IDENTIFYING THE EFFECTS OF DIAGENESIS ON RESERVOIR QUALITY, ADIGRAT SANDSTONE, OGADEN BASIN, SOUTH EAST ETHIOPIA.

A Graduate Project Work Submitted to

Centers for Ethio-mines development

Addis Ababa Institute of Technology.

OFFICE OF GRADUATE STUDIES

ADDIS ABABA UNIVERSITY

JULLY, 2023

ADDIS ABABA, ETHIOPIA

IDENTIFYING THE EFFECTS OF DIAGENESIS ON RESERVOIR QUALITY, ADIGRAT SANDSTONE, OGADEN BASIN, SOUTH EAST ETHIOPIA.

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DECLARATION

By signing, I attest that the graduate project work titled "Identifying the effects of diagenesis on reservoir quality, Adigrat Sandstone, Ogaden Basin, South East Ethiopia" is mine. It hasn't been submitted to any other university for the award of a degree, diploma, or certificate, in other words. Each and every source of information used in this thesis has been properly recognized through citation.

Gemeda Ayansa	________________________	________________
Name of student	Signature	Date

RECOMMENDATION

As the advisor(s) of this graduate project work, I/we hereby attest that I/we have read the revised version of the thesis titled "Identifying the effects of diagenesis on reservoir quality, Adigrat Sandstone, Ogaden Basin, South East Ethiopia" that Gemeda Ayansa prepared under my/our direction and submitted as a partial fulfillment of the requirements for the degree of Master of Engineering in Petroleum Engineering. I/we therefore advise submitting a revised version of the Graduate Project Work to the Center in accordance with the relevant procedures.

__________________________ _______________________ ________________

Major Advisor Signature Date

__________________________ _______________________ ________________

Co-advisor Signature Date

ABBREVIATIONS

E	East
ENE	East North East
GSE	Geological Survey of Ethiopia
MoM	Ministry of Mine
M	Meter
N	North
NE	North East
NW	North West
NNE	North East
NNW	North West
LEM	Light electronics microscope
S	South
SE	South East
SW	South West
SSW	South West
Sst	Sandstone
SE	South East
Vp	pore volume
Φe	effective porosity
W	west
WSW	west south west

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ABSTRACT

The Ogaden basin is a vast sedimentary basin having 350,000 km^2 areal coverage. Although it is the most studied region in Ethiopia, so far 72 wells have been drilled in the area, i.e. the number of wells per area coverage is 4861 km^2. Due to large area coverage of Adigrat Sandstone reservoirs there, the Ogaden Basin in SE Ethiopia is of great importance for hydrocarbon exploration and development. However, diagenetic processes, which modify the rock's physical properties, affect its ability to store and flow hydrocarbons, and can have a significant impact on reservoir quality.

Despite its significance as a reservoir, it is practically impossible to predict how diagenesis may affect the sandstones' reservoir quality. This study was conducted to find out the types of digenesis and its effect on the quality of Adigrat sandstone reservoir. To this end, 15 (fifteen) thin sections of Adigrat sandstones from YH-4 well were prepared and, ImageJ, JMicroVision, and petrographic analyses were employed to characterize the reservoir's diagenetic effect.

The cementation of authigenic clay, silica, growth of authigenic glauconite, mineral dissolution, and load compaction are the key diagenetic processes that have impacted the reservoir quality of Adigrat sandstones. According to the framework grain-cement interactions, Clay cements, particularly illite, that partially line and fill pore spaces, developed alongside or after the early calcite cement's precipitation. Thus, it is inevitable that the reservoir rock’s porosity and permeability will decrease by this clay, which acts as a pore-choking cement.

Key words:*Diagenesis; reservoir quality; porosity; Adigrat sandstone; Ogaden Basin*

CHAPTER ONE

1. INTRODUCTION

1.1. Back ground

Ethiopia's sedimentary areas are divided into five main sedimentary basins: the Ogaden, Abay (Blue Nile), Mekele, Gambela, and Southern Rift Basins. The general processes that occur quickly after the deposition of sediments are collectively known as diagenesis. Compaction, cementation, grain packing, and fracture are the four main diagenetic processes that reduce porosity in sandstone (Hayes, 1979). The framework grains' linear and convexo-concave connections demonstrate how tightly packed and compacted they are as a result of the overburden pressure. Muscovite grain bending along grain boundaries is another sign of grain compaction. Secondary porosities, which are fracture-controlled digenetic products, make up the majority of the pore spaces that are currently present. (Chima P.,et al., 2018). Additionally, there are intra-granular porosities (vacuoles), which are believed to be dissolution porosities brought on by calcite and silica dissolution. The inter-granular pore spaces have occasionally even been obliterated due to the close packing of the framework grains, the presence of the matrix, and the cement. The majority of the pore spaces found in calcareous sandstone and sandy limestone samples are diagenetic and the result of calcite breakdown.

Diagenesis influences sediments during and after lithification as well as during and after deposition, which has an effect on the volume and distribution of porosity and permeability in sedimentary rocks. In the process of diagenesis, a core group of physical, chemical, and biological processes are at play.

These mechanisms regulate the fluid movement, mineralogy, and structure of sedimentary rocks (Worden & Burley, 2003). Sandstone, for example, has permeability and porosity that can either be destroyed, retained, or even improved by diagenesis (Baiyegunhi, et al., 2017). The depositional environment initially affects porosity and permeability, and diagenesis then regulates them. Understanding the processes and byproducts of diagenesis is crucial for understanding the evolution of sedimentary basins because it has an impact on the creation, maintenance, and destruction of porosity (Sciscio, 2015). More precise assessments or forecasts of sandstone reservoir quality have been made possible by recent research and advancements in diagenetic investigation

The study of diagenesis and its effects on reservoir quality is essential for understanding the behavior and performance of petroleum reservoirs. In the context of the Adigrat Sandstone in the Ogaden Basin,, this topic has significant implications for the petroleum industry and future exploration efforts. This research work focus on identifying the effects of diagenesis on reservoir quality within this specific geological formation. The hypothesis of this work is that diagenetic processes have a notable impact on the Adigrat Sandstone's reservoir quality, thereby influencing its potential for petroleum production.

The Adigrat Sandstone plays a crucial role in understanding reservoir quality and its petroleum potential. However, diagenetic processes can significantly impact the characteristics of this reservoir, i.e. its porosity and permeability. Thus, this research tried to identify the effects of diagenesis on reservoir quality of the Adigrat Sandstone, which in turn will have implications for optimizing its exploration and exploitation in the future.

