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FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY OIL

OIL AND GAS ENGINEERING DEPARTMENT

NANO-TECHNOLOGY APPLICATION IN OIL INDUSTRY / DRILLING ENGINEERING

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE

OF BACHELOR OF SCIENCE

IN OIL AND GAS ENGINEERING

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DECLARATION

We hereby declare that this Bachelor's Project is the result of our own work، except for quotations and summaries which have been duly acknowledged.

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APPROVAL

This is to certify that the project titled **Nano-technology Application in Oil Industry / Drilling Engineering** has been read and approved for meeting part of the requirements and regulations governing the award of the Bachelor of Engineering (Oil and Gas) degree of Emirates International University, Sana'a, Yemen.

Project Supervisor: **Dr. Eng. Ibrahim Ali fare**

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ABSTRACT

Nanotechnology is a field of science that is applied to study the matter on nanometer scale. Over the past decades, significant progress has been achieved in nanotechnology which has emerged as a tool and technology that has been implemented successfully in different fields including medicines, electronics equipment, composite materials and oil and gas industry…etc. Now it is possible to design and synthesize materials at atomic level with extraordinary mechanical, optical and magnetic properties for different applications. In oil drilling industry we face a number of major drilling-problems that are directly related to the drilling fluid and drilling practices. To tackle the challenge of controlling the rheological profile of drilling muds in situ in response to changing environmental conditions down hole we use nanoparticles to enhance and modify rheology of drilling fluid.

The main application of nanoparticles would be to control the spurt and fluid loss into the formation and hence control formation damage. The presence of nanoparticles can lead to better sealing at an earlier stage of filter cake formation and, subsequently, a thinner impermeable mud cake. Nanoparticle addition into drilling fluid provide a novel benefit, especially on filtration problem, since the addition of Nano give a satisfied reduction in the volume of mud loss during drilling process. Through our Lap experiment, we studied the effect of (Nano-silver) filter on the Rheology and loss of drilling mud. Therefore, we conclude many points: Nano-silver has effect on the characteristic of the drilling mud, which has little effect on Rheology and more effect on the mud filtration, addition of Nano-silver into WBM does not have a significant effect on the density of mud, show slight decrease in density as Nano-silver concentrations increase, addition of Nano-silver into WBM has a significant effect on the filter loss of mud, the optimum filter loss reduction was 34% at 10%vol of Nano-silver concentration. Any increase in Nano-silver concentration more than 10% not given valid different reduction in filter loss. The optimum concentration of Nano-silver is approximately 4%, any further increase in Nano-silver will not reduce mud filtration.

ACKNOWLEDGMENTS

First of all, we owe our most sincere gratitude to Allah the almighty and the most powerful for offering us such a strength, endurance, willingness, and capability to accomplish this project.

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Special thanks to Yemen Oil Investments Company and Data Bank Development Project for providing us with necessary Data for the project and their goodness. Our special gratitude is due to all those who have helped in carrying out the research and contributed in any way for the success of this Project. Finally, yet importantly, we would like to express our heartfelt thanks to our beloved family for their blessings, our friends/classmates for their help and wishes for the successful completion of this project.

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API	**American Petroleum Institute**
BHA	**Bottom Hole Assembly**
CALI	**Caliper**
CCL	**Casing Collar Locater**
CEC	**Cation Exchange Capacity**
CMR	**Combinable Magnetic Resonance**
DST	**Drill Stem Test**
E&P	**Exploration And Production**
EOPP	**Early Oil Production Phase**
FOL	**First Oil Level**
FWLS	**Free Water Levels**
FWS	**Full Waveform Sonic**
GOC	**Gas Oil Contact**
GR	**Gamma Ray**
GRclean or GRmin	**Gamma Ray Reading In Clean Sand**
GRSH or GRmax	**Gamma Ray Reading In Shale Formation**
GST	**Gamma Ray Spectroscopy Tool**
GWC	**Gas Water Contact**
HI	**Hydrogen Index**
ID	**Inner Diameter**
IPL	**Integrated Porosity Lithology**
JHOC	**Jannah Hunt Oil Company**
K	**Formation Permeability**
LLD	**Laterolog Deep**
LLS	**Laterolog Shallow**

LTPP	**Long-Term Production Phase**
LWD	**Logging While Drilling**
M	**Cementation Factor**
M	**Mobility**
MD	**Measured Depth**
MSFL	**Micro Spherical Focused Log**
MWD	**Measurement While Drilling**
N	**Saturation Exponent**
N/G	**Net To Gross Ratio**
NMR	**Nuclear Magnetic Resonance**
NPHI	**Compensated Neutron Porosity**
NW-SE	**North West-South East**
OBM	**Oil Based Mud**
Øeff	**Effective Porosity**
Øtotal	**Total Porosity**
OWC	**Oil Water Contact**
PC	**Capillary Pressure**
PEF	**Photoelectric Effect**
PPM	**Part Per Million**
PVT	**Pressure/Volume/Temperature**
RHOB	**Bulk Density**
RMF*	**Resistivity Of Mud Filtrate**
ROP	**Rate Of Penetration**
RT*	**Resistivity Of True Zone**
RW*	**Formation Water Resistivity**
SCAL	**Special Core Analysis**
SP	**Spontaneous Potential**
SW*	**Water Saturation**

SWCS*	**Sidewall Cores**
TD	**Total Depth**
TDT	**Thermal Decay Tool**
TVD	**True Vertical Depth**
Vsh*	**Volume Of Shale**
PB	**Bulk Density**
PF	**Fluid Density**
PG	**Gas Density**
PM	**Matrix Density**
ΔT	**Interval Travel Time**

CHAPTER ONE

CHAPTER I

1. INTRODUCTION

1.1 Overview.

Nanotechnology is considered as a revolution in science and technology, a novel benefit resulted from the application of nanotechnology in many fields, such as medicine, electricity, military ...etc. And more recently the energy industries. Like other fields, this revolution effects of oil and gas industry, many researches and papers have been investigated and written about the benefits for application of nanoparticle in oil and gas industry such as exploration, drilling, completion, production, enhanced oil recovery, workover, oil and gas separation, refining and distribution .

For example, nano sensors might provide more detailed and accurate information about reservoirs; specially fabricated nanoparticles can be used for scale inhibition; structural nanomaterials could enable the development of petroleum industry equipment that is much lighter and more reliable and long-lasting; and nano membranes could enhance the gas separation and removal of impurities from oil and gas streams. Other emerging applications of nanotechnologies in the petroleum industry are new types of "smart fluids?? for enhanced oil recovery (EOR) and drilling. In short, there are numerous areas in which nanotechnology can contribute to more efficient, less expensive, and more environmentally sound technologies.

1.2 Aims and Objectives

1.2.1 Aims

Performing an applied, experimental and analytical study of block 14 by using nanoparticles in drilling fluids.

1.2.2 Objectives of the Project

In order to reach the aim of the project, we had to state the following objectives :-

1. Study borehole problem related to drilling fluid in Al-Masilah Field .
2. Review the result of nanoparticles applications used in the drilling fluid .
3. Investigate the effect of nano-silver/ nano-nickel on the characteristics of drilling fluid .
4. Enhance the mud rheology by nano-silver/ nano-nickel .
5. Investigate the effect of nano-silver/ nano- nickel on fluid loss .

6. SBF reduce the mud cost .
7. Reduce of the fluid loss into the formation by Nano-silver .
8. Minimize the thickness of filter cake by Nano-silver .
9. Modify the rheology of drilling mud by Nano-silver.

1.3 Project Statement

A number of major drilling-problems are directly related to the drilling fluid and drilling practices. Drilling into a pay zone with a conventional fluid can introduce a host of risks all of which diminish reservoir connectivity with the wellbore or reduce formation permeability such as salt formation, pipe sticking, shale instability, barite sag, hole cleaning and fluid loss .

The cost of the fluid system often represents one of the single greatest capital outlays in drilling an oil well. To minimize the cost of fluids and to ensure an efficient drilling program, the fluid properties must be maintained continuously during the drilling operation .

Research is being conducted to develop nanoparticle-amended drilling fluids with the enhanced functionalities. Such enhancements include improved rheological, thermal, mechanical, magnetic and optical profiles .

To tackle the challenge of controlling the rheological profile of drilling muds in situ in response to changing environmental conditions down hole, super paramagnetic iron oxide nanoparticles are being added to create drilling fluids with viscosities that can be rapidly altered in situ by applying a magnetic field. Similarly, the addition of carbon nanoparticles is effective at controlling the viscosity of drilling muds. The addition of nano-particles to drilling muds can also be used to remove the highly toxic and corrosive Hydrogen sulphide gas that diffuses into drilling fluids during drilling operations.

1.4 Significance of Project

The main application of nanoparticles would be to control the spurt and fluid loss into the formation and hence control formation damage. The presence of nanoparticles can lead to better sealing at an earlier stage of filter cake formation and, subsequently, a thinner impermeable mud-cake.

1.5 Scope of Project

Planning by using nanotechnology to enhancing drilling fluid which ensure minimize cost and efficient drilling program.

Total 1.1 **Scope of Project**

Well. N	Well Type	Block	Field	Zone	Latitude	Longitude
Tawila 70	Development	14	tawila	S2 – S3	15.441 (°)	49.048
Tawila 138	Development	14	tawila	S1A-S1B	15.430 (°)	49.036

1.6 Location of Block 14

located in the Arabian Peninsula in Hadhramaut region in east-central Republic of Yemen (**figure1.1**).

