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Identification of Upper Sandstone Reservoir Rocks, Properties and Structural Mapping of the Abay Basin for Petroleum Exploration

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ABSTRACT

The Abay Basin covers a sizable area of the country. It includes Were Ilu, Mechale and Legehida, which have notable oil seep exhibits. In order to undertake the experimental tests for this study, samples are gathered from the field and sent to laboratory centers. 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. Based on the results of the experiments, the reservoir rock for the Abay (Blue Nile) Basin formation is an Upper Sandstone reservoir rock with relatively good porosity and excellent permeability. The Upper Sandstone rocks in the Abay basin have porosity values that range from 32.31 to 34.35% and permeability values that range from 1766 to 2350 mD, which suggests that the reservoir quality is generally very good (porosity)and excellent permeability. The presence of a petroleum system in the Abay Basin is strongly supported by the oil seepage at Were Ilu. The study area is characterized by rough structures and the basin requires further study regarding the main hydrocarbon fluids reservoir rocks, the total organic carbon contents of the source rocks and the carbonate reservoir rocks.

Keywords: Upper sand stone; Reservoir rocks; Structural mapping; Petroleum exploration; Abay basin

Introduction

The Abay (Blue Nile) Basin is located in the northwestern part of the country and covers an area of over 63,000 square kilometres. It is primarily composed of sandstones, shales and volcanic rocks that were deposited during the Mesozoic and Cenozoic eras. This basin also contains significant hydrocarbon reserves and several exploration companies are actively exploring the area[1,2]. The numerous investigations were conduct in the Abay Basin like geological structure, geomorphology and geological set up have been made and estimation of the source rocks were also made in the basin[3-5]. The several researches were conduct based on their stratigraphic and structural development of the northwest plateau of the Abay Basin[6]. Overall, the sedimentary basins of Ethiopia hold significant potential for the exploration and development of oil, gas, geothermal energy and other mineral resources and its hydrocarbon potential[7,8]. The source rock in the Abay Basin is predominantly composed of organic-rich shales of the Upper Jurassic-Lower Cretaceous deposits.

These shales were deposited in a deep marine environment and have the potential to generate significant amounts of oil and gas. Geochemical analyses of the source rocks have shown that they have good to excellent oil-prone and gas-prone properties[9]. Besides the source rocks, the Abay Basin also contains several potential reservoir rocks such as sandstones and carbonate rocks of the Mesozoic and Cenozoic deposits. These reservoir rocks have good porosity and permeability properties, making them suitable for hydrocarbon accumulation[10]. Despite the potential for hydrocarbon exploration in the Abay Basin, they have been few exploration activities conducted in the area, primarily due to geopolitical instability and a lack of investment in the oil and gas sector. However, recent changes in the government's policies have led to increased interest from international oil companies and several exploration blocks have been awarded to companies for exploration activities[11,12].

In conclusion, while, the Abay Basin has not been extensively explored for hydrocarbons, preliminary studies suggest that it has significant potential for oil and gas exploration. Further exploration and evaluation activities are needed to confirm the hydrocarbon potential and identify commercial reserves in the basin[5].

This study proposes to document some information about the source rocks characteristics which have their own contribution for the formation of hydrocarbon resources in the reservoir rocks to accumulate the oil and gas resources through it and economic potential of the central portion of the Abay sub- basin of Were Ilu area[13]. The current Upper Sandstone reservoir rocks identification and structural mapping of Abay Basin is conducting the detail study of the reservoir rocks properties and making the structural mapping of the area in the basin analysis[14]. Reservoir rocks are porous and permeable rocks where hydrocarbon fluids accumulate and can be economically recovered. Traps are geological structures that prevent hydrocarbons from continuing their migration and hold them within the reservoir rock[15]. These structures can take different forms such as anticlines, faults or stratigraphic traps. Seals are rock formations that form an impermeable barrier above the reservoir rock, preventing hydrocarbons from escaping. Trap structures in the Abay Basin may include both structural and stratigraphic traps, such as anticlines and fault blocks.

The Impermeable rock formations such as shale or evaporites act as seals preventing hydrocarbons from escaping[16].

Methodology

Materials

The materials and the equipment that are require to conduct the project works during and after the field works includes; Geographic Position System (GPS), digital camera, stationary materials, sleeping bag, pen, geologic hammer and sample bag etc.