1.2. Location of the study Area

The Calub and Hilala gas field are located in the Ogaden basin, in Somalia Regional State of the Democratic Republic of Ethiopia (Figure-1.1). The Ogaden basin in southeast Ethiopia covers an area of over 350,000 square kilometers and contains over 6000m of Permian to Tertiary sediments. The research region is located 970 kilometers along a main road in the eastern Ogaden basin, distant from Addis Abeba. (Getaneh, 1988)

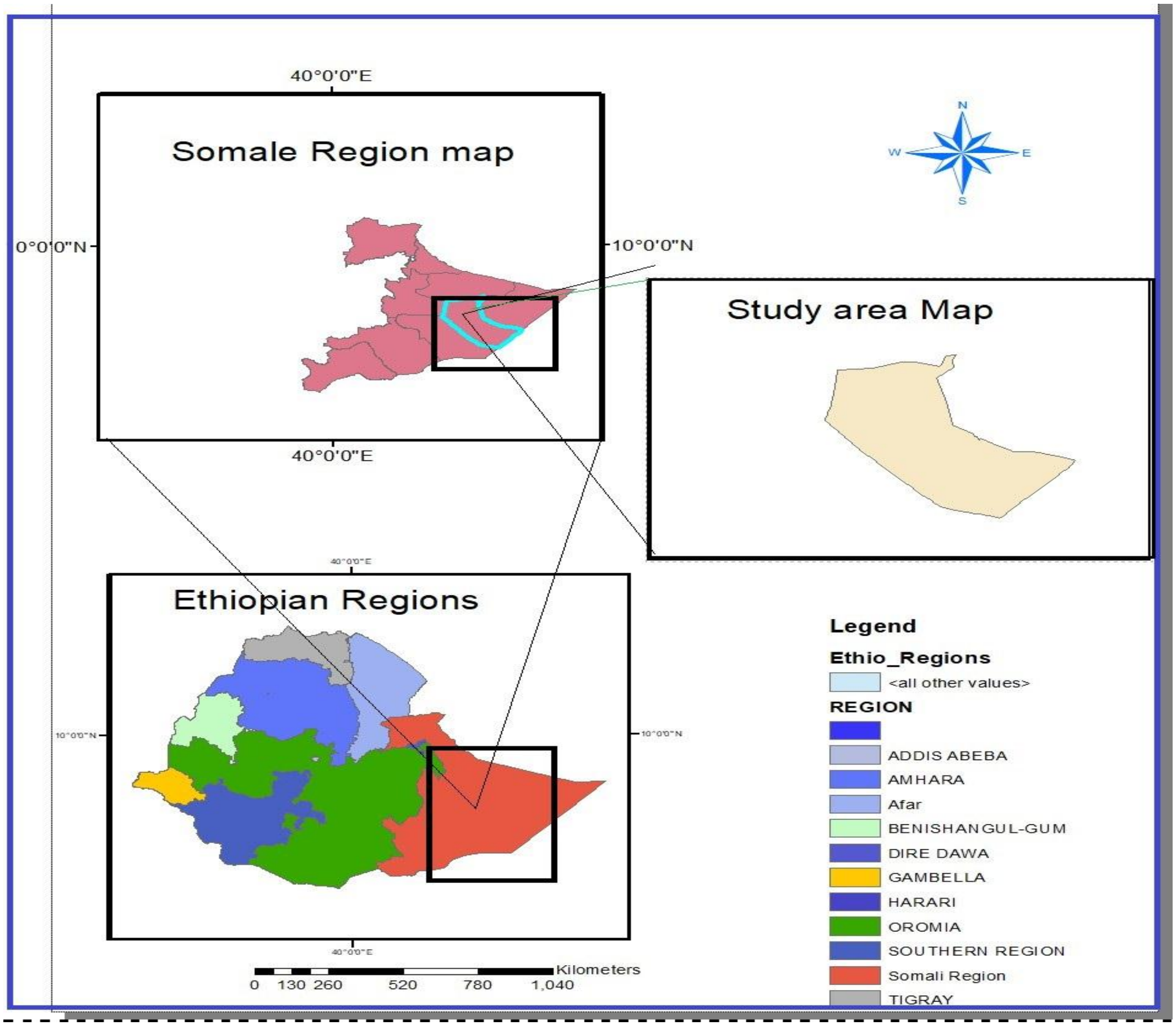

Figure 1.1: Location map of the area. (Source: Modified from Arc GIS)

1.3. Statement of problem

The Ogaden Basin in Southeast Ethiopia is an area of significant interest for petroleum exploration, owing to the presence of all the petroleum elements, where Adigrat Sandstone reservoir is part and parcel of it.

The Ogaden basin is a vast sedimentary basin having 350,000 km^2 areal coverage. Although it is the most studied region in Ethiopia, so far 72 wells have been drilled in the area, i.e. the number of wells per area coverage is 4861 km^2; this indicates that Adigrat sandstone is not studied well or was not well covered by the previous exploration wells. To better understand the reservoir rocks in undrilled areas, various studies should be conducted. The porosity and permeability of the reservoir rock are the factors that define the quality of the reservoir. Adigrat sst is a reservoir rock with low porosity and medium permeability, according to earlier reports. This reservoir rock has a low projected gas recovery rate. There may be different reasons for the poor reservoir rock properties of Adigrat sst. Hence, different studies, like this one, should be conducted to identify the causes behind the poor nature of the reservoir rock properties, and in general to characterize the reservoir quality via studying the diagenetic effects.

1.4Objectives of the project

1.4.1 General objective of the project

The main objective of the project is to identify the diagenesis effect on the reservoir quality of Adigrat sst.

1.4.2 Specific objective of the project

- To quantify the mineralogical compositions of the sandstone

- To identify the type of pores and minerals affecting the pores

- To comprehend the relationships between porosity and sst composition

1.5 Significance of the project

This project will provide a comprehensive overview of the diagenesis impact on the reservoir quality of Adigrat sst . The result of this study will provide essential information for Ministry of Mines (MoM) and other concerning stakeholders about the diagenesis impact on Adigrat sst reservoir quality. Additionally, this research work will serve as a baseline for further future research regarding the diagenesis effects on reservoir quality of Adigrat sst, in particular, and its effects on sandstone reservoir quality, in general.

1.6 Scope of the study

Only the Calub and Hilala gas field in the Ogaden basin is included in this project work. Additionally, it is limited to the impact of diagenesis on the Adigrat sandstone reservoir's quality in the Calub and Hilala gas fields. The study includes petrology thin section examination and image analysis in the lab work to assess the impact of diagenesis on reservoir quality.

CHAPTER TWO

2. LITRATURE REVIEW

2.1. Regional Geology and Local Geology

The Miocene-Quaternary East African Rift, which is located in Ethiopia, borders the Ogaden basin to the north and northwest, the basement complex to the west and southwest, and the basement complex to the south, east, and northeast (Hunegnaw, Sage, & Gonnard, 1998). (Figure 2.1). A sedimentary basin in Somalia that formed in the same regional setting as the Ogaden Basin in Ethiopia is adjacent (Barnes, 1976). The Ogaden basin, which offers an economically feasible hydrocarbon deposit, has a total sediment thickness of 10,000 m (Getaneh, 1988).