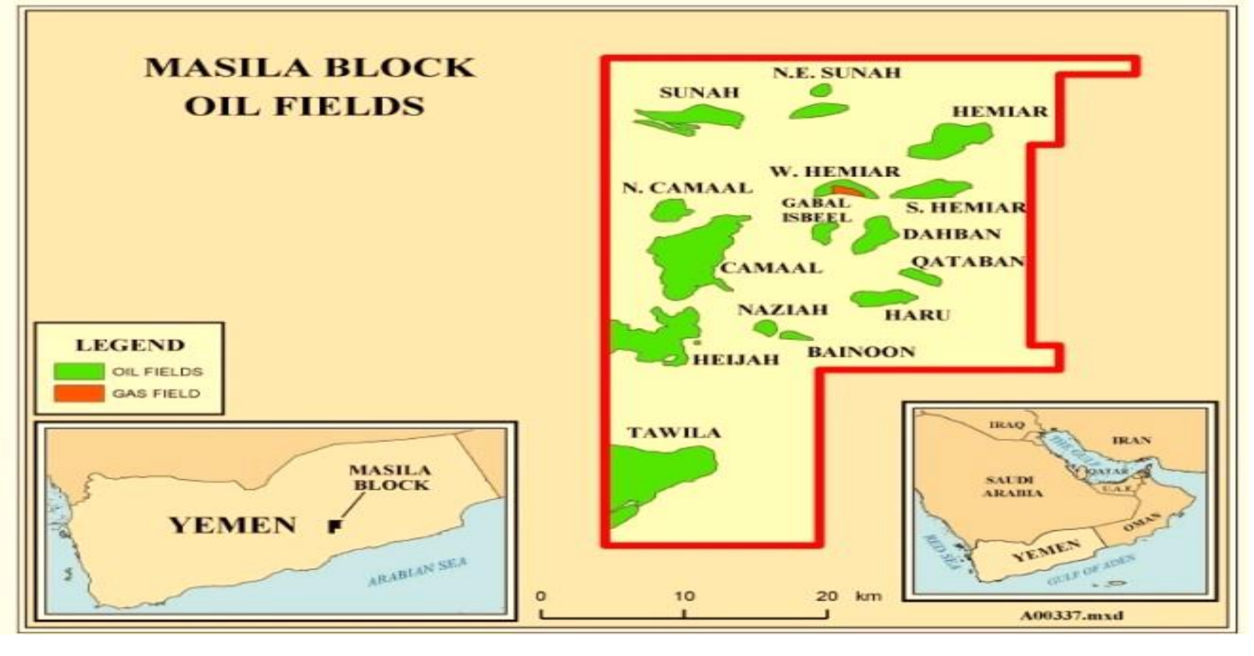

Figure1.1. Location of Block 14

1.7 Block 14 Overview

Block-14 is the second biggest block in Yemen. It's located in (Masila-Sya'un) basin, with area of 1,257 Km2. Block (14) is operated by Canadian Nexen petroleum Company- Canadian company.

The main reservoirs in the block are (Qishn clastic), (Saar clastic & Saar carbonate, Basil sand), (Madbi carbonate) in addition to Basement rocks.

In General, it contains 16 fields with an average production of (58,627) BOPD .

The total number of wells ware 639 until Des. 2011 .

The block is connected with the export Terminal of ASShihr in Hadhramout province by pipeline (long of 138 Km and 24 inches' diameter), with maximum capacity of 350,000 BOPD .

The produced oil is intermediate oil in the different fields with a density between (28-32 API) for the main reservoirs, whereas is light oil in basement rocks with (41 API).

The partners in the Production Sharing Agreement with the Yemeni government are:

- ***Nexen (52%)***
- ***CCC (10%)***
- ***Occidental (38%).***

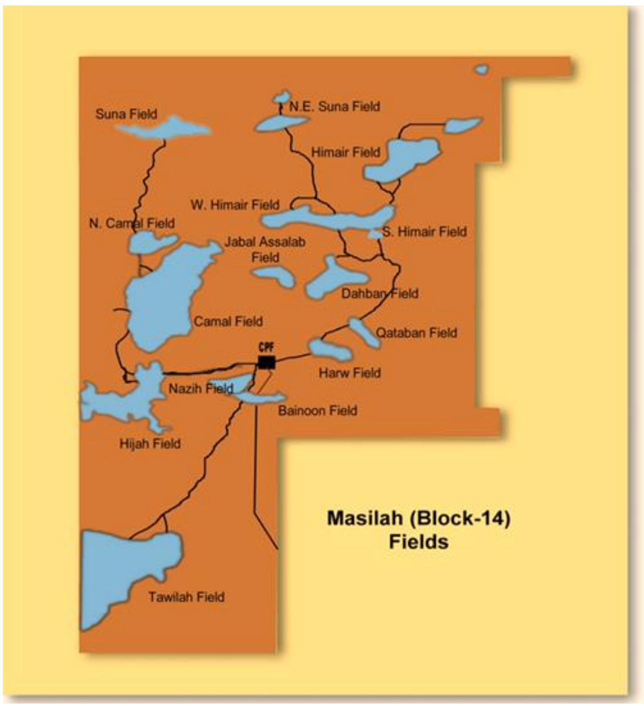

Figure 1.2 ***masilah (Block-14) field***

Masila block 14 is operated Canadian Occidental Petroleum Yemen on behalf of its partner's occidental peninsula. and consolidated contractors international, (Canadian nexen petroleum yemen as known now) and is located in the hadhamaut region, in east-central republic of Yemen. oil production at masila degan in july 1993. The Masila fields are in the Jurassic to Lower Cretaceous aged, Saar Graben. Almost 90% of the Masila reserves are reservoired in the Lower Cretaceous Upper Qishn Clastics Member of the Qishn Formation. Oil is also found in at least seven other reservoirs consisting of Lower Cretaceous and Middle to Upper Jurassic ageclastics and carbonates as well as fractured granitic basement

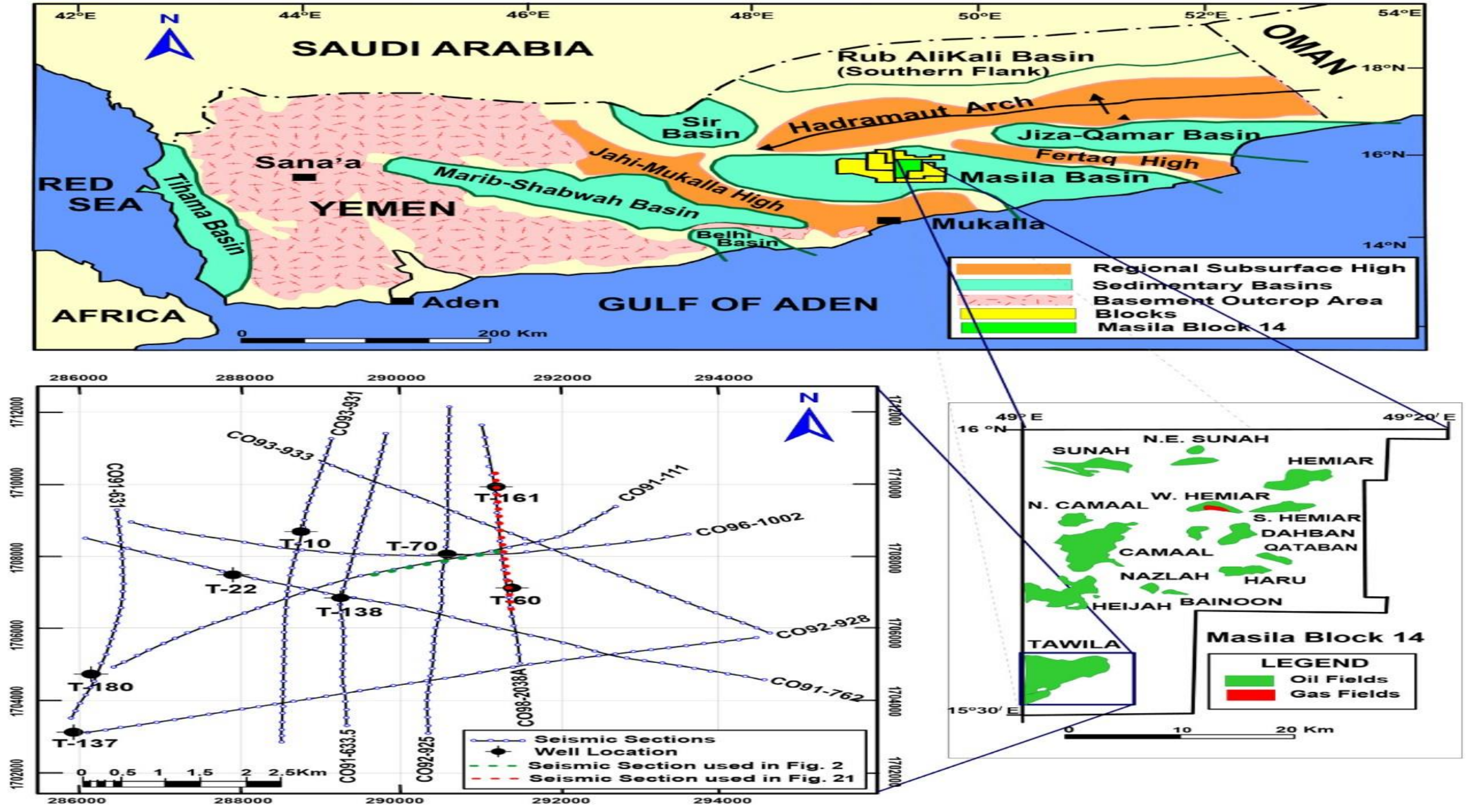

Figure1.3. Map of the location masila block in Yemen

1.8 Main topics of this study

The main topics of this study on the reservoir rock of qishn formation

(masila block 14) are the following:

- to show the great importance of masila (block 14) and the reservoir rocks of qishn formation for nexen Inc .
- to give a brief on the whole pervious activities done on studying the geological research history work of the eastern part of the republic of Yemen (the study area and the adjacent area)
- to follow qishn formation location on the whole surface to study it in the sub surface of the studied area and to highlight the upper qishn classic's rocks stratigraphy
- to explain the petroleum system of qishn formation. its source rock, maturation, migration, reservoir rock, traps and seals
- Masila block 14 is operated Canadian Occidental Petroleum Yemen on behalf of its partner's occidental peninsula, Inc. and consolidated contractors international ltd, (Canadian nexen petroleum yemen as known now) and is located in the hadhamaut region, in east-central republic of Yemen. oil production at masila degan in july 1993.
- To explain the petroleum system of Qishn Formation, its source rocks, maturation, migration, reservoir rocks, traps and seals.
- Qishn Formation is divided into four members, Clastic and Carbonate members.

1.9 Source rocks (Block 14)

The Upper Jurassic (Kimmeridgian) source rock of the Madbi Formation is organicrich black shales deposited in the deeper portions of rifts in the Late Jurassic, Madbi Formation is the main potential source rocks for the reservoir rocks of Qishn Formation.

1.10 Maturation

Source rocks began generating in the central rift basin in latest Cretaceous to earliest Paleogene time and the process were largely completed by the end of Paleogene time. Degree of maturation: (Oil Window) 0.6. Type of kerogen: I and 2 type of organic mater types.

1.11 Migration

In the Masila Basin, oil and gas migrated along faults to horst blocks. Numerous horst uplifts occur; however, migration resulted in hydrocarbon accumulations, where sealed by Early Cretaceous carbonate (Qishn Carbonate Member). Heavy oil is known to occur marginal to the accumulation sites.