Data

The data on the Upper Sandstone reservoir rock could be gathered from previous researchers and written materials in order to build a relevant relationship between the types of reservoir rocks and structural mapping of the study area. The following is a list of the many data sections found in data analyzing technology (DAT) files: Measurements of porosity and permeability of the reservoir rock Reservoir rock descriptions Physical and chemical properties of reservoir rocks Structural maps of the study area.

Sample collection

The Ministry of Mines (MoM) of Ethiopia was not provided the reservoir rock samples for the basin from Were Ilu area of various locations used in this study. It took a small number of reservoir rocks (Upper Sandstone samples) to collect and analyze the representative units of the research area in the laboratory. The samples were prepared for three different analyses: a large number of samples were used to measure the rocks porosity and permeability while, the remainder was used to assess its chemical composition. The representative samples of the reservoir rocks are collected and take from selected sites of the study area and want to determine the chemical composition, measure the porosity and permeability values are analyzed in the laboratory.

The representative samples of the Upper Sandstones are collected from the road cutting areas due to the absence of drilling wells in the Abay Basin. The lack of the Drilling well data in the Abay Basin has its own effects on the laboratory results and difficult to know the accurate values of the porosity and permeability values of the reservoir rocks.

The four Upper Sandstone rock samples collected from different outcrops in the Abay Basin are considered representative of the entire basin based on three factors:

- **Widely distributed localities:** The samples were collected from outcrops located in various places around the basin margin which indicating that they are likely to be representative of the different areas within the basin.
- **Paleozoic to Mesozoic strata:** The rocks from which the samples were collected represent a wide range of geological time periods and covering the Paleozoic to the Mesozoic era. This suggests that the samples are representative of the different geological formations within the basin.
- **Oil seep areas:** The sampled material covers the oil seep areas, suggesting that it is likely to represent the conditions and properties of the rocks that contain hydrocarbon reserves.

The Easting and Northing coordinates are used to locate and map the exact position of the sample collection sites within the study area which helps to identify the spatial distribution of the Upper Sandstone rocks. The other collected data such as lithology, grain size, mineral composition and porosity are also important for constructing a location map as they provide information on the physical and chemical properties of the rock.

By integrating these data into a location map, it becomes possible to visualize the geological features and characteristics of the study area, including the distribution of the Upper Sandstone rocks and potential hydrocarbon reservoirs.

From the many species in the study area, representative samples of the Upper Sandstone reservoir rocks of the Basin were collected. Based on location, samples were taken from the study area and the Geographic Positioning System (GPS) readings are reported in the **(Table 1)** below:

Results and Discussion

Field description of the reservoir rocks of the Basin

The Upper Sandstone reservoir rocks in the Abay Basin have the potential to contain significant hydrocarbon resources that could be economically extracted. However, in order to successfully explore and develop these resources, it is necessary to understand their characteristics and properties. The project work will focus on studying the chemical composition of the Upper Sandstone reservoir rocks; including the presence of organic matter and hydrocarbon- bearing fluids. This will provide important information on the potential for hydrocarbon formation and accumulation. In addition, the physical properties of the reservoir rocks, including their porosity and permeability values will be measured.

Table 1: The measurement locations of collected samples, measuring of dykes, strike and dip direction of the study area during field work.

No	Samples Code	Reading					
		Easting	Northing	Strike	Dip	Altitude	Depth
1	USS1	0547392	1214515	N15E	N65	2044	2
2	USS2	0547230	1211261	N10E	50	1860	2
3	USS3	0547160	1226551	N5E	60	2150	1
4	USS4	0547090	1276725	N50E	N20	1860	1

Porosity refers to the amount of open space within the rock that can hold fluids such as oil and gas while, permeability refers to the ability of fluids to flow through the rock. These measurements will provide important data on the suitability of the Upper Sandstone reservoir rocks for hydrocarbon exploration and production. The project work will contribute to a greater understanding of the potential for hydrocarbon resources in the Abay Basin and could help to inform future exploration and development efforts in the region.