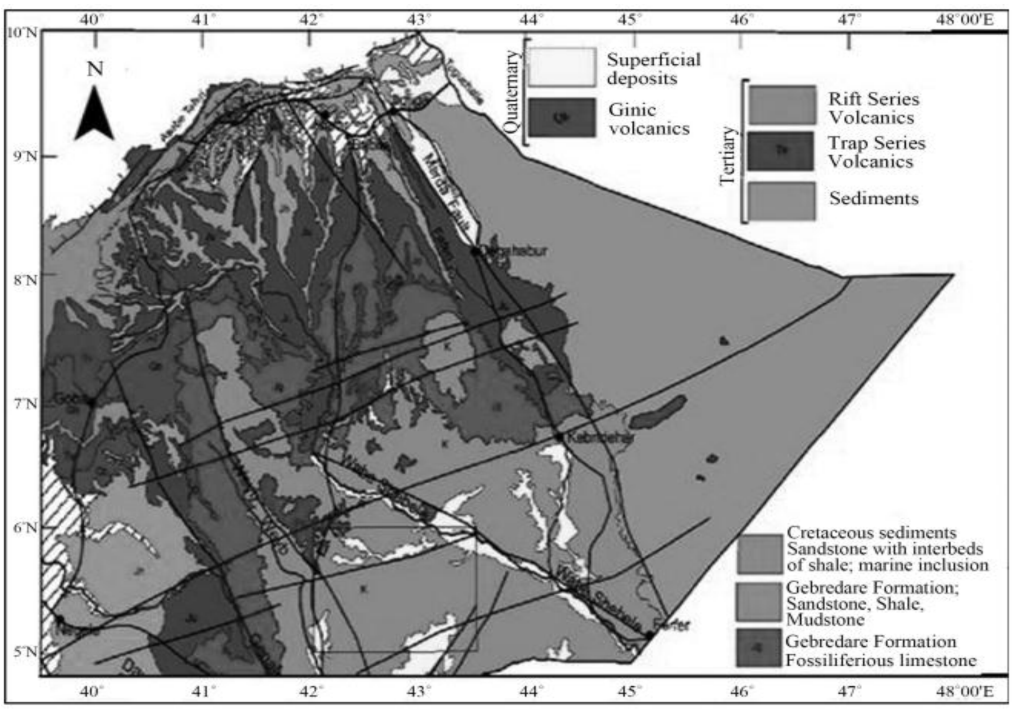

Figure 2.1: Geological map of Ogaden basin (Olijira, Niton, & Sonibare, 2020)

With an aerial size of roughly 75,000 km2, the Ogaden basin is believed to have a maximum sediment thickness (at deeper parts) of 7 km in the middle and southwestern part of the sub-basin around Bodle deep (Tsegaye, Nton , Boboye, & Ahmed, 2018). The Ogaden Basin's growth is connected to Gondwanaland's disintegration (Kazmin, 1972). The source of the sedimentary fill is mainly the Tethys sea during the Mesozoic times, the cross-river channels, and lacustrine depositional environments (Tsegaye, Nton , Boboye, & Ahmed, 2018).

As a result of the North Atlantic and Proto-Indian Oceans opening throughout the Permian to Jurassic periods, a tri-radial system of NE-SW, NW-SE, and north-south trending grabens formed (Bosworth, W.1994). The Ogaden basin's Calub Formation is linked to various stages of deformation, as are the initial rift sediments (Bokha and Gumburo Formation), early rift sediments (Adigrat Sandstone Formation and Lower Hamanlei Formation), syn-rift sediments (Middle Hamanlei), and post-rift sediments (Antalo Limestone and Ambaradam Formation) (Figure 2.2). The Ogaden basin's stratigraphy is made up of the following formations: the Calub, Bokha, and Gumburo formations; the Adigrat sandstone, Hamanlei, Uarandab, Gabredarre, and Ambaradam formations; and the Antalo limestone. From oldest to youngest, these formations are listed. (Getaneh, 1988).

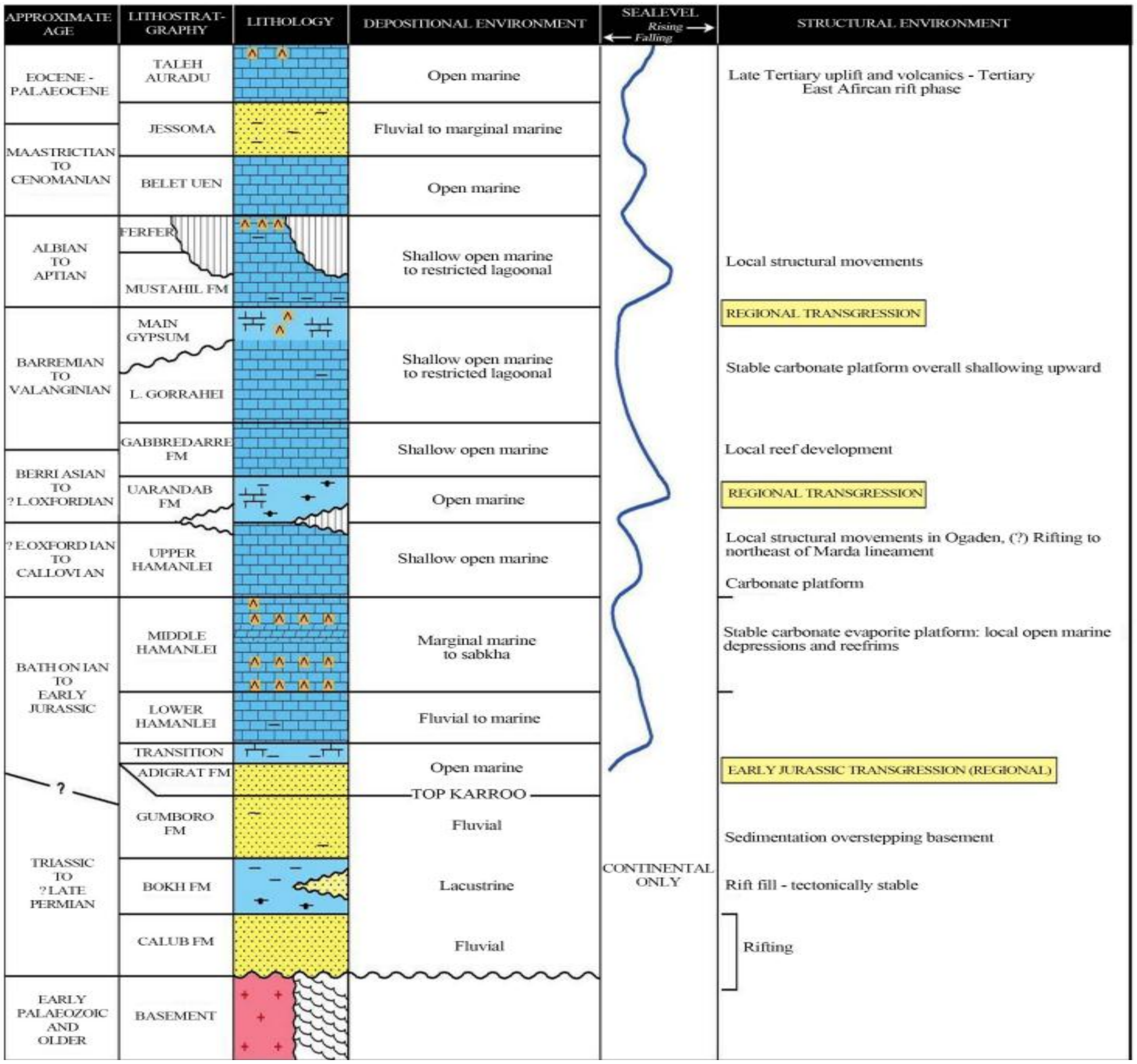

Figure 2.2: Stratigraphy and petroleum system of Ogaden basin (Getaneh, 1988)

A complex association of argillaceous clastic, (Olijira, Niton, & Sonibare, 2020) very thick shallow to deep marine carbonates, and evaporates make up the geology of the Ogaden basin. (Beicip, 1985). According to palynological study, which varies from continental alluvial fans, fluviatile and deltaic clastics, to lacustrine argillaceous types, the Ogaden basin's depositional environment can be inferred to be one of immense lithologic variability in both lateral and vertical expansions. These environments span the late Paleozoic to the Mesozoic. Later, (Getaneh, 1988)used the Lopatin Model to construct time-temperature indices of rock maturation and hypothesized that the Paleozoic and Mesozoic rocks of the Ogaden Basin contained suitable conditions for the production of petroleum, particularly gas.On this note, he proposed that probable hydrocarbon source rocks might include the Bokha Shale and the

Hamanlei Formation. (Hunegnaw, Sage, & Gonnard, 1998)stated that the organic-rich Bokh Shale, transition zone, and Urandab Shales with fair to good petroleum potential up to 20 kg HC/ton rock could be the possible source inside the Ogaden basin. According to (Hunegnaw, Sage, & Gonnard, 1998), Potential reservoirs include the carbonate facies of the Hamanlei Formation, sandstone facies of the Calub Formation, and Adigrat Sandstone Formations in line with the basin also has structural and stratigraphic traps (Hunegnaw, Sage, & Gonnard, 1998).

