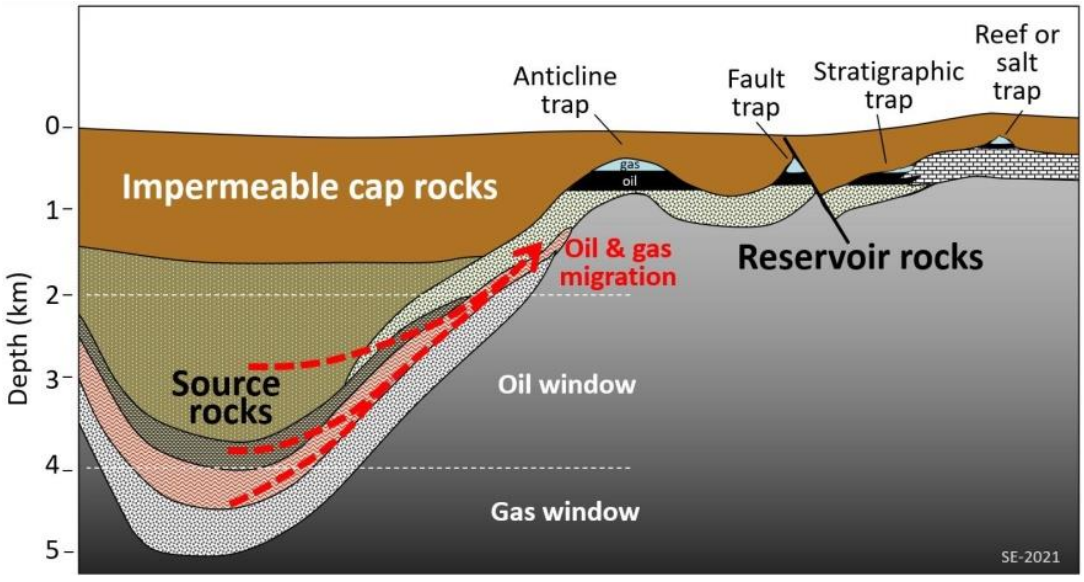

Figure 10. *The stratigraphic trap on petroleum configurations.*

C. Fault-related or combination trap

A fault, fold or stratigraphic boundary can work together with a seal to create a hydrocarbon accumulation. A successful trap generally needs; Reservoir rock with adequate storage and flow properties, a seal above or around the reservoir, a closed or otherwise effective trapping geometry, a viable hydrocarbon charge and migration route, and formation and sealing at an appropriate time.

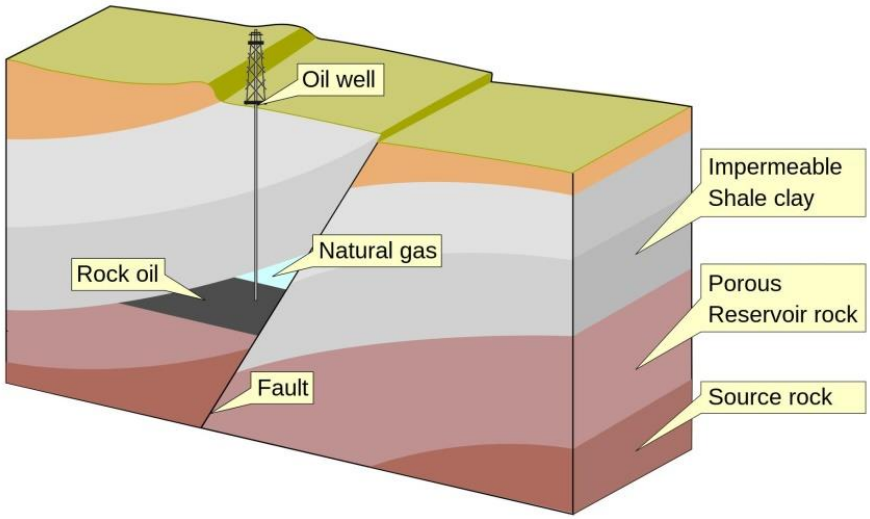

Figure 10. *The stratigraphic trap on petroleum configurations.*

4.7. Types of Reservoir Rocks

4.7.1. Carbonate Reservoirs

Carbonate reservoirs can be especially heterogeneous. Porosity may be inter particle, intra particle, and fracture-related. Dissolution can increase pore volume, while cementation and compaction can destroy it. Because pore systems may be poorly connected, permeability can vary dramatically over short distances. This makes carbonate reservoir characterization dependent on both matrix properties and fractures.

4.7.2. Sandstone Reservoirs

Sandstone reservoir quality is strongly influenced by grain size, sorting, packing, clay content, compaction, and cementation. Clean, well-sorted sandstones commonly have relatively good intergranular porosity and permeability. Fine-grained or clay-rich sandstones may retain pore volume but have very small pore throats, producing low permeability.