1.12 Reservoir rocks

In the Masila Basin, the Early Cretaceous estuarine sandstones of the Qishn Formation (Berremian/Aptian), mainly the Upper and Lower Qishn Clastics Members are the primary reservoir. Porosity average: 18 % -21%. Permeability average: 140-2000 ml).

1.13 Traps and seals

The Qishn Carbonate Member (Aptian) provides the seal for the underlying Qishn Clastic Member in the Masila Basin.

- Masila Block's Fields are located within the Sirr-Sayun Rift Basin that formed during the Upper Jurassic when the Africa-Arabian Plate separated from the IndiaMadagascar Plate. The Sirr-Sayun Basin is a few hundred kilometres wide and several hundred kilometres long, and is oriented northwest southeast, the basin is bounded on the west by Jahi - Mukalla High, to the south by the South Hadramaut Arch, to the east by the Ras Fartak High and partially interrupted to the northwest by the Sayun High, The Masila Block is situated on an intragraben terrace, and is ideally located to access migrating hydrocarbons from mature deeper buried Jurassic Madbi source rocks.
- I found that one of the most famous, more complex and interesting topic problems, which faces any researcher who would like to make any kind of academic works. Such as any kind of geological studies on Masila Block 14 reservoir rocks of Qishn formation or any other geological research studies on the whole area.

CHAPTER TWO

CHAPTER II

2. LITERATURE REVIEW

2.1 Introduction

The Literature review is one of the main phases in performing any research, as it usually highlights the main gaps in the previous studies, which may need to be filled. It helps also to understand the necessary direction to follow to develop the study.

2.2 Analysis of Block-14 (Tawila)

The Tawila (S2- S3) Upper Qishn S2 sandstone is expected to be of similar reservoir quality to the S2 encountered at Tawila 29. An estimated net pay interval of 38 feet is expected. The top of the S2 will be encountered at approximately –2,595 ft. SS, which is 55 feet above the original OWC at –2,650 ft. SS.

The top of the S3 at Tawila (S2-S3) is prognosed to be at –2,663 ft. SS, which is 13 ft. below the original OWC. There is no pay anticipated in the S3. The attached Tawila Field Qishn S2 structure map is the June 2004 mapping and includes drilling results up to and including Tawila 132. The Tawila Field Qishn S2/S3 original net pay map includes drilling results up to and including Tawila(S2-S3).

The proposed S2 location is considered to have a very low technical risk.

Table 2.1: Expected Reservoir Properties

Zone	Net Pay (ft)	Permeability (md)	Porosity (%)	Sw (%)	Productivity Index (b/d/psi)
S2	38	750-2000	18.0	20	4-6
S3	0	1000-2500	19.5	100	-

- **Drilling Recommendation**

Nexen Petroleum International Ltd. recommends the Masila Block Partnership drill the vertical development producer Tawila 138 (P11-02). This location is planned to begin drilling as per the current CNPY drilling schedule. This well is required to maximize oil recovery from the Qishn S2 reservoir in the Tawila Field. The well will be drilled 200 ft. into the Saar Carbonate.

2.3 Geologic setting of the study area

Masila Basin is located in the Hadhramout province at the east–- central part of Yemen with an WNW–ESE orientation inherited from reactivation of the Infra–Cambrian Najd Fault System. Of the many blocks contained in this basin, Block-14, covering an area of about **1250 km2**, was the first to be discovered.

Masila Block-14 contains 16 oil-producing fields, of these, Tawila oil field is the largest and most important.

a) Stratigraphy

The stratigraphic column of the Masila Basin shows rock units ranging in age from Pre-Cambrian to Tertiary **(Fig2.1)**. Most of these sediments were deposited during the pre- syn and post-rift active tectonic events and are contained in rock units belonging mainly to Mesozoic and Tertiary periods **(Fig2.1)**.

The pre-rift sedimentary sequences are represented by the Bathonian /Callovian Kuhlan Formation and the Oxfordian Shuqra Formation. The Kohlan Formation constitutes the basal unit of the Jurassic succession and consists of fine-to medium-grained, well-sorted sandstones with poor to good porosity and several conglomeratic horizons. The Shuqra Formation consists of well-bedded neritic oolitic sandy limestone interbedded with rubbly fossiliferous marls.

The early syn-rift sediments are represented mainly by the Madbi, Naifa, and Saar Formations. The Madbi Formation consists of organic-rich marine shale and well-bedded limestone and is divided into two members: the lower Meem Member, which is rich with bituminous shale, and the upper Lam Member, which is composed of shale and turbidites.

The Madbi shale is a source rock for all reservoirs in the Masila block. The Naifa Formation conformably overlies the Madbi shale and consists of carbonates, dolomitic shale, and marls. The Saar Formation is a thick, shallow shelf carbonate and is considered to be a secondary reservoir that contributes to 18% of the hydrocarbon production.

The post-rifting sediments are represented by the Tawilah Group that lies unconformably over the Saar syn-rift clastics .The Qishn Formation constitutes the lowest sediments of the Tawilah Group and informally is divided into the following four members, from top to bottom: The Upper Carbonate, Red Shale, Lower Carbonate, and Clastic Members.

The Qishn Clastics are informally subdivided into two upper and lower members. The upper Clastic Member is deposited in an inner neritic to shallow marine platform and exhibits good hydrocarbon potential. The impermeable Qishn carbonates and shales act as cap rocks that offer sealing for the migrated oil from the deep-seated, thermally maturate source rocks of the Madbi Formation.

b) Tectonic setting

The Arabian plate has been subjected to complex tectonic events accompanied by eustatic sea-level changes that have played significant role in the development of sedimentary sequences and petroleum systems in the Arabian Platform.

The geodynamic setting of Tawila filed is complicated by many Mesozoic، Oligocene, and Late Miocene tectonic events as reflected in the structural features and sedimentation processes. Importantly, the Mesozoic rift basins in Yemen experienced four major tectonic episodes during rifting periods in the Mesozoic and Cenozoic **(Fig.2.2)**.

The first is Late Jurassic separation of the Indian plate from the Afro–Arabian plate accompanied by reactivation of the ancient Najd Fault System, which initiated a series of rift basins in Yemen. Tectonic stress associated with this movement led to development of the **Marib–Shabwah–Balhaf and Sirr–Sayun–Masila** basins, which were separated by the Jahi Mukalla High. The second event is related to the end of Africa–Arabia and Madagascar–India separation in the Late Cretaceous and the spreading development between India and Madagascar, which led to opening of the Arabian Sea.