2.3 Diagenesis

Diagenesis is a compaction process that takes place at low temperatures and pressures. When proteins, lipids, and carbohydrates (organic aquatic sediments) are deposited, they are extremely saturated with water and mineral-rich.

Diagenesis, which affects the pore type and geometry existent at formation, determines the eventual porosity and permeability of a sandstone. The composition and environment of the sedimentary record have an impact on early diagenetic patterns. Later diagenetic processes cross facies boundaries and depend on regional fluid circulation patterns (Stonecipher & J.A, 1990). For precise sandstone quality prediction, sediment composition, fluid migration patterns, and depositional environments must be considered.

2.3.2. Impact of diagenesis on reservoir quality

The reservoir qualities of rocks are mostly determined by permeability and porosity. Primary and secondary porosity are two different types of porosity. Secondary pores, also known as post-depositional porosity, are generated after deposition, whereas primary pores, also known as depositional porosity, are formed during the sedimentation process (Selley, 2000).Inter-particle porosity, which is primarily influenced by the textural maturity of the sediments and is mostly regulated by depositional processes and environments, but compositional maturity also plays a role to some extent, makes up the majority of the primary porosity in sandstones. When grains are soluble, the breakdown of unstable grains causes an increase in porosity, which is related to compositional maturity. However, the main porosity is typically reduced by the production of cements and clay minerals. Long and sutured contact between nearby clastic grains suggests that compression caused by the burial may also reduce the fundamental porosity of the rock.

2.3.3 Diagenetic Processes

Three processes cause sandstone diagenesis. These are;

1, Cementation

2, Dissolution (leaching)

3, Compaction.

Pore space is created by grain leaching, not destroyed by cementation. By grain reorganization, plastic deformation, pressure solution, and fracturing, compaction reduces porosity.

2.3.4 Diagenetic zones

Diagenetic zones are identified by subsurface temperatures by Surdam et al. The depths of these zones might change depending on the geothermal gradient. Major diagenetic processes and their effects on pore shape are summarized in the table below (table 2.1).

Zone	**Temperature**	**Major diagenetic processes**	
		Preserves or enhances porosity	**Destroys porosity**
Shallow	<80°C or 176°F (<5,00 to 10,00 ft)	• Grain coatings (inhibit later overgrowths) • No pervasive carbonate cements that can be dissolved later	• Clay infiltration • Carbonate or silica cement (in some cases irreversible) • Authigenic kaolinite • Compaction of ductile grains
Intermediate	80-140°C or 176–284°F	• Carbonate cement dissolved • Feldspar grains dissolved	• Kaolinite, chlorite, and illite precipitate as a result of feldspar dissolution • Ferroan carbonate and quartz cement
Deep	> 140°C or 284°F	• Feldspar, carbonate, and sulfate minerals	• Quartz cement (most destructive)

		dissolved	• Kaolinite precipitation • Illite, chlorite form as products of feldspar dissolution • Pyrite precipitation

Table 2.1: diagenesis table (https://wiki.aapg.org/diagenesis

The impact of temperature on diagenesis might vary depending on geothermal gradient. At each increase of 10 °C (1000 times greater with each increase of 100 °C), many diagenetic reaction rates double (Wilson, 1994a). When many different minerals become more soluble at higher temperatures, pore fluids get saturated with more ionic species.

2.3.5 Effects of pressures

Compaction is pressure's major effect. Overpressures slow down the process of porosity loss as burial depth increases. According to (Scherer, 1987), who based his conclusions primarily on North Sea sandstones, sandstones retain about 2% of their porosity for every 1000 psi of overpressure during compaction. Because the stage of compaction at which the overpressure originated determines how pressure affects porosity.

2.3.6 Effects of ages

Sandstones typically become less porous as they age. In other words, the amount of porosity that sandstone loses over time. A Tertiary sandstone with a Trask sorting coefficient of 1.5, a quartz concentration of 75%, and a burial depth of 3000 m, according to (Scherer, 1987), likely has an average porosity of about 26%. The average porosity of a Paleozoic sandstone with the same sorting, quartz percentage, and burial depth is probably around 13%.

2.3.7 Effects of composition and textures

Composition and diagenesis

Composition has two effects on sandstone diagenesis:

• The mechanical stability increases with increasing quartz concentration (less compaction occurs).

• The chemical stability decreases as mineral variety increases (more cementation or dissolution occurs).

Less quartz overgrowths occlude the porosity in sandstones that are rich in lithics, feldspars, or chert, and more secondary porosity results from the dissolution of less stable grains. A crucial factor in compaction porosity loss is the proportion of quartz to ductile grains.

2.4 Sediment composition

Sand particle mineralogy and sediment maturity are influenced by provenance. Sand grains undergo mechanical and chemical deterioration while being transported. The origin, degree of reworking, and transportation distance are all reflected in the finished product.

For instance, subduction trench boundary sandstones typically have immature mineralogy. They frequently contain terrigenous debris rich in pelagic and volcaniclastic material. Sandstones formed along a cratonic basin's border typically have mature mineralogy and textures and contain reworked sedimentary debris.

CHAPTER THREE

3. METHODS AND MATERIAL

3.1. Methodology

The following techniques were used to accomplish the goals of project;

3.1.1 Primary Data

Fifteen (15) core samples of Adigrat sandstone, from YH4were taken from Ministry of Mines, Addis Ababa. The samples were cut and thin sections prepared at GSE laboratory center.

3.1.2 Thin section preparation

The Thin section analysis was carried out at the Geological Survey of Ethiopia. For the LEM (Fig 3.1(c), the core samples were catted in the requested orientation to obtain a rectangular section. The catted section grinded on face only; grinded on diamond impregnated will(120-181 micron), then grinding successively on glass plat with 400,600,1200 Griti AL_2O_3 abrasive powders. Mounted after the portion had been ground. Using a two component resin and hardener (Epofix and Petropoxy), the ground side of the core slab is glued onto the glass slide. A thin section that has been mounted is removed to leave a section on glass that is thin with a thickness of 0.5 to 1.5 mm. The excised piece is then ground once more on the core specimen. The core slab has a thickness of 22–30 micron after being ground on a diamond-impregnated wheel (120–181 micron) and a glass plate using progressively finer abrasive powders (400, 600, and 1200 grit). The narrow piece is then sealed with a thin glass cover slip and mounted with Canada palsam (EPOFIX hardener and Resin).