4.7.3. Unconventional Reservoirs

Some shale, tight sandstone, and other unconventional reservoirs contain hydrocarbons despite very low matrix permeability. Their storage and flow behavior can involve nanometer-scale pores, organic-matter pores, natural fractures, and induced hydraulic fractures. In these systems, conventional porosity–permeability interpretations are insufficient by themselves; pore-size distribution, organic-matter content, saturation, stress sensitivity, and fracture networks are also important.

4.8. Field Structural Mapping of the Study Area

The faulting and fracturing patterns are affecting the migration of hydrocarbons that can be produced by the NW-SE and NE-SW faults. The fault system may also offer helpful information for locating possible locations for the exploration of resources, such as minerals and hydrocarbons. The resulting structural map is an essential tool for study the region's geological formation.

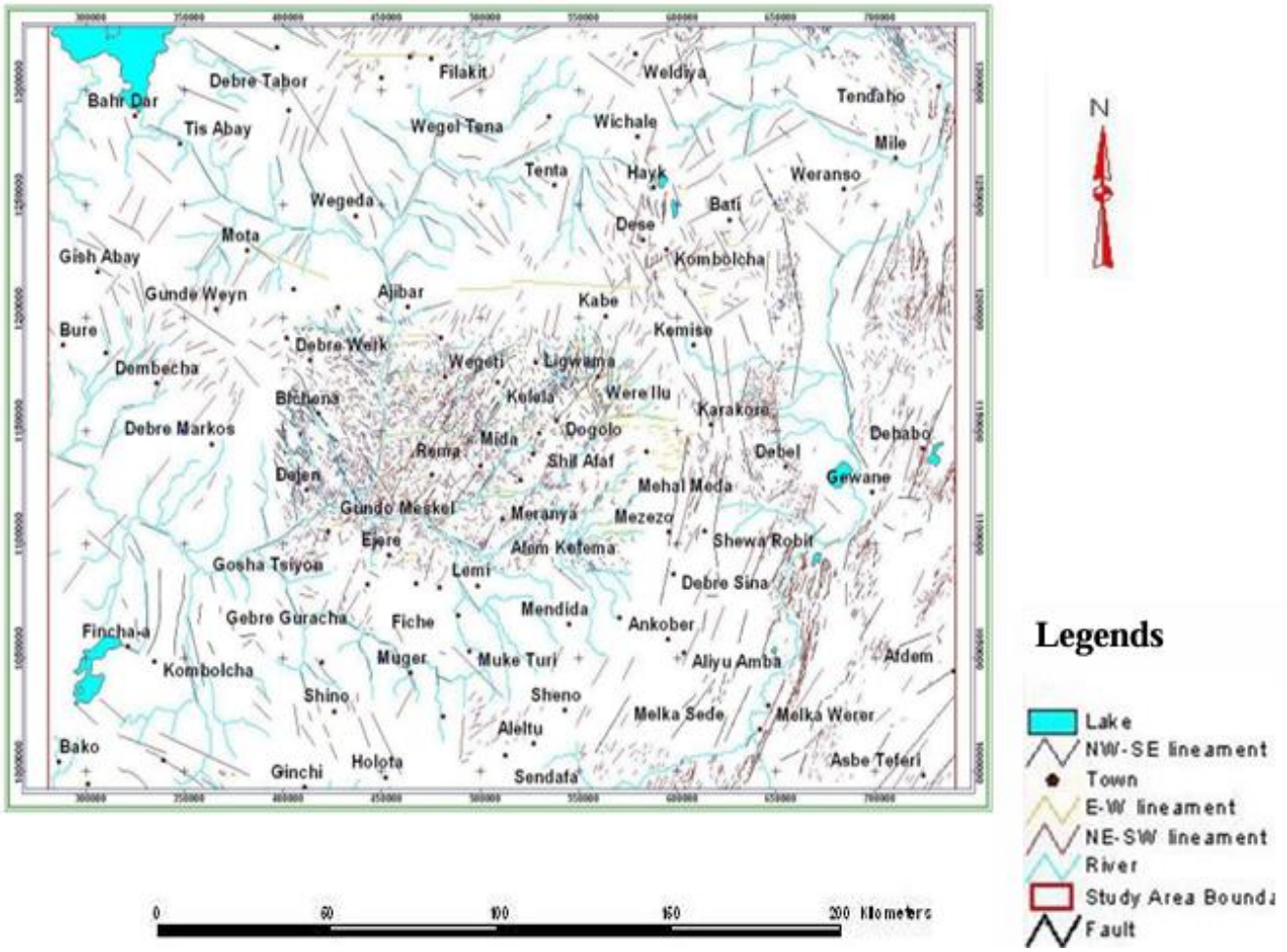

Figure 11. *Structural Map of the study Area.*

4.9. Hydrocarbon Potential of the Abay (Blue Nile) Basin

The reservoir rocks in the Abay Basin appear to have ideal reservoir qualities for the accumulation of hydrocarbons. The basaltic flows intercalated with late Cretaceous strata may also serve as an excellent reservoir.