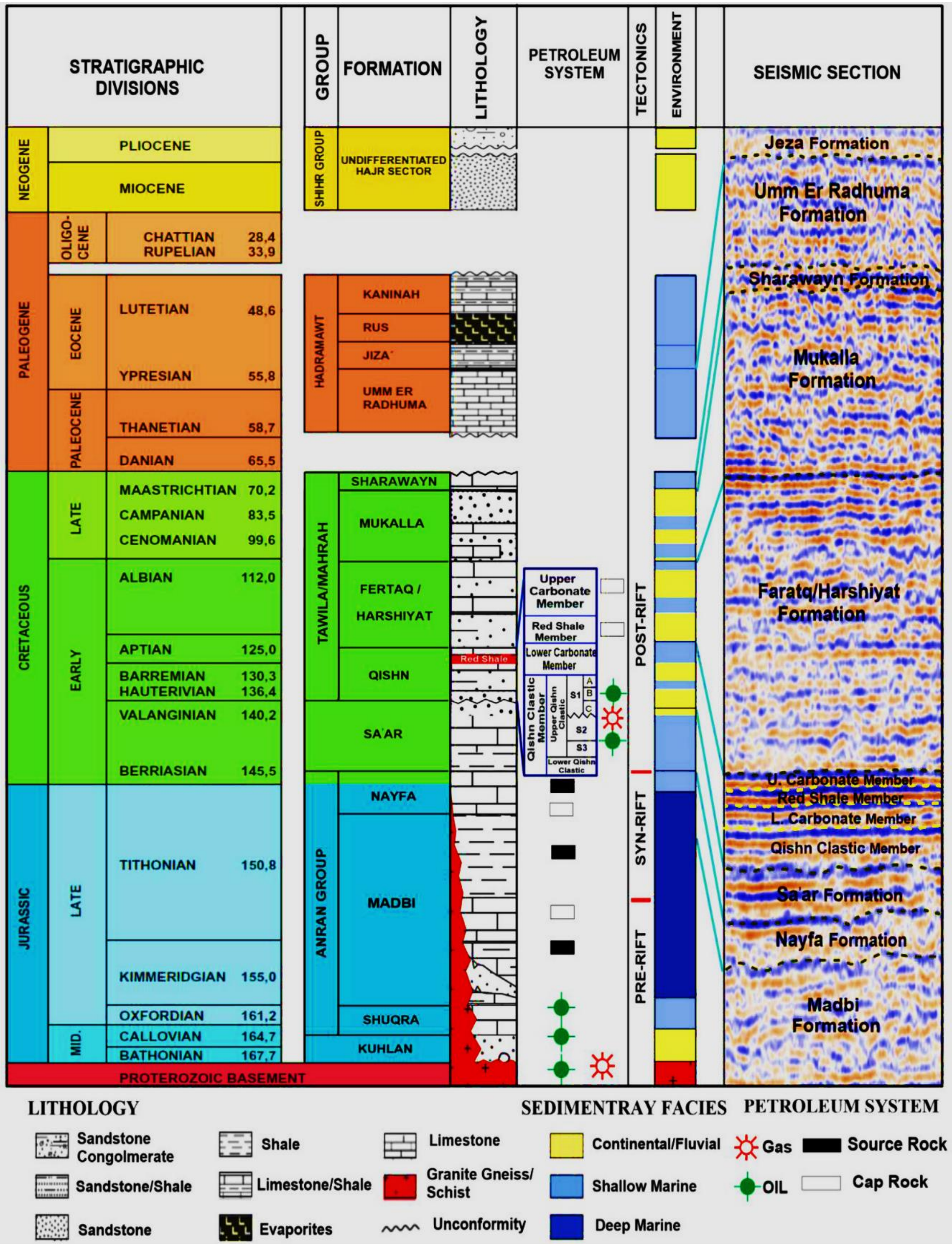

Figure 2.1 Generalized stratigraphic column of the Masila Basin-Yemen

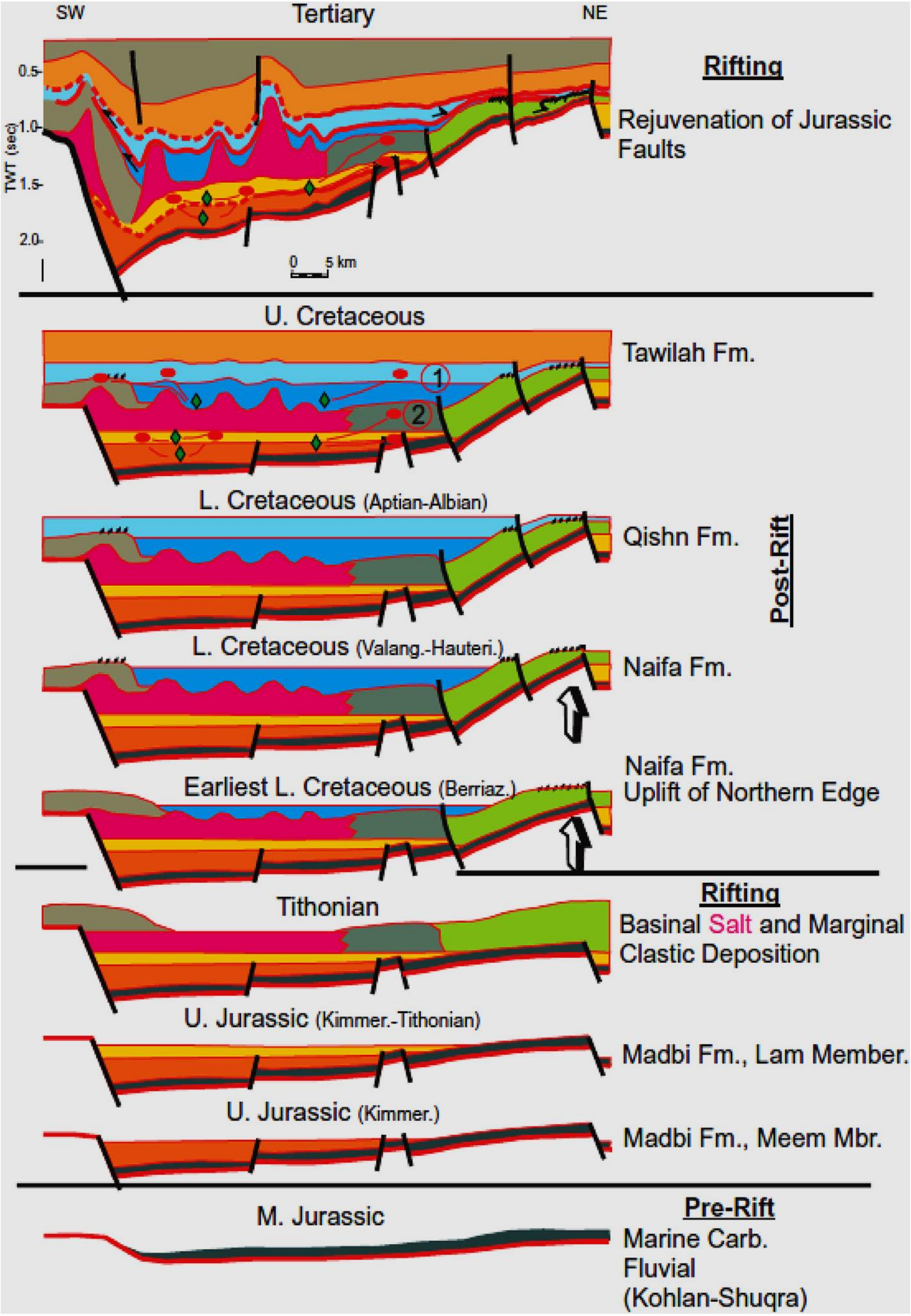

Figure.2.2 Major tectono-stratigraphic events in central Yemen including Masila Basin.

2.4 Data and research methods

2.4.1 Well log analysis

The petrophysical analysis was based on the digitized logs of eight wells penetrating the Upper Qishn clastic reservoir. The data were processed, corrected, and analyzed using Interactive Petrophysics software (IP v. 4.10). Owing to the clastic nature of the reservoir, we applied the Schlumberger Saraband program and approaches utilized in areas of similar geological/petrophysical characteristics. The volume, type, and distribution of shales are important reservoir properties.

Determination of shale volume of shale was based on gamma ray log (GR) calculations. Since shale distribution in sand can be laminated, structural, or dispersed; combinations of two of these types also occur. The basic Thomas–Stieber model was used for determining the type and manner of shale occurrence. Porosities were estimated from sonic, density, and neutron logs and are corrected for shaliness. Furthermore, fluid saturation was measured in front of both clean and shaly beds as well as by using the Pickett plot. A cut-off model was applied to detect the net pay and reservoir flags in front of the most promising intervals in the reservoir.

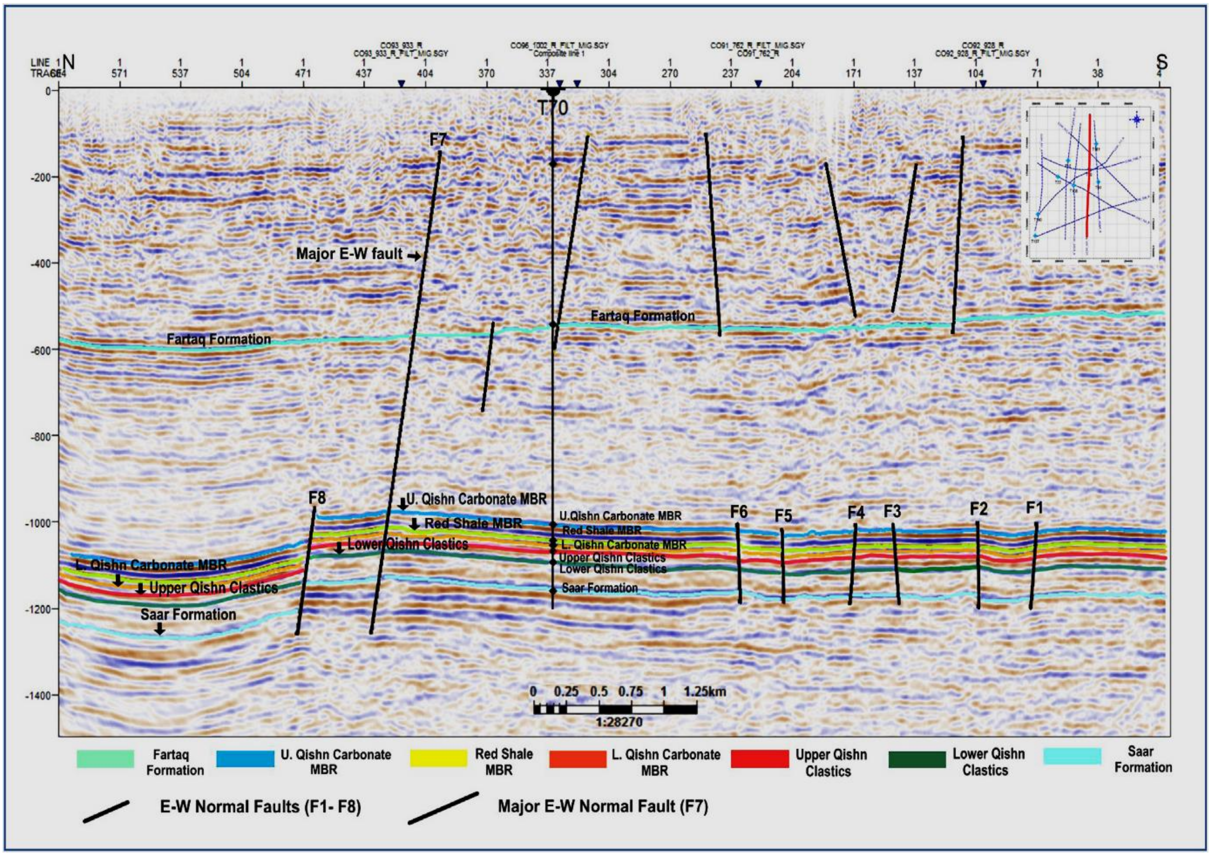

Figure 2.3 ***2D interpreted seismic section CO 92-925 running NeS, Tawila field, Masila Basin-Yemen. The section passes through well T-70 at the central part of the study***

The facies analysis was enhanced along the interpreted seismic profiles by matching the GR and sonic log facies with the seismic amplitude and the lithology indicated from drilling records. The different deduced petrophysical properties are represented depth-wise as vertical analogs, whereas water and hydrocarbon saturations are mapped along with the main seismic structures.

Figure 2.4 a) structural map, and **b)** Depth structural map of Fartaq Formation, Tawila field, Yemen. The maps show one major E–W normal fault cuts through the northern area. The large, blue-colored, elongated anomaly represents the downthrown side of this fault, at the extreme northern area. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