From the total core sample (Fig3.1 (a)), 17m thick, 15samples (Fig 3.1(b)) taken for thin section preparation from Adigrat sst (YH4 well), for each well, at Geological survey laboratory. Petrographic analysis conducted using Optical Microscope For quantification of mineralogical composition, Rock AR2/Jmicrovision application used. For mineralogical quantification, point counting methods employed. This technique used for all thin sections, and per thin section 200-300 counts made.

Table 3.1: Table core sample taken from drilled well.

HY3 well core samples taken(Adigrat sand stone		
Sample id	**Core no**	**Core sample depth(m)**
H4-1	**Core 11**	**3134.7**
H4-2	**Core 11**	**3135**
H4-3	**Core 11**	**3136.5**
H4-4	**Core 12**	**3137**
H4-5	**Core 12**	**3138.7**
H4-6	**Core 12**	**3139.4**
H4-7	**Core 12**	**3140.5**
H4-8	**Core 12**	**3141.5**
H4-9	**Core 12**	**3143**
H4-10	**Core 13**	**3144.5**
H4-11	**Core 13**	**3146**
H4-12	**Core 13**	**3147.5**
H4-13	**Core 13**	**3149**
H4-14	**Core 13**	**3150.5**
H4-15	**Core 13**	**3152**


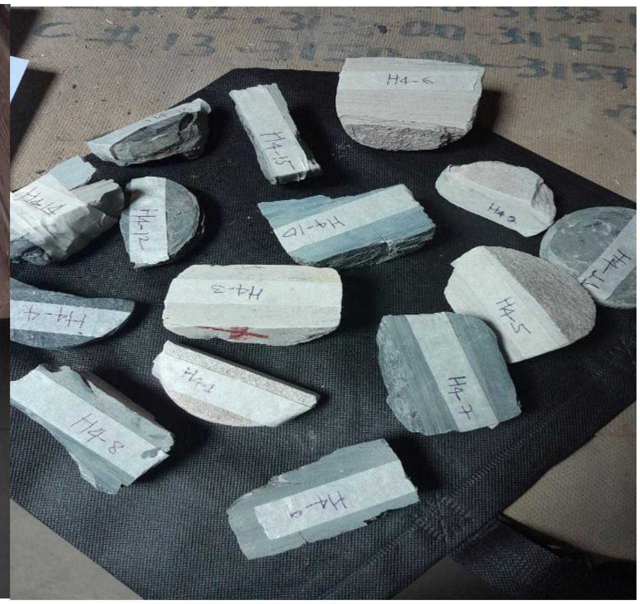

Figure: 3.1(a): Adigrat sand stone core sampleFigure: 3.1(b) selected core samples

Figure 3.1(c): Light electron micro scope

3.1.3 Petrographic (microscope) study

These thin sections are made with the intention of doing a thorough investigation of composition and texture, two factors that are crucial in revealing information about porosity and the impacts of diagenesis on reservoir properties. For each thin-section, several components and textural elements have been examined using a petrographic microscope (Fig 3.1(c)). Through the use of the point counting approach, the relative proportions of the major framework grains have also been discovered, tallied, and seen in thin sections. A petrographic microscope investigation of these thin slices will reveal several components, and JMicroVision and ImageJ software is used to quantify the percentages of the main framework grains. The compositional analysis will be used to determine both the diagenetic impact and the textural characteristics.

3.3 Porosity measurement

To ascertain the reservoir quality of the formation sandstones, the porosity of the thin section samples was evaluated. Porosity and permeability are the two key elements of reservoir quality. Two distinct techniques were used to measure the porosity of the thin sections: Using the applications Jmicro Vision and ImageJ: The thin sections were dyed, which made the porosity appear red in the images and made it easier to estimate porosity. The cumulative area of the hand-drawn outlines was then calculated as a percentage of the overall area of the thin section picture for each pore that demonstrated non-clay porosity. The indicated porosity is the type of porosity that can accommodate hydrocarbons, such as intergranular porosity.Since the porosity indicated here does not account for the micro-porosity of clay, it is likely to be less than the total porosity determined by laboratory measurement of porosity.

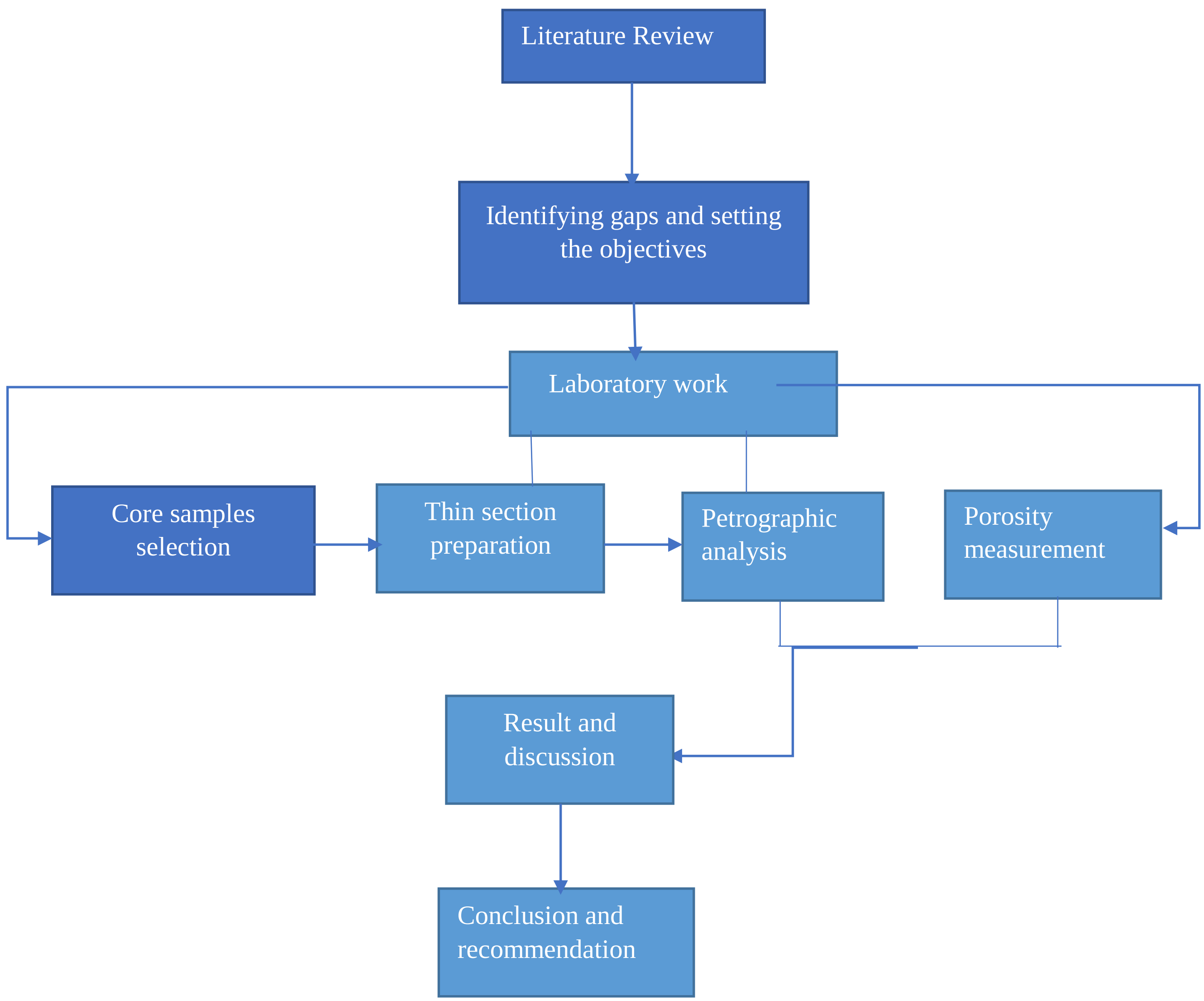

Figure 3.2: Project flow diagram

3.4 Data analysis tools

After collecting all necessary data concerning each study parameters and environmental conditions from checklist, laboratory and observation results were summarized by Microsoft Excel and Rock AR2/Jmicrovision