Regarding to the indicators of oil seeps in the Abay Basin, the areas of Were Ilu, Mechale, Legehida, and Dengle Ber all show signs of oil seeps. Were Ilu has been specifically selected as the area of focus for this project work.

The physical properties of the upper sandstone reservoir rocks found in the basin has similar characteristic within the other basin.

There is strong evidence of a petroleum system in the Abay Basin at Were Ilu area. The presence of a petroleum system in the Abay Basin of the Ethiopian Plateau is demonstrated by the reservoir rocks described above at the Were Ilu Oil Seep Site. The ratio of sandstone's porosity and permeability indicates, there may be the presence of hydrocarbon formation in the basin as well as Were Ilu area.

A successful petroleum system depends on the interaction of geological elements and processes. An organic-rich source rock must contain suitable kerogen and attain appropriate thermal maturity to generate petroleum. Hydrocarbons must then be expelled and migrate through viable pathways into a reservoir with adequate porosity and permeability. A suitable trap and effective seal must retain the accumulation, while later geological events must not destroy it.

Therefore, the existence of a reservoir alone does not prove that a petroleum accumulation exists. Successful petroleum exploration requires integrated geological, geochemical, geophysical and basin-history evidence demonstrating source, generation, migration, accumulation, preservation and correct timing.

5. Limitations

The structural layout of the basin, the political issue, the absence of drilled wells, the existence of documented resources relating to the basin, and other challenges I faced on the field made it challenging for me to finish my work in the basin. Generally speaking, while I prepared this project work, the following factors limited my responsibilities:

The lack of a laboratory measurement of the reservoir rocks' permeability and total organic carbon content based on correlation which may be limit the results' accuracy levels.

The absence of seismic and other geophysical data makes it impossible to accurately describe the basin's structural features.

There is no wells have been dug in the basin and no well data, which is difficult to get core samples.

6. Conclusions

The sedimentary basins have unique geological characteristics and holds different types of sedimentary rocks, such as sandstones, shale's, carbonates, and volcanic rocks. The analysis is used to determine how the physical properties of reservoir rocks such as porosity, permeability, grain size, rock density, specific gravity, water absorption, influence hydrocarbon storage, migration, and accumulation.

The representative samples are send to the laboratory, and determine the quantity of reservoir rocks properties that includes; porosity, permeability, and the chemical composition.

Higher effective porosity and higher permeability, generally increases the volume of pore space available for oil and gas storage, which provides better pathways for hydrocarbon migration and reservoir flow.

My project work focused on the effect of reservoir rock Properties on Hydrocarbon accumulation in sedimentary basins, such as their porosity and permeability values. The reservoir rocks, which have average values of 33.5% porosity and 2100mD permeability that are crucial for the accumulation of hydrocarbons in the basin.

The faulting and fracturing patterns are affecting the migration of hydrocarbons that can be produced by the NW-SE and NE-SW faults.

A successful petroleum system depends on the interaction of geological elements and processes. An organic-rich source rock must contain suitable kerogen and attain appropriate thermal maturity to generate petroleum. Hydrocarbons must then be expelled and migrate through viable pathways into a reservoir with adequate porosity and permeability. A suitable trap and effective seal must retain the accumulation, while later geological events must not destroy it.

Therefore, the existence of a reservoir alone does not prove that a petroleum accumulation exists. Successful petroleum exploration requires integrated geological, geochemical, geophysical and basin-history evidence demonstrating source, generation, migration, accumulation, preservation and correct timing.

Abbreviations

E	East
GIS	Geographic Information System
GSE	Geological Survey of Ethiopia
GPS	Geographic Positioning System
K	Permeability
Kg	Kilogram
M	Meters
Mm	Milimeters
mD	Millidarcy
MoM	Ministry of Mines
N	North
NE	North East
NW	North West
S	South
SE	South East
SW	South West
S_w	Water absorption
TOC	Total Organic Carbon Content
γ	Specific Gravity
Φ	Porosity

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Author Contributions

Seid Endrie: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft

Ketsela Tadesse: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing

Yimam Ali: Data curation, Formal Analysis, Investigation, Validation, Visualization, Writing – review & editing

Conflict of Interest

The authors declare no conflicts of interest.

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