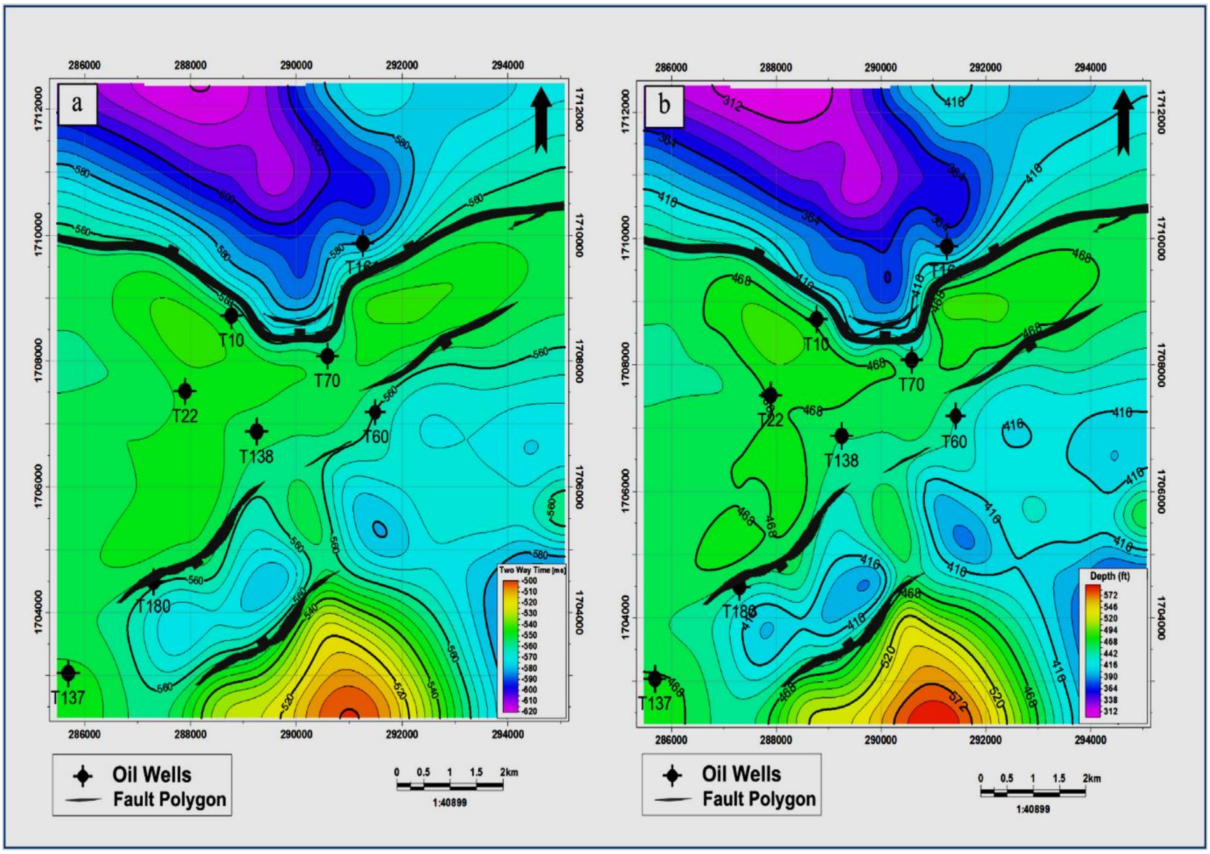

***Figure 2.4** map of Fartaq Formation, Tawila field, Yemen.*

Figure2.5 a) TWT structural map, and **b)** Depth structural map of Upper Qishn Clastics reservoir, Tawila field, Yemen. The major E–W, and minor ENE–WSW and E–W normal faults dissect the top of the reservoir producing numerous structurally controlled horsts of good hydrocarbon potentiality. A small prospective hydrocarbon semi-circular uplift was detected in the southwestern part of the area.

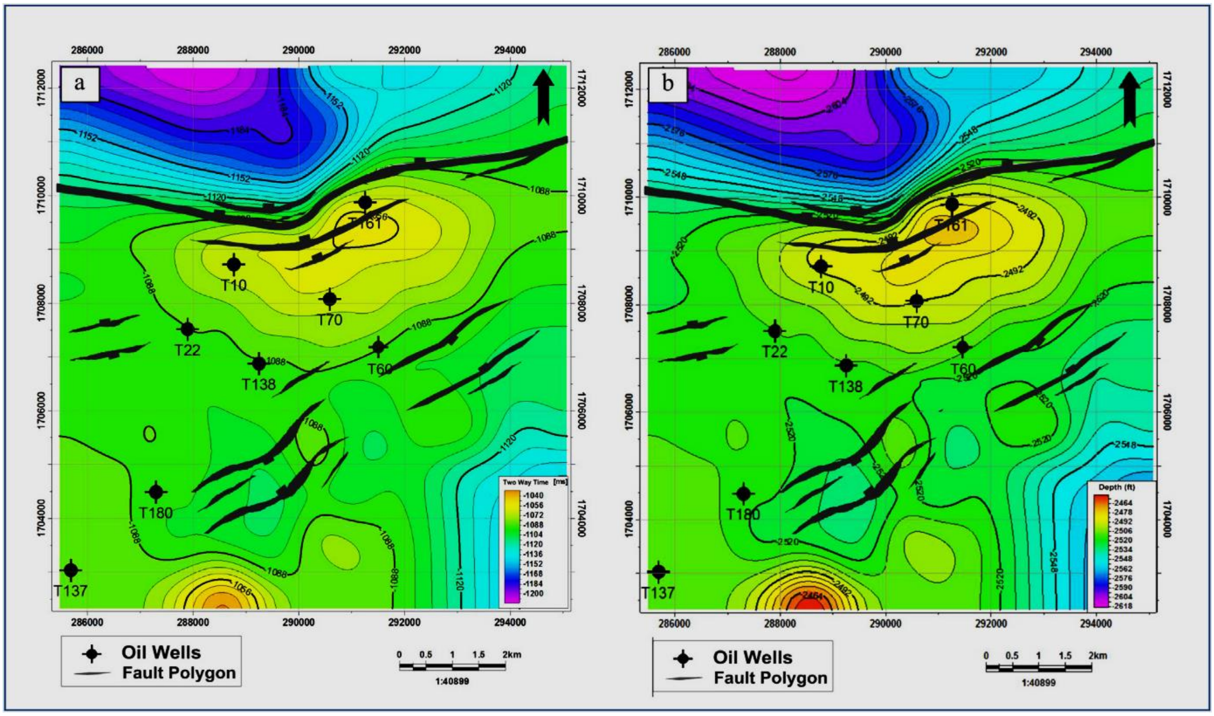

Figure2.5 map of Upper Qishn Clastics reservoir

Figure 2.6 a) TWT structural map, and **b)** Depth structural map of Saar Formation, Tawila field, Yemen. The top of the Saar Formation is dissected in a similar way like the overlying horizons. However, the geometry of the up thrown E–W elongated closure is reduced in dimensions.

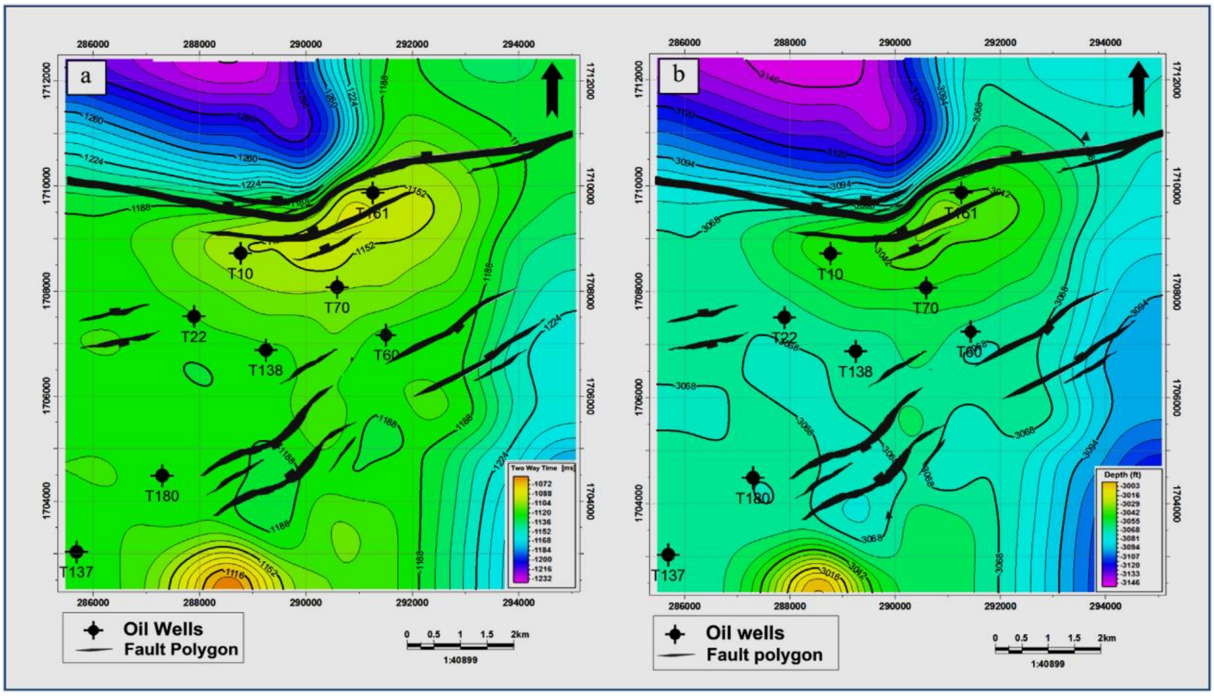

Figure.2.6 map of Saar Formation, Tawila field, Yemen.

Lithology identification using **Figure2.7.**

a) apparent uranium matrix – apparent density matrix plot and

b) apparent sonic matrix-apparent density matrix plot for Upper Qishn reservoir at well T-60, Tawila field,

Yemen. The clusters of units S2 and S3 are located mostly close to the quartz point indicating sandstone lithology. The data points for S1 A, B subunits are shifted away from the quartz lithology toward the calcite point.