The upper sandstone reservoir

The Upper Sandstone rock in the Abay Basin is considered to be a good type of reservoir rock for hydrocarbon accumulation due to its physical properties. Within the Upper Sandstone formation, there are two types of rocks. These includes; Mugher mudstone and Debre Libanoes sandstone. The Cretaceous Sandstone rock within the Upper Sandstone formation is characterized by medium to coarse grained and moderately to well sorted sandstones which are associated with thin beds of conglomerates. These sandstones are expected to have good reservoir potential due to their favorable texture which is characterized by packaging of similar sized grains rather than a combination of coarse- and fine-grained composition. The performance of the Sandstone as a reservoir rock is described by its combination of porosity and permeability which depends on the degree to which sand dominates the rock. The best Sandstone reservoirs are those that are composed mainly of quartz grains of sand size of nearly equal sizes or silica cement with minimal fragmented particles. This indicates that the Upper Sandstone rock in the Abay Basin has the potential to be an excellent reservoir rock for hydrocarbon accumulation. The project work focused on studying the chemical composition and physical properties of the Upper Sandstone reservoir rocks will provide valuable insights into the potential for hydrocarbon resources in the region **(Figure 1)**.

Physical properties of upper sandstone rocks

The Upper Sandstone reservoir rocks in the Abay Basin are expected to have a moderate to high porosity due to the presence of well-packaged quartz grains and minimal fragmented particles. The porosity can range from 32.31-34.35% or even higher depending on the lithology. The Upper Sandstone reservoir rocks in the Abay Basin are expected to have moderate to high permeability due to their well-sorted grains and good porosity. The permeability values can range from 1766-2350 mD. However, it should be noted that these physical properties need to be measured using laboratory tests to obtain accurate values. The project work was conducting such tests in the Geochemical Laboratory of the Geological Survey of Ethiopia and the Ethiopian Construction Design and Supervision Works Corporation.

Figure 1: The Upper Sandstone, light grey, fine to medium grained sandstone.

In addition to their physical properties, the Upper Sandstone reservoir rocks in the Abay Basin are characterized by their lithology which gives rise to unique structures such as caves and mountains. The Upper Sandstone formation in the Northwestern part of Ethiopia is typically light grey in color while, in the study area it is dominated by light white in color. The grain size can range from fine to medium to coarse depending on the location within the formation. The texture of the Upper Sandstone rocks in the Abay Basin is characterized by the size and shape of the grains as well as the arrangement of the framework grains of detrital components.

The texture also includes the presence of non-clastic and fragmental material which can affect the porosity and permeability of the rock. The grain size of the Upper Sandstone rocks in the Abay Basin can range from fine to coarse with a relatively uniform size distribution. The grains are usually angular to sub- angular in shape and may exhibit some surface features such as pits or grooves. The arrangement of the framework grains is also an important aspect of the texture of the Upper Sandstone rocks. In general, the texture of the Upper Sandstone rocks in the Abay Basin plays a critical role in determining the physical and mechanical properties of the rock, including its porosity, permeability and strength. The Upper Sandstone rocks in the Abay Basin can have a variety of colors depending on the presence of different impurities within the minerals.

The most common colors are including; yellow, reddish, grey, white and light white. The project work was also considering the color of the Upper Sandstone rocks in the Abay Basin in its analysis and characterization of the rock. The shape and roundness properties of the Upper Sandstone rock grains are important characteristics for understanding the effectiveness of the rock as a hydrocarbon reservoir. These properties are important because they can affect the porosity and permeability of the rock which in turn can impact the flow of hydrocarbon fluids through it. For example, more angular and irregular grains may have lower porosity and permeability due to the presence of void spaces between grains, whereas, more rounded grains may be able to pack more tightly and have higher porosity and permeability.

Overall, understanding the shape and roundness properties of the Upper Sandstone rocks in the Abay Basin is important for understanding the distribution and behavior of hydrocarbon fluids in the region **(Figures 2, 3)**.