3.5 Ethical Considerations

All of the project participants who are a part of this study will be properly informed about the goal of the project, and their agreement and willingness will be obtained. Regarding the respondents' right to privacy, I uphold the secrecy of some sensitive information and each participant's identification. Names are never revealed, so we'll just refer to people collectively as study participants.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Petrographic analysis

Fifteen thin-sections made from representative samples were used in a petrographic study. Different components have been discovered through the petrographic microscope inspection of these thin sections, and the point counting technique is used to calculate the percentages of major framework grains. The chemical and textural properties of quartz-arenite-quartz-wacke have been analyzed under a microscope, and medium-well rounded and medium-well sorted Petro-facies have been discovered. In this sandstone level, it's typical to find sub-rounded to rounded quartz grains, small amounts of mica, feldspar, and rock fragments, flakes of muscovite, a sizable amount of muddy matrix, and reddish brown cement made of carbonate mud and sparse calcite cement.

The lithological characters of Adigrat formation is mainly composed of arkose, followed by lithic feldsparsandstone. Adigrat sandstone is mainly composed of feldspathic quartz sandstone andsecondarily of quartz sandstone.

Among the 15 analyzed samples of Adigrat sst 9counts were feldspathic quartz sandstone which occupies 70.6%; whereas 6counts fall in the zone of quartz sandstone which takes up 29.4%; so that Adigrat sandstone is mainly composed of feldspathic quartz sandstone and secondarily of quartz sandstone (Table 4.1). The grains are medium-well sorted; they are mainly sub rounded-angular; they are distributed evenly; as to grain contact relationship, line-point contact is predominant. In general, it is medium mature both in terms of compositional and textural maturity.

Table 4.1: petrographic and textural results observed under LEM

Depth (m)	Mineralogy						Texture		
	Quartz	Clay	Opaque	Sericite	Biotite	Muscovite	Roundness	Sorting	Grain Contact
3134.7	86	10	4				Subangular-Angular	Poor	Line, Point
3135	80	14	6				Subangular-Angular	Medium -Good	Point, Line
3136.5	12	80	5	3			Subangular-Sub rounded	Medium -Good	Line, Point
3137	10	82	5	3			Subangular-Angular	Good	Line,Point
3138.7	78	16	6				Subangular-Angular	Good	Line,Point
3139.4	83	12	5				Subangular-Angular	Medium -Good	Point,Line
3140.5	80	13	4		3		Subangular-Angular	Medium -Good	Line,Point
3141.5	77	15	3		5		Subangular-Angular	Good	Line,Point
3143	75	15	4		6		Subangular-Angular	Good	Line,Point
3144.5	73	18	4		5		Subangular-	Medium	Point,Line

							Angular	-Good	
3146	76	16	6		4		Subangular-Angular	Medium -Good	Line,Point
3147.5	75	15	4		6		Subangular-Angular	Good	Line,Point
3149	78	13	6		3		Subangular-Angular	Good	Line,Point
3150.5	79	16	5			trace	Subangular-Angular	Medium -Good	Point,Line
3152	81	14	5			trace	Subangular-Angular	Medium -Good	Line,Point

Table 4.2: Compositional details of Hilala Well-X's Adigrat Sandstone

Composition	Description
Quartz	The predominant mineral grain that can be seen in all thin-sections of sandstone is quartz. Quartz grains come in two different varieties: monocrystalline and polycrystalline. The primary difference between the two varieties of quartz is that one quartz crystal makes up monocrystalline quartz, whereas two or more quartz crystals make up polycrystalline quartz. The quartz grains in some of the samples are severely fractured and have minute holes (vacuoles).
Feldspar	Feldspar is one of the crucial elements of sandstone that is employed in compositional classification. Despite having a lower

	proportion than quartz grains, the two most prevalent feldspar variants are plagioclase feldspar and microcline. Feldspar comes in a wide variety of forms.
Lithic fragment	These make up the bulk of sandstone as well, which is made up of various mineral grains and polyminerals. Under a microscope, particularly when using cross-polarized light, these elements are easily seen and identified. Some of the samples contain rock shards with sedimentary origin.
Cement	Hematite, a cementing material with reddish-reddish brown and dark brown colouring, is frequently seen covering grains and partially or completely filling intergranular pore spaces. Calcareous sandstones also contain significant amounts of carbonate cement.
Matrix	This extremely tiny and compact murky component fills between the granules' pore spaces. Sand-sized quartz grains that are used in some samples serve as matrices to fill the spaces between larger grains. While carbonate mud also appears as matrix in other samples.
Other mineral grains	Other minerals are hardly ever found. In contrast, a few samples have crystals of the heavy minerals Zircon and Sillimanite as well as the mica group (Biotite and Muscovite).

4.2. Sandstone Classification

200–300 principal framework grains (quartz, feldspar, and lithics) count was made from each thin section under a petrographic microscope, and their relative proportions were calculated out of a total of one hundred. Estimates have also been made of the relative ratios of cement and matrix.

4.3. Modal Composition

Mostly fine to medium grained grains with varying degrees of sorting were found. The Adigrat sandstone is composed of the framework grains, auxiliary minerals, matrix, cement, and pores. The framework minerals are quartz, feldspar, and lithic pieces, whereas the accessory minerals are mica (biotite and muscovite). Quartz grains typically range in shape from subangular to Angular and make up between 73 and 86% of the framework grains (Table 4.2). The feldspar grains, which make up about 10.0–20.0% of the framework grains, are frequently angular to subangular in form. The framework grains' lithic fragment content ranges from 3.0 to 7.0%, with an average of 7%. Sedimentary lithic fragments, which are typically fine-mdium-quartz grains in clay matrix, and metamorphic lithic fragments, which are clasts of sutured grains without matrix, are two common forms of these lithic fragments. The sedimentary lithic fragments, which include mud rock and sandstone pieces, make up a bigger portion of the total lithic fragment population. Cement and the matrix act as binders for the bigger or framework grains. Clay minerals make up the majority of the matrix or groundmass, accounting for between 3.2 and 13.8%, while cement makes up range from 1.8 and 10.0% of the total composition.

4.4 Adigrat Sandstones mineralogical composition

Petrographically analysis LEM Quartz is among the most prevalent minerals, according to study. (73–86%) and Clay82%), while the dominant clay mineral is kaolinite (Table 4.3, Fig 4.2(a)). The observed clay minerals are kaolinite, illite, smectite and chlorite.