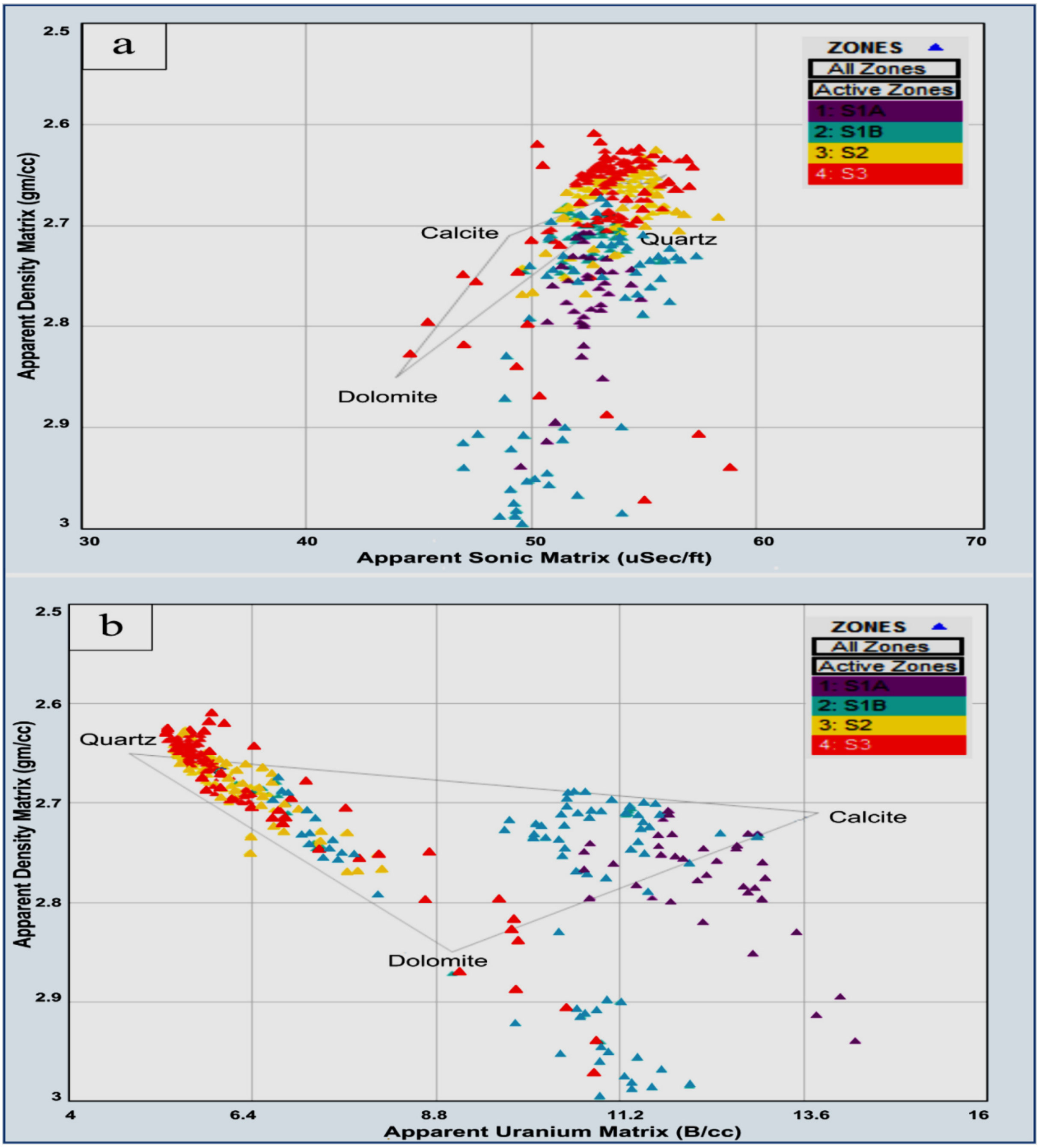

Figure 2.7 ***Lithology identification of units S2 and S3***

2.5 Reservoir properties

The reservoir properties of the sandstone reservoir are represented, The Qishn sandstone is divided petrophysically throughout the investigated oil fields in Masila Basin into three main units: S1, S2, and S3. Detailed analysis showed that zone S1 can be subdivided into two subunits of S1A, and S1B. The petrophysical parameters of the three main units are represented in **Table 2.2**. Zones S2 and S3 have retained good hydrocarbon content.

A) Lithology and fluid content

Subunit S1A and the upper part of S1B are dominantly carbonates with minor sandstone and shale, whereas the lower part of the S1B is composed of sandstone, a small amount of carbonates, and a major content of shale. The datapoints for these two subunits shift away from the quartz lithology toward the calcite point in the apparent uranium matrix–apparent density matrix plot and downward in the apparent sonic matrix-apparent density matrix plot. Thus, indicating an increase in carbonate matrix. Units S2 and S3 are composed of sandstone, very little carboantes and frequent interbeds of shale. Clusters of these two units are located mostly close to the quartz point.

The nonhydrocarbon-bearing nature of subunits S1A and S1B is clear in the Pickett plot. Most of the clusters of these subunits are located beyond the 100% water saturation line (SW) on the decreasing order of the porosity axis. On the contrary, a reasonable number of clusters of units S2 and S3 are located between water saturation lines of 40% and 80%, giving rise to a considerable hydrocarbon range of 20%–60%. However, the average hydrocarbon content of all clusters of units S2 and S3 is about 30%.

b) Shale type/distribution and petrophysical properties

Since the Qishn reservoir contains a considerable amount of shale and frequent shale interbeds, it was very important to investigate the type and distribution of its shale. There are three main types of shale: dispersed shale (DIS), laminated shale (LAM), and structural shale (STS).

DIS is composed of clay minerals that form after deposition owing to chemical reactions between minerals and chemicals in the formation water. These minerals occupy the pore spaces to significantly reduce the effective porosity and fluid content. A DIS volume exceeding 40% will severely disturb the reservoir quality. LAM usually occurs as thin lamina of allogeneic clay that has no impact on the reservoir properties; rather, only the vertical permeability and fluid flow of the reservoir are affected. STS occurs in the host sands as clasts or particles deposited during early depositional stages. This type sometimes has a considerable effect on the reservoir properties.

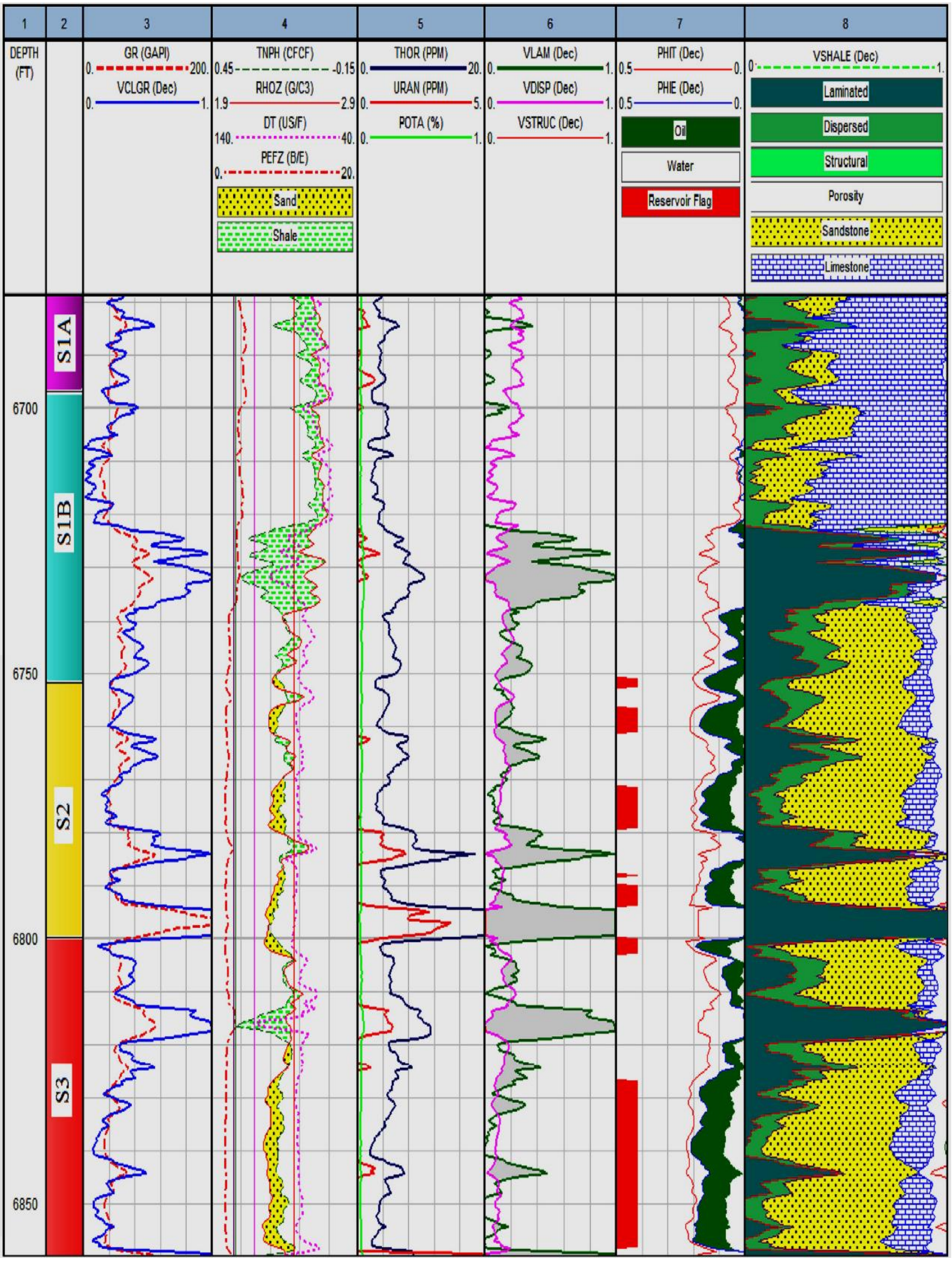

***Figure 2.8** Vertical petrophysical analog of the Upper Qishn reservoir at well T-60, Tawila field, Yemen. Good reservoir properties (effective porosity and hydrocarbon content) was recorded in front of units S3 and S2 which are mainly sandstone in lithology with minor carbonates*

Table2.2 Showing the different deduced petrophysical parameters of the three main units of the reservoir (S1 A&B, S2, and S3).

Zone	Well Name	Top	Bottom	Gross Thickness	Shale Volume	Total Porosity	Effective Porosity	Water Saturation	Hydrocarbon Saturation
S1A	T-10	5570	5588	18	0.09	0.23	0.24	0.56	0.44
	T-22	5758	5765	7	0.21	0.13	0.09	0.93	0.07
	T-60	6679	6697	18	0.15	0.07	0.03	1.00	0.00
	T-70	5852	5865	13	0.26	0.20	0.12	0.72	0.28
	T-137	6180	6189	9	0.21	0.20	0.20	0.74	0.26
	T-138	5936	5943	7	0.32	0.14	0.08	1.00	0.00
	T-161	5686	5693	7	0.33	0.24	0.16	0.79	0.21
S1B	T-10	5588	5616	28	0.11	0.12	0.11	0.96	0.04
	T-22	5765	5806	41	0.33	0.16	0.09	0.97	0.02
	T-60	6697	6751	54	0.25	0.11	0.04	0.97	0.03
	T-70	5865	5901	36	0.25	0.13	0.06	0.91	0.09
	T-137	6189	6218	29	0.13	0.06	0.04	0.97	0.03
	T-138	5943	5974	31	0.22	0.11	0.06	0.85	0.15
	T-161	5693	5742	49	0.36	0.14	0.07	0.94	0.06
S2	T-10	5616	5700	84	0.50	0.24	0.12	0.93	0.07
	T-22	5806	5875	69	0.24	0.12	0.19	0.43	0.57
	T-60	6751	6800	49	0.31	0.18	0.13	0.82	0.18
	T-70	5901	5960	59	0.41	0.20	0.08	0.88	0.12
	T-137	6218	6298	80	0.24	0.20	0.17	0.59	0.41
	T-138	5974	6038	64	0.43	0.20	0.11	0.92	0.08
	T-161	5742	5829	87	0.44	0.20	0.16	0.58	0.42
S3	T-10	5700	5748	48	0.13	0.18	0.12	0.38	0.61
	T-22	5875	5940	65	0.25	0.21	0.17	0.66	0.34
	T-60	6800	6860	60	0.30	0.19	0.13	0.83	0.16
	T-70	5960	6050	90	0.28	0.22	0.16	0.74	0.26
	T-137	6298	6360	63	0.18	0.22	0.20	0.62	0.38
	T-138	6038	6086	48	0.22	0.21	0.17	0.90	0.10
	T-161	5829	5878	50	0.16	0.22	0.21	0.44	0.56

fluid flow of the reservoir is affected. STS occurs in the host sands as clasts or particles deposited during early depositional stages. This type sometimes has a considerable effect on the reservoir properties. Consequently, the constructed Thomas–Stieber cross-plot of neutron porosity–density porosity for well T-60, show that the rocks of the Qishn units S1A and S1B are clustered within the DIS model area. Some points located within the dispersed/laminated area most likely represent the lowermost part of the unit, which has considerable porosity and fluid content **(Fig. 2.7)**. Other points are included in increasing order of neutron porosity below the shale point, signifying high-density calcareous shale.