Figure 2: The Coarse Upper Sandstone rock of the basin

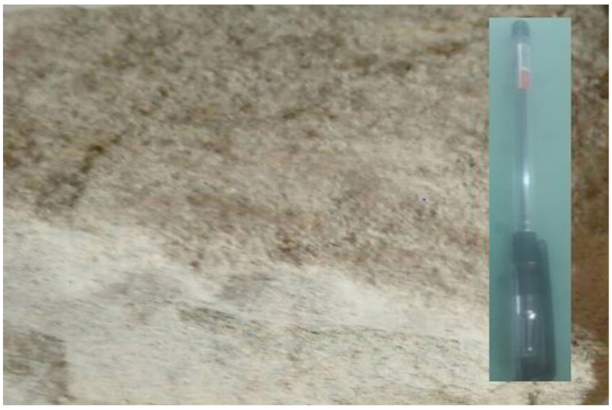

Figure 3: The white sandstone reservoir rocks of the Basin

Experimental analysis methods

The method used to measure the value of the porosity and permeability of the Upper Sandstone reservoir rocks as well as the chemical composition analysis, is essential in characterizing the rocks and understanding their potential as hydrocarbon reservoirs in the Abay Basin. After collecting the rock samples from the field, they are crushed into fine powder in the laboratory to enable the experimental tests. The experimental tests are grouped into two main categories. These include; the determination of the chemical composition of the rocks and the measurement of the porosity and permeability of the Upper Sandstone reservoir rocks in the basin.

The porosity and permeability values vary slightly between the samples but overall, they suggest that the Upper Sandstone reservoir rocks in the Abay Basin have good reservoir potential. The chemical composition analysis shows that the rocks are primarily composed of silica (SiO2) with smaller amounts of aluminum oxide (Al2O3) and iron oxide (Fe2O3). These results will be considered in conjunction with other data and analysis to evaluate the potential for hydrocarbon production from the Upper Sandstone rocks in the basin **(Table 2)**.

Chemical composition of the upper sandstone 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. This information can provide insight into the origin and evolution of the rocks, as well as their potential as hydrocarbon reservoirs. To determine the chemical composition of the reservoir rocks, representative samples were collected from the study area and sent to the Geological Survey of Ethiopia (GSE) for laboratory analysis. The GSE uses various techniques such as X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) are important to determine the chemical composition of the samples.

Table 2: The physical properties of Upper Sandstone reservoir rocks.

No	Description	USS1	USS2	USS3	USS4
1	Unit weight rock (g/cc)	1.62	1.7	1.65	1.71
2	Specific gravity	1.9	1.89	1.85	1.88
3	Water absorption (%)	20.98	23.02	21.85	22.1
4	Porosity (%)	32.31	34.35	33.25	302.6*

For the determination of the chemical composition of the Upper Sandstone reservoir rocks, the representative samples of the Upper Sandstone rocks were sent to the GSE. From the results, the primary mineral composition of the rocks can be determined, which helps to identify potential porosity and permeability characteristics that can lead to hydrocarbon accumulation. In general, the chemical composition analysis of the reservoir rocks in the Abay Basin is an important component in evaluating their potential as hydrocarbon reservoirs. The laboratory analysis of the chemical composition of rocks can involve a range of analytical methods and techniques. The methods used were depending on the type of rock being studied and the specific elements or minerals of interest. In the case of the Upper Sandstone reservoir rocks in the Abay Basin, the chemical composition analysis was likely conducted using a combination of analytical techniques. Some commonly used methods for this type of analysis include: X-ray fluorescence (XRF): - This technique involves analysing the energy emitted by the sample after being bombarded with X-ray which is commonly used for non- destructive, rapid elemental analysis.

The following table provides a summary of the laboratory analysis findings about the chemical composition of representative samples of reservoir rocks from the Upper Sandstone that was collected from the GSE **(Table 3)**:

The chemical analysis of Upper Sandstone rocks typically reveals varying proportions of major and minor elements, including SiO2, Al2O3, Fe2O3, MgO, CaO, Na2O, MnO, K2O, P3O5, TiO2 and H2O.

Table 3: Chemical composition of the upper sandstone rock

No.	Sample Code	Chemical Composition of Upper Sandstone										
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_3O_3	TiO_2	H_20
1	USS_3	65.4	15.58	4.12	1.5	0.6	1.76	2.2	0.08	0.14	0.21	1.6
2	Weight of Sample	1.3 Kilograms										

Based on the average chemical composition we provided, the Upper Sandstone reservoir rocks in the Abay Basin can be classified as arkose sandstone, which is a type of sandstone that contains more than 65% silica (SiO2). This high silica content is a defining characteristic of arkose sandstone and can have implications for the physical and mechanical properties of the rock such as its porosity and permeability.