Table 4.3: Mineralogy of the Adigrat Sandstones

	Borehole Depth	Mineralogical composition

Sample id	(m)	Quartz	Clay	Opaque	Sericite	Biotite	Muscovite
H4-1	3134.7	86	10	4			
H4-2	3135	80	14	6			
H4-3	3136.5	12	80	5	3		
H-4	3137	10	82	5	3		
H4-5	3138.7	78	16	6			
H4-6	3139.4	83	12	5			
H4-7	3140.5	80	13	4		3	
H4-8	3141.5	77	15	3		5	
H4-9	3143	75	15	4		6	
H4-10	3144.5	73	18	4		5	
H4-11	3146	76	16	6		4	
H4-12	3147.5	75	15	4		6	
H4-13	3149	78	13	6		3	
H4-14	3150.5	79	16	5			Trace
H4-15	3152	81	14	5			Trace

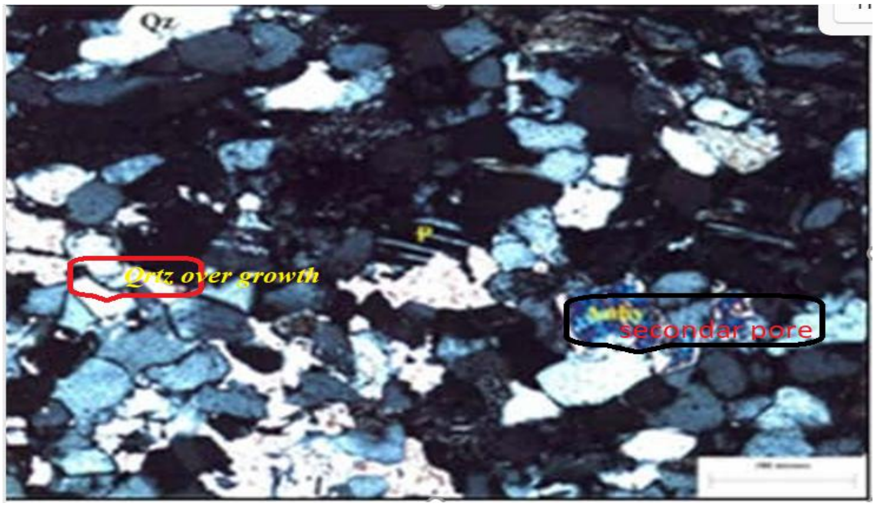

Figure 4.2(a):@3139.4m depth of Well H4-6: Sub-arkose Thin Section. Quartz over growth decrease porosity, large amount of quartz (Qz), secondary porosity due to kaolinite dissolution.

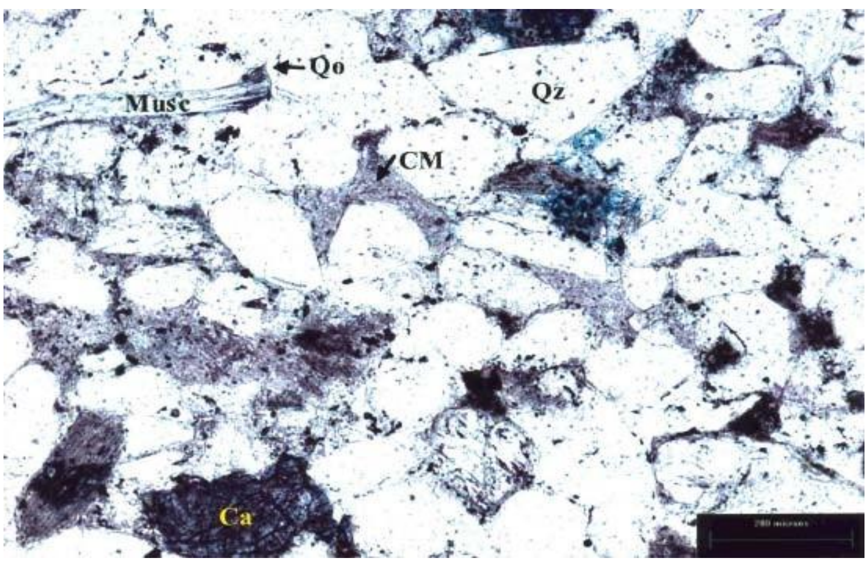

Figure 4.2(b) :) @3149 m depth of Well H4-13: Sub-arkose thin sectionPhotomicrographs showing Sub rounded quartz grain (Qz), Muscovite (Musc), Calcite dissolution

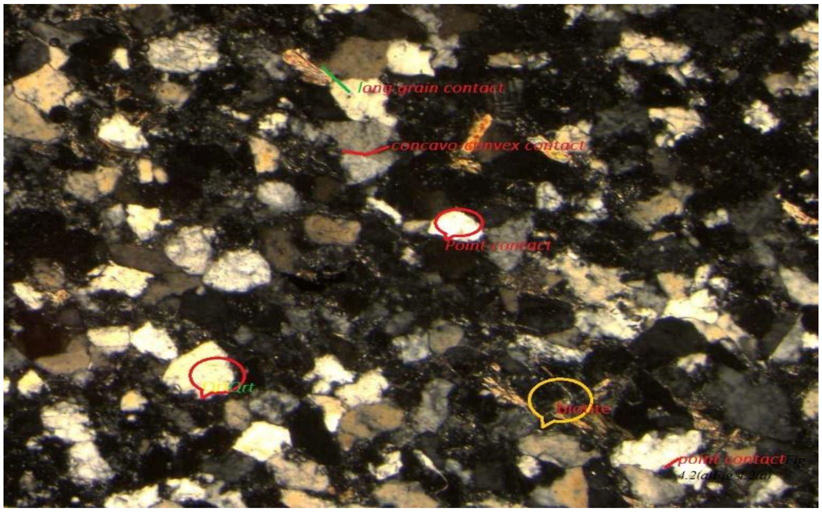

Figure 4.3: Sand stone @3136m depth (Adigrat Formation) in Well H4-14) Point contact, long grain contact, convex-concave

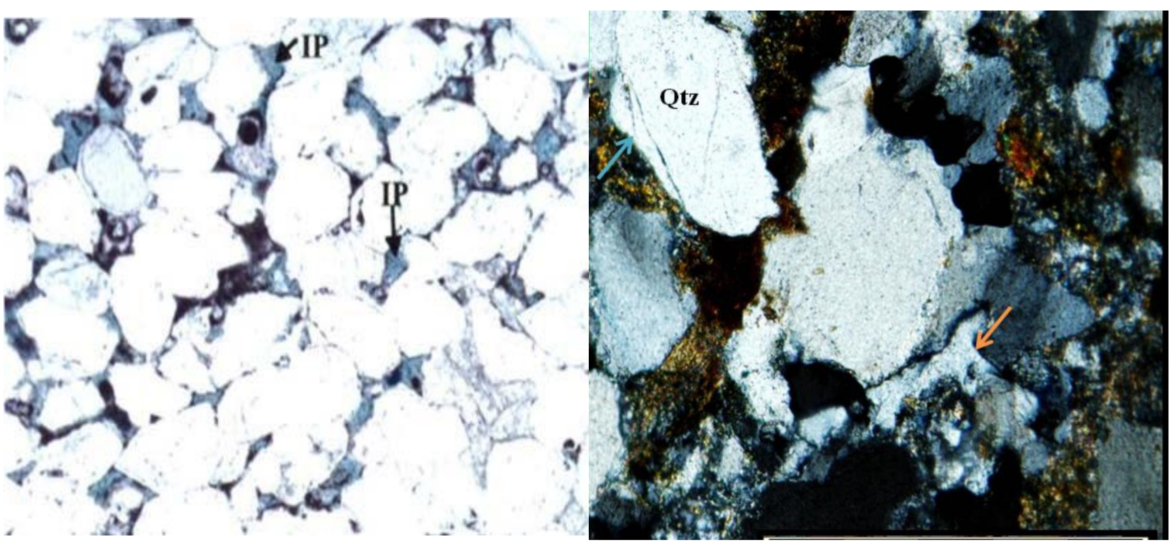

Figure 4.4: Sandstone at 3150m depth (Adigrat Formation) in Well H4-14Plaquecementsincludekaoliniteandenlargedquartz (Qo), asmallamountofsiderite, pyriteandclayfilmvisible.Intergranular pores (IP) and secondary pores developed