The increasing order of the DIS, on the expanse of the laminated type (Fig.2.8, Track 6), is clearly reflected in the undesirable petrophysical properties of this unit such as very low effective porosity and no hydrocarbon content. On the contrary, most of the datapoints of units S2 and S3 are contained in the triangle bounded by the laminated and dispersed lines, which indicates a dispersed/laminated model with laminated style priority **(Fig. 2.7)**. The volume of LAM (VLAM) is much higher than the volume of DIS (VDIS), as presented in Track 6 in **Fig. 2.8.** No STS was detected in this section. The thick shale interbeds that dissect the reservoir into different counterparts appear to complicate the fluid flow between units. Moreover, the thorium content (THOR) is much higher than the uranium content (URAN), particularly in front of the high VLAM intervals (Track 5).

VLAM, are recognized in the middle of S1B (Track 8). On the contrary, good hydrocarbon content of 30%–58% and 10%–60% was recorded in front of units S3 and S2, respectively. The lithology is mainly sandstone with frequent shale interbeds and minor carbonates **(Fig. 2.8)**. The total porosity is more than 20% throughout the section، with effective porosity ranging from 5% to 18% in front of the sand zones. Reservoir flags associated with good hydrocarbon potentiality are indicated in front of the intervals of low dispersed and laminated curve overlays (**Fig. 2.8,** Tracks 6 and 7).

c) Pay cut-offs

Cut-off parameters (reservoir and pay) of > 15%, < 50%, and> 20% were taken in front of units S2 and S3 for the effective porosity، water saturation and shale volume, respectively (Table 2). These parameters were selected on the basis of the published works on the Qishn reservoir in similar fields in the Masila and Sab'atayn basins shows the pay cut-off plot of well T-60. As shown in the figure, different levels at the upper, middle, and lower parts of the S2 unit fulfill the reservoir and pay characteristics, and the entire lower section of unit S3 exhibits good cut-offs parameters. No reservoir or net pay characteristics were detected in front of unit S1 A or B

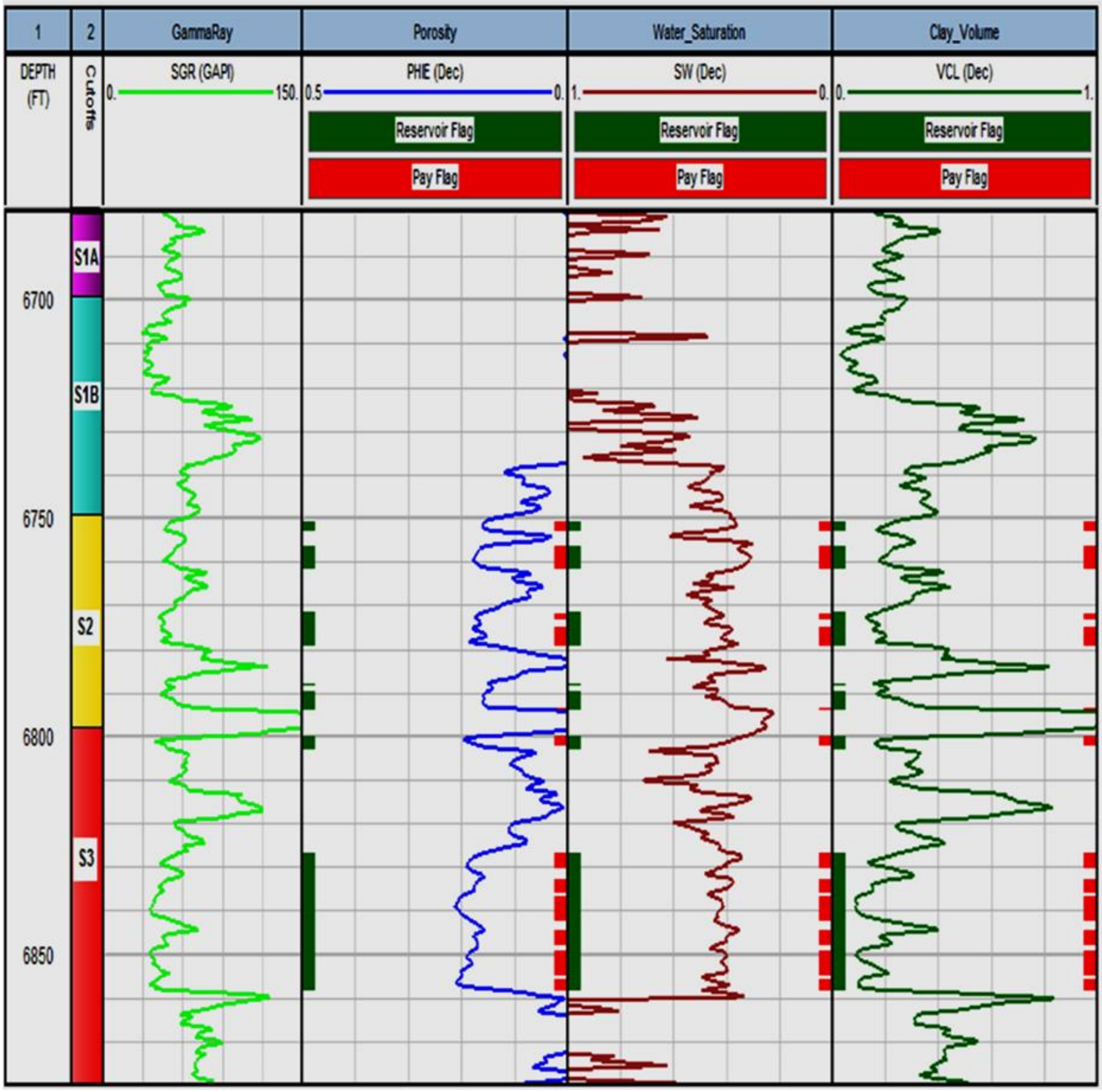

Figure2.9 The pay cut-off plot well T-60, Tawila field, Yemen. Nearly the entire lower section of unit S3 is of good cut-offs parameters, while scattered levels at S2 unit

d) Petro-facies analysis

Fig 2.8 exhibits the interpreted seismic section CO98-2038A described in, which passes through wells T-161, T-170 (projected)، and T-60 from north to south. This section was selected as an example to illustrate the different petro-facies of the encountered formations in the study area, as supported by well log data and the available drilling records. In the figure, the GR logs are given at the left, and the sonic logs are shown at the right. The fluctuations in both of the GR and sonic logs in front of the formations of different clastic and carbonate natures are clearly accompanied by considerable seismic amplitude changes. At the upper part of the section, strong seismic amplitude is indicated in front of the Umm Er Radhuma Formation associated with week GR and sonic responses. This indicates clean, non-shaly characteristics of this formation, which is considered in many cases a good producing reservoir.

The underlying Sharawayn Formation is thin with mixed carbonate lithology at the top and shale at the base. The cyclic deposition of carbonates and clastics is well represented in front of the Mukalla Formation. Carbonate facies with strong seismic amplitude are observed at the top section of the formation. Grading of the GR from the top (low) to the base (high) indicates variation in organic nature. The middle section is characterized by clastic facies with week seismic amplitude and low GR. The base of the Mukalla Formation and the underlying Fartaq Formation are characterized by high GR response and strong seismic amplitude, reflecting organic-rich carbonate facies. The Harshiyat Formation, which directly overlies the Qishn Formation، exhibits a change from marine carbonate facies to continental clastic facies. The upper part contains mixed carbonates and shales; the middle part is represented by clastic facies with seismic amplitude and low GR؛ and the lower part contains mixed carbonates and clastic with high GR fluctuation/cyclicity. The Qishn Formation, including the Qishn reservoir, also shows facies change from an upper carbonate/shale section to clastic facies at the base. Most of the wells end at the top of the Saar Formation, which is represented by weak seismic clastic facies at the top, carbonate lithology in the middle, and calcareous shale at the base.

section is not clear due to its little thickness as compared with the thick overlying/underlying formations. However, a detailed geo-seismic cross-section was constructed for this formation (Fig. 6, red-rectangular area) to clarify the detailed facies/lithological content of the different members in relation to the overlying cap and underlying source rocks.

2.6 Discussion

a) structural setting and hydrocarbon entrapment

The Fartaq–Saar and Qishn–Saar fault groups are attributed most likely to Middle–Late Cretaceous tectonic movement. This movement was initiated during the Early Cretaceous divergence between the Africa–Arabia and Madagascar–India plates and then development between India and Madagascar, which caused the Arabian Sea opening and anticlockwise rotation of the India plate throughout the Late Cretaceous. The development of the Jeza Trough Basin and its separation from the north-bounding Hadhramaut Arc (Redfern and Jones, 1995) are associated with Early Cretaceous movement through Middle–Cretaceous time (Brannan et al., 1997).

The Tertiary–Saar normal fault groups are attributed clearly to the Tertiary tectonic events through rifting of the Red Sea and the Gulf of Aden opening. Late Eocene–early Oligocene movements are associated with the development of several offshore basins along the Gulf of Aden and the Red Sea and uplifting of the South Hadramaut Arch. It appears that the Tertiary–Fartaq fault system is limited and dominant in the southern parts of the study area, whereas the Tertiary–Cretaceous fault system is responsible for the major normal E–W faulting that affects the entire succession in the northern parts. Overall, the northern area of Tawila field is the most affected by these structural elements. It is subjected to extensional faulting through geologic times, whereas the southwestern area is intersected to lesser extent by isolated normal faults. Few structural elements were detected in the central area; only tilting of the Lower Cretaceous units was observed toward the southeastern direction.

Fig.2.10. The petro-facies analysis of the interpreted seismic section CO98-2038A. The fluctuations in both of the GR and sonic logs in front of the formations of different clastic and carbonate natures are clearly accompanied by considerable seismic amplitude changes (weak for clastics and strong for carbonates). At the upper part of the section, strong seismic amplitude is indicated in front of the Umm Er Radhuma Formation associated with week GR and sonic responses. The vertical seismic resolution of the Qishn Formation in this section is not clear enough owing to its modest thickness as compared with the overlying/underlying formations.