Determination of porosity and permeability of the rocks

Porosity and permeability are important physical properties of reservoir rocks like Upper Sandstone that can influence the amount and flow of fluids (such as oil, gas or water) that can be produced from them. Porosity is a measure of the amount of empty space (or pores) within a rock, expressed as a percentage of the total volume. It can be determined by various methods, including core analysis, image analysis and fluid displacement techniques. Permeability, on the other hand, is a measure of how easily fluids can flow through a rock determined by the size of the pore spaces and their connectivity. It can also be measured using various methods, including core analysis, fluid flow through porous media and well tests. These properties are essential for understanding the potential reservoirs as well as developing effective drilling and production strategies in the petroleum industry.

Porosity (Φ) determination: The porosity of the reservoir rock is the property that tells how porous a rock is and also defined as a measure of the capacity of a reservoir rock to contain or store fluids. The porosity value of the sandstone reservoir rocks may be between 10 and 40%. Estimates of the reservoir porosity can be obtained from several sources both direct and indirect methods but in this project the porosity value is calculated by using direct method.

Sample preparation: Direct methods of determining porosity involve physically measuring the volume of void spaces (or pores) within a rock sample. One common direct method is the fluid saturation technique in which the sample is first weighed and then completely saturated with a fluid (such as water) under controlled conditions. The saturated sample is then re-weighed to determine the amount of fluid that was added which represents the volume of the void spaces. The porosity can then be calculated as the ratio of the volume of void spaces to the total volume of the rock sample. In this study, the direct method was used to determine the porosity values of the Upper Sandstone reservoir rocks. The rock samples were prepared using unconsolidation with a weight of one (1) kilogram and were saturated with water for 24 hours to ensure complete saturation of the pore spaces. The wet shaping method was used to uniformly distribute the wet content in the dry sandstone and the samples were deposited in layers with increasing density from the bottom to the top of the tool, resulting in more uniform samples and repeatable test results.

The saturated samples were then weighed before and after immersion in water to determine the volume of void spaces and the porosity values were calculated as the ratio of the volume of the void spaces to the total volume of the rock sample. These direct measurements provide an accurate assessment of the porosity values of the Upper Sandstone reservoir rocks which can inform further analyses and production strategies in the petroleum industry.

Direct methods: On the samples of the reservoir rocks collected in the study area, direct measurements are made. These samples are known as representative samples of the basin that are gathered during field study may consist of rock fragments and fractured boulders that are brought from the surface. The ASTM D7263 (Standard Test Method for Apparent Porosity D7263) which measures the bulk unit weight values of the Upper Sandstone rocks, is the Standard Test Method that is used to measure the physical attributes of the Upper Sandstone reservoir rocks in the laboratory analysis and the fundamental standard test method for determining the water absorption and porosity values of rocks is ASTM C128 (Standard Test Method for Apparent Porosity C128). This test method is crucial for determining the values of the physical characteristics of Upper Sandstone reservoir rocks, including the rock's unit weight, specific gravity, water absorption and porosity. The Ethiopian Construction Design and Supervision Works Corporation Laboratory conducted measurements of the porosity of the reservoir rocks using the direct approach in the study. The results are presented in the following tables **(Table 4)**:

Table 4: The Porosity value of the Upper Sandstone reservoir rock

No.	Sample Code	Porosity Value (%)
1	USS_1	32.31
2	USS_2	34.35
3	USS_3	33.25
4	USS_4	32.6

Permeability (K) determination: Another direct method for determining the permeability of reservoir rocks is through laboratory tests using a device called a permeameter. Unlike indirect methods that utilize well tests or production data, a permeameter provides a direct measurement of the rock's ability to transmit fluids such as oil, gas or water. A permeameter typically consists of a core holder that allows a cylindrical rock sample (core) to be placed under controlled pressure conditions.

A fluid (such as oil or water) is then allowed to flow through the sample and the flow rate is measured and used to calculate the permeability of the rock.

The permeability test can be performed using core samples collected from a reservoir or by using oil samples obtained through oil extraction processes. This test may take less time to complete and produces reliable results in comparison to indirect methods. By measuring the permeability of the reservoir rock, the flow characteristics of the fluids through the rock can be estimated and numerical simulation models can be developed to predict the fluid flow behavior in the reservoir. This information is essential in developing effective reservoir production strategies, selecting drilling locations and maximizing hydrocarbon recovery from the reservoir. Due to a lack of Permameter in the laboratory, we were unable to measure the permeability of the Upper Sandstone reservoir rocks in the representative samples that were brought from the study area. As a result, we had to estimate the permeability of the reservoir rocks using an indirect method.