Table 4.5: point count porosity results and effects of diagenesis

Borehole	Depth(m)	Count porosity	Dominant matrix under LEM	Effects of Diagenesis on the Reservoir Properties
H4-1	**3134.7**	0.723	Clay and minor quartz	Porosity is Generally Poor.
H4-2	**3135**	1.088	Clay and minor quartz	Porosity is Poor. Quartz overgrowths reduce intergranular porosity
H4-3	**3136.5**	9.349	Quartz overgrowth, illite and kaolinite	Good porousness. the rise in ofillite and kaolinite concentrations and the existence of pseudo matrix
H4-4	**3137**	5.155	Clay is the major constituent of matrix and minor amount of quartz, sericite and opaque minerals	Porosity is good Quartz overgrowths and clay cementing reduce porosity
H4-5	**3138.7**	6.342	Quartz overgrowth, illite and kaolinite	Good calcite have reduced intergranular
H4-6	**3139.4**	13.102	Quartz grain, minor clay and opaque	Porosity Good to medium Secondary porosity is developed
H4-7	**3140.5**	5.365	Quartz overgrowth, illite and kaolinite	Porosity is good. Quartz over growth reduce porosity
H4-8	**3141.5**	12.243	Quartz grain, minor clay and opaque	Porosity Good to medium Secondary porosity is developed.
H4-9	**3143**	9.439	Quartz grain, minor clay, opaque, biotite	Porosity is commonly reduced to micro porosity byauthigenic illite
H4-	**3144.5**		Quartz grain, minor clay, opaque,	Porosity is good

10		8.025	biotite and	Quartz overgrowths and clay cementing reduce porosity
H4-11	**3146**	7.701	Quartz grain, minor clay and opaque	Porosity is good Quartz overgrowths and clay cementing reduce porosity
H4-12	**3147.5**	10.389	Quartz grain, minor clay and opaque	Porosity Good to medium Secondary porosity is developed
H4-13	**3149**	11.544	Quartz grain, minor clay, opaque and muscovite	Porosity Good to medium Secondary porosity is developed
H4-14	**3150.5**	13.06	Quartz grain, minor clay and opaque	
H4-15	**3152**	9.653	Quartz grain, minor clay, opaque and biotite	Porosity Good to medium Secondary porosity is developed(kaolinite dissolution)

CHAPTER FIVE

5. CONCLUSION AND RECCOMENDATION

5.1 CONCLUSION

Thin section analysis, focusing on textural characteristics and the effects of diagenesis, has revealed that the framework grains are tightly packed and the inter-granular pore spaces are filled with cement and matrix, significantly lowering the structure's capacity to hold and transfer fluid.

On typical samples, thin section and porosity tests were run to examine the lithological, pore structural, and fluid mobility characteristics. The following is a summary of several recent discoveries: - The low-medium porosity of the Adigrat sandstone is visible. During the initial stage of diagenesis, the strong compaction causes the sandstone to become generally denser. Different clay cementation and dissolution at a later time encourage the creation of various diagenetic facies and differentiate reservoir quality.

A major contributing element to the decrease in reservoir permeability is the presence of kaolinite and illite, which reduce the effective pore radius, increase the internal specific surface area of the sandstone, and improve binding to the fluid. The Adigrat sandstones are classified as subarkosic and lithic arkose because to its mineral composition, which is primarily fine-grained and somewhat well-sorted. Due to their strong permeability and porosity in some intervals, these sandstones exhibit good reservoir properties; yet, due to their low porosity in other intervals, they exhibit fair to poor reservoir properties. The diagenetic processes (such as dissolution, leaching, and grain fracture) that increased the porosity were the cause of the good reservoir quality in the Boreholes H4-6 and H4-14. Contrarily, compaction (i.e., concavo-convex and suture contacts) and the prevalence of cementation by authigenic clays are to blame for the poor reservoir quality in H4-1. In every borehole, at varying depths, and with different sand units, the various controls on reservoir quality behave differently. The main causes of the decline in reservoir quality include the cementation of quartz, calcite, illite, illite-smectite, kaolinite, and other minerals, as well as pore-filling chlorite.

5.2 Recommendation

The reservoir quality of adigrat sandstone, southeastern part of Ethiopia has an interesting oil and gas potential area this has not been thoroughly researched, especially the reservoirs successor with far more thorough recordings of petroleum potential of Ethiopian history. Because the region is a possible location for a wide range of scientific inquiries, scientists need to focus their attention on this overlooked reservoir quality of the basin. Based on thin section examination, principally of textural features and the influence of diagenesis, it is known that the framework grains are closely packed together and the inter-granular pore spaces are filled with matrix and cement, entirely eliminating its potential to store and transfer fluid. The Adigrat Sandstone in the Ogaden Basin is therefore thought to have a medium to poor reservoir quality. However, I made an effort to conduct analyses using well-drilled core samples. However, additional research and effort are required to assess the permeability and porosity of the wells and to suggest drilling techniques and drilling fluids for the basin.

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Appendix

(Point count porosity/ImageJ/

Slice	Count	Total Area	Average size	% Area	Feret	FeretX	FeretY	FeretAngle	MinFeret
H4-1.jpg	1442	99.049	0.069	0.723	0.353	684.556	300.093	125.858	0.184
H4-2.jpg	1462	149	0.102	1.088	0.309	684.991	393.651	128.919	0.173
H4-3.jpg	1777	1280	0.72	9.349	0.695	645.594	403.92	121.067	0.39
H4-5.jpg	1122	868.358	0.774	6.342	0.695	513.821	498.611	122.226	0.399
H4-6.jpg	2188	1793.877	0.82	13.102	0.781	586.229	457.514	118.825	0.436
H4-7.jpg	2769	734.593	0.265	5.365	0.454	585.988	367.415	125.741	0.242
H4-8.jpg	1930	1676.21	0.869	12.243	0.778	613.784	455.939	120.45	0.45
H4-9.jpg	1857	1292.333	0.696	9.439	0.741	622.328	445.265	122.347	0.415
H410.jpg	2333	0.439	1.88E-04	8.025	0.015	606.395	422.332	121.764	0.008
H4-11.jpg	2718	0.422	1.55E-04	7.701	0.01	613.787	403.866	129.15	0.005
H4-12.jpg	3979	0.569	1.43E-04	10.389	0.011	673.581	383.213	125.466	0.006
H4-13.jpg	6041	1580.494	0.262	11.544	0.526	677.754	417.073	126.776	0.289
H4-14.jpg	4137	1788.062	0.432	13.06	0.516	636.721	473.695	123.931	0.284
H4-15.jpg	1014	1321.667	1.303	9.653	1.027	562.9	415.065	124.275	0.517