Indirect methods: Different empirical equations and values have been proposed for different types of rock formations.

However, the accuracy of the permeability estimations based on such empirical correlations largely depends on the validity of the assumptions and the limitations of the correlation being used. In the absence of permeability data obtained through direct or laboratory methods, the use of empirical correlations can provide quick estimates of permeability for preliminary analysis. However, it is important to note that these estimations should be considered as initial approximations and verified with laboratory measurements and field data to ensure their accuracy for practical applications **(Figure 4)**. The correlation between Porosity and Permeability as the following formula[17].

$K = 19.17^{*}\ e0.14^{*\Phi}$ (1)

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

Based on the information provided above, we can estimate the permeability of the Upper Sandstone reservoir rocks and present the results in the table below **(Table 5)**.

Correlation

Table 5: The permeability values of the Upper Sandstone rocks (correlation).

No	Sample Codes	$K = 19.17^{*}\ e^{0.14^{*}\ \Phi}$	
		Porosity Value (%)	Permeability Value(mD)
1	USS1	32.31	1766
2	USS2	34.35	2350
3	USS3	33.25	2015
4	USS4	32.6	1840

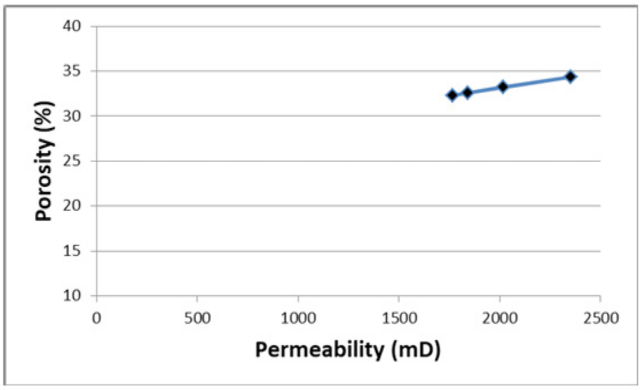

Figure 4: Porosity vs Permeability graph (Correlation).

Were ilu oil seep site

The presence of a petroleum system in the Abay Basin is strongly supported by the oil seepage at Were Ilu. Due to the lack of drilled wells throughout the basin and the availability of rock samples from the research region, the location of the Were Ilu oil seep site is identified using Ministry of Mine (MoM) documented data and pseudo well sites. Were Ilu Oil Seep Site is the location to demonstrate the existence of a petroleum system in the Abay Basin within the Ethiopian Plateau due to the above reservoir rocks.

A portion of the petroleum that is escaping from the subsurface and leaking on areas of deep fractures is represented by the oil seeps. Therefore, the existence of an oil seep provides indirect information about deeper subsurface hydrocarbon deposits that may drive exploration efforts in the basin. The basin can also be evaluated and a thorough explanation of where these oil seeps originate will be obtained. The development of the Upper Sandstone reservoir rocks demonstrates the presence of hydrocarbon seeps in the basin. However, because to technological limitations, study was first limited to identifying the fundamental geochemical properties of the oil seeps in the basin. In order to better understand the formation and provide information for the development of the oil and gas in the basin, this study presents geochemical data from four reservoir rock samples collected from four separate outcrop locations inside the Abay Basin. The Abay Basin's potential reservoir is the Upper Cretaceous Amba Aradam deposit (Upper Sandstone). Depending on how much sand predominates, the combination of porosity and permeability in sandstone describes how well it performs as a reservoir rock. When compared to the Adigrat sandstone rocks, the Upper Sandstone reservoir rocks in the region are generally covered in a large area. The physical characteristics of the Upper Sandstone rocks are described as texture, color, grain size, form and roundness. In general, the Upper Sandstone rock that is found in the study area is usually characterized by light white in color, fine grains and medium to coarse grains. The chemical analysis of Upper Sandstone rocks typically reveals varying proportions of major and minor elements, including SiO_2, $Al2O_3$, Fe_2O_3, MgO, CaO, Na_2O, MnO, K_2O, P_3O_5, TiO2 and H_2O. The Upper Sandstone reservoir rocks of the Abay (Blue Nile) Basin formation exhibit exceptional permeability and moderately good porosity, according to experimental results. According to the results of the laboratory analysis, the Upper Sandstone reservoir rocks in the Abay basin have porosity values that range from 32.31 to 34.35% (Table 4.3), suggesting that they may be a good reservoir for the buildup of hydrocarbons.

The permeability of the Upper Sandstone reservoir rock values are similarly discovered in the range of 1766 and 2350mD and the reservoir rocks have practically good porosity values (Table 4.5). This outcome suggests that the permeability values are rather excellent for the reservoir quality. The computed values of the permeability of the Upper Sandstone reservoir rocks of the Abay Basin are shown in figure 4.5 by taking into account the results of the laboratory tests for porosity acquired from the experimental laboratory center. The Upper Sandstone rocks, which have average values of 33.13% porosity and 1993mD permeability, are generally good reservoir rocks for the accumulation of hydrocarbons in the basin. In many locations around the Abay Basin, there are signs that oil leaks are present. Were Ilu, Mechale, Legehida and Dengle Ber are some of these regions. The Abay Basin's oil seeps could typically be found atop buildings for accumulating petroleum on land. The hydrocarbon fluids could leak through geological layers and the area is more important for hydrocarbon exploration across them through rock fractures or directly from an outcrop of oil- bearing rock because it has good reservoir rocks and organic rich sediments at various stratigraphic levels, connected with multiple unconformity surfaces and repeated faulting with northeast ward thickness increment of the marine sediments **(Figure 5)**.

The geochemical data offer crucial information on the origins of the seeps, the geochemical properties of the reservoir rocks and the chemical makeup of rocks that could be used as a guide for upcoming studies and sophisticated exploration for finding hydrocarbons in the Were Ilu region. Pseudo Well in Were Ilu Area Since no wells have been drilled in the Abay Basin, we chose to simulate the situation using fictitious wells. It is challenging to assume the input parameters because the Abay Basin lacks well data.

We need to know the age, thickness, lithology of the sediments, subsurface temperature was carried out a trustworthy maturity calibration and make a realistic approximation regarding hydrocarbon formation. Unfortunately, the Abay Basin lacks any wells that have been drilled, which is how these data are often gathered. Furthermore, we were unable to locate any trustworthy data on heat transport or subsurface temperature.

Figure 5: Were Ilu oil seep site of the Abay Basin.

In conclusion, the simulation's creation of oil and gas was altered or made easier by the existence of very thick basalts which also increased the burial depth and geothermal temperature. As a result of the capacity of geological data on the Abay Basin, further research on its geology is required in order to evaluate the basin and conduct petroleum exploration.

Conclusions

The basin has unique geological characteristics and holds different types of sedimentary rocks, such as sandstones, shales, carbonates and volcanic rocks.

- This study focuses on the briefly exposed sub-basin of the deep section of the Were Ilu oil seep reservoir rocks in northwest Ethiopia.
- The sedimentary basins of Ethiopia hold significant potential for the exploration and development of oil, gas, geothermal energy and other mineral resources.
- The goal of this research is to provide an understanding of the Upper Sandstone reservoir rocks and the structural mapping of the study region for the role that petroleum resources creation had in the formation of the Abay Basin's geology.
- As for the absence of research on the reservoir rocks in the Abay Basin, this lack of information may pose a challenge for hydrocarbon exploration in the area.
- Understanding the physical and chemical features of the reservoir rocks is crucial for determining their potential for hydrocarbon accumulation, evaluating their economic value and designing appropriate development plans.
- The Upper Sandstone reservoir rocks have the potential to be a good reservoir in the Abay Basin for the accumulation of petroleum resources. Additionally, the Upper Sandstone reservoir rocks have a high degree of permeability, indicating that they have good to excellent permeability and can easily transmit liquids.
- During fieldwork, it was discovered that the following fault systems dominate the study area: faults with a northwest-southeast trend, faults with a northeast-southwest trend and faults with an east-west (E-W) trend.
- Hydrocarbons such as oil and natural gas can gather and be stored in reservoirs thanks to geological features known as hydrocarbon traps. The presence of a petroleum system in the Abay Basin is strongly supported by the oil seepage at Were Ilu.
- The Upper Sandstone rocks, which have average values of 33.13% porosity and 1993mD permeability, are ideal reservoir rocks for the accumulation of hydrocarbons in the basin. The Abay Basin is more crucial for hydrocarbon development since it crosses them via rock cracks or straight from an outcrop of rock that contains oil.

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