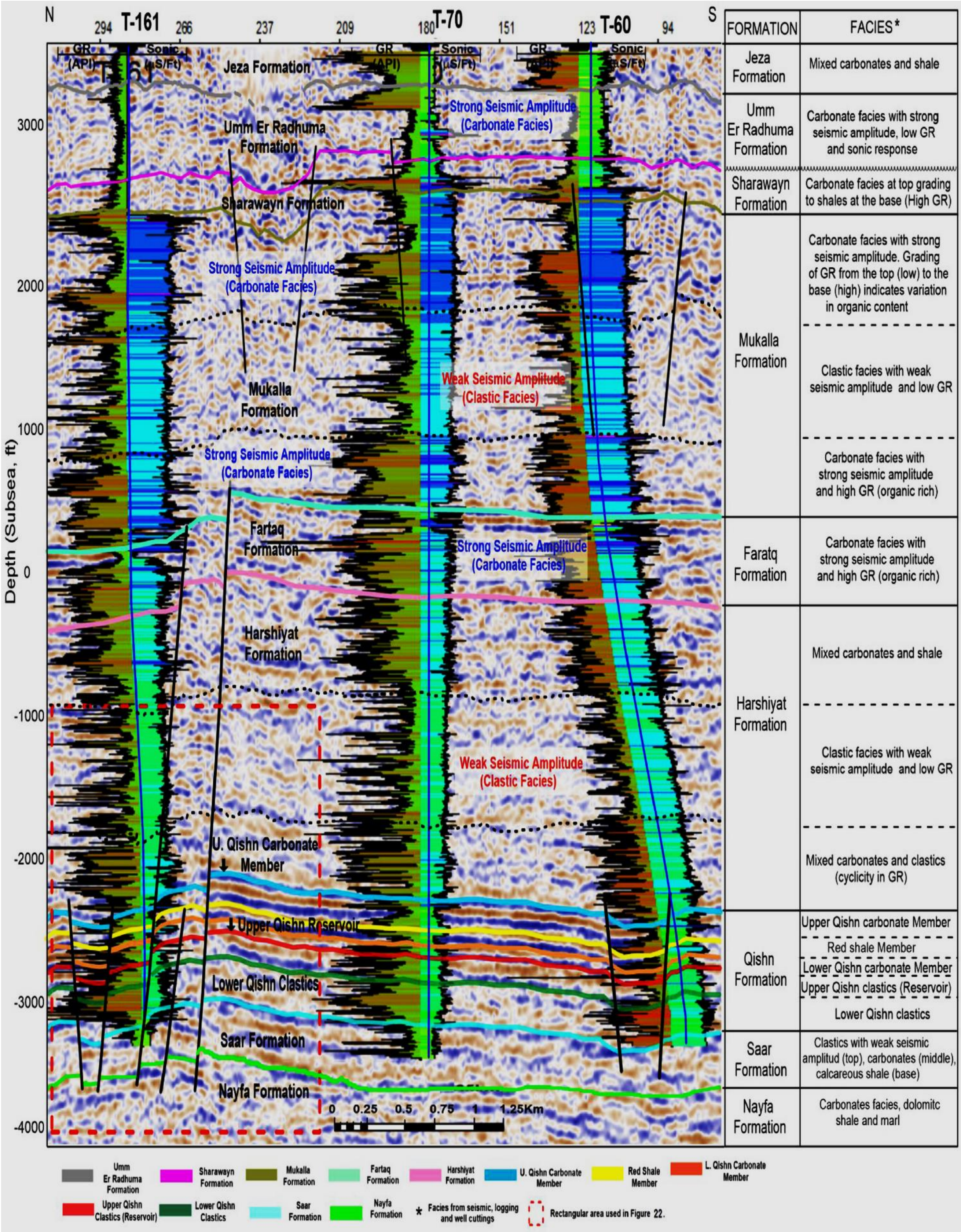

Figure 2.10 ***The petro-facies analysis of the interpreted seismic section CO98-2038A***

b) Reservoir distribution maps

Distribution maps for velocity, AI, RC, water, and hydrocarbon were constructed for S2 and S3, the two reservoir zones retaining good hydrocarbon content, incorporating the fault structural data deduced from seismic data analysis. shows the velocity, AI, and RC maps of the S2 sand reservoir unit. The average velocity shows a remarkable decrease in velocity from south to north, particularly in the up thrown side of the E–W fault. A good velocity closure of 12450ft/s was detected in the area occupied by wells T-70, T- 10 ،and T-22. Nearly the same distribution was observed in the AI map، where AI contours decrease from the south to north and northwest areas from a value of 23,200 to 28,400. The RC map exhibits two distinct anomalies with negative values to the north. The low seismic velocity, low AI, and negative RC values are generally representative of hydrocarbon content. The velocity, AI, and RC maps of unit S3.

The same response of the distribution of seismic velocity and AI are indicated, although a slight shift was noted in decreasing order to the north and northeast, where a minimum velocity of 12,150 and AI value of 27,800 were recorded at wells T-70 and T-161. The RC map shows maximum negative response throughout the study area to the east and north directions. The fluid maps of the S2 reservoir unit show that the middle of the structural high is mainly water saturated. An elongated high water saturation anomaly is recognized bordering wells T-10, T-22, T- 138 and T-60. However, the axis of this anomaly is titled slightly toward the northwest (NNW–SSE) with more than 82% water saturation. The hydrocarbon saturation increases away from this anomaly, to northeast and west. Good hydrocarbon saturations of 58% and 43% are indicated in these areas at wells T-161 and T-22, respectively. For zone S3, the hydrocarbon saturation increases from the south and southeast toward the north and northeast. Good hydrocarbon content of more than 50% was recognized close to the sealed E–W fault corresponding to the structural high. In general, the northern, northwestern, and northeastern parts of the study area exhibit good hydrocarbon content, which is matched with low recorded velocity, low AI distribution, and negative RC values.

In the **Figure 2.11**

a) 3D visualization of the Cretaceous overlapping successions from the Fartaq Formation to the Qishn reservoir, **b)** A depth-wise northward shift of the major E–W fault plane c**)** The prospective uplifted area of the Upper Qishn Clastics reservoir (potential hydrocarbon traps).

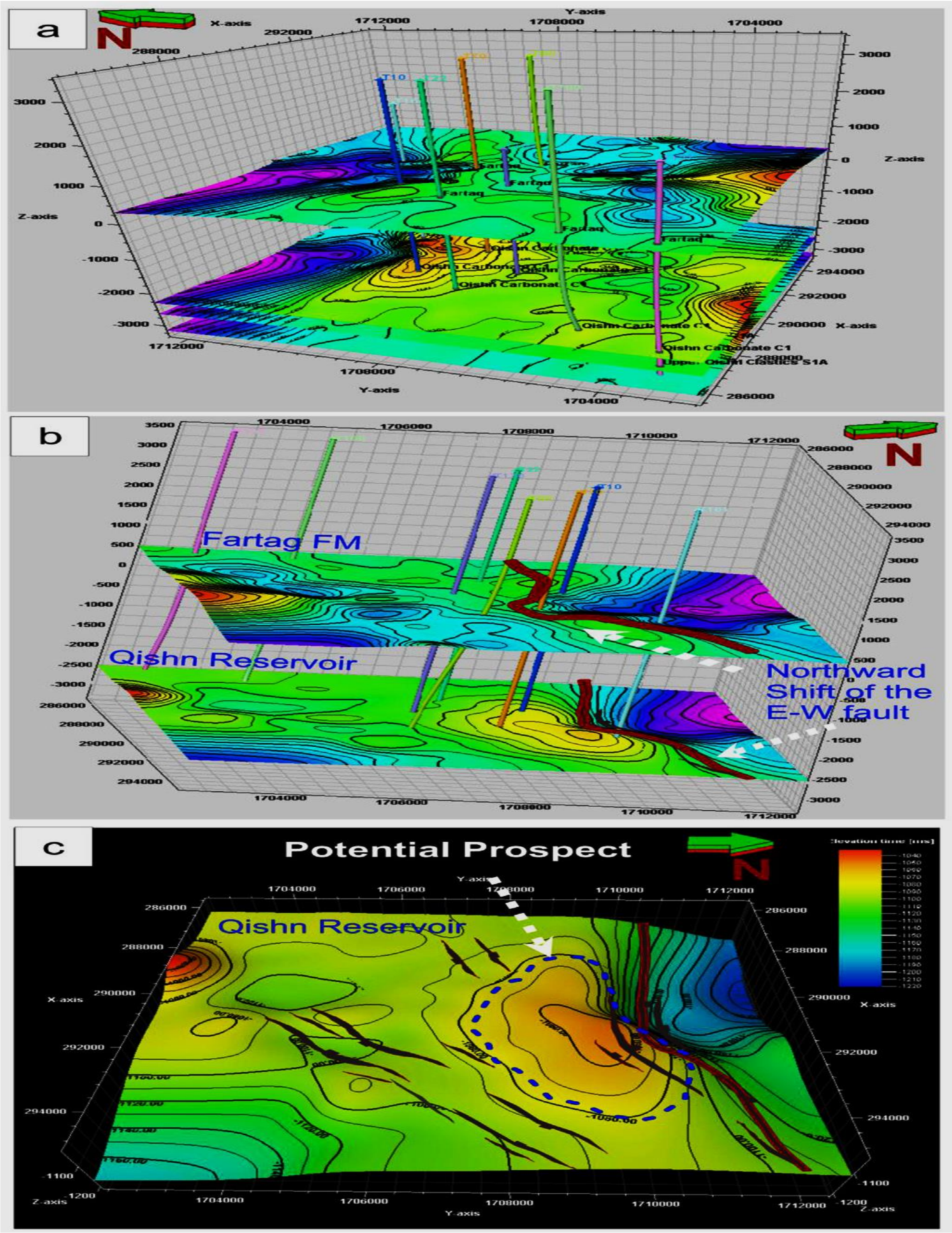

Figure 2.11 sumlation of Formation to the Qishn reservoir

Figure 2.12 shows a geo-seismic cross-section of the northern part of seismic profile CO98-2038A with a shot point range of 209–295. As shown in the figure, the Qishn reservoir is mainly clastic facies overlain by the UQCM, RSM, and Lower Qishn Carbonate Member forming three sealing lithologies of shales and limestone. Owing to faulting, the reservoir is juxtaposed at the top and bottom against the limestone and shale lithology, particularly in the northern part. The Lower Qishn clastics are composed of thick shales embedded with thin sand beds in the middle. The Saar Formation grades from sands with weak seismic amplitude at the top to carbonates in the middle and calcareous shale at the base (Fig. 22). The Nayfa Formation is represented by dolomitic facies with marl and shales, as indicated from the drilling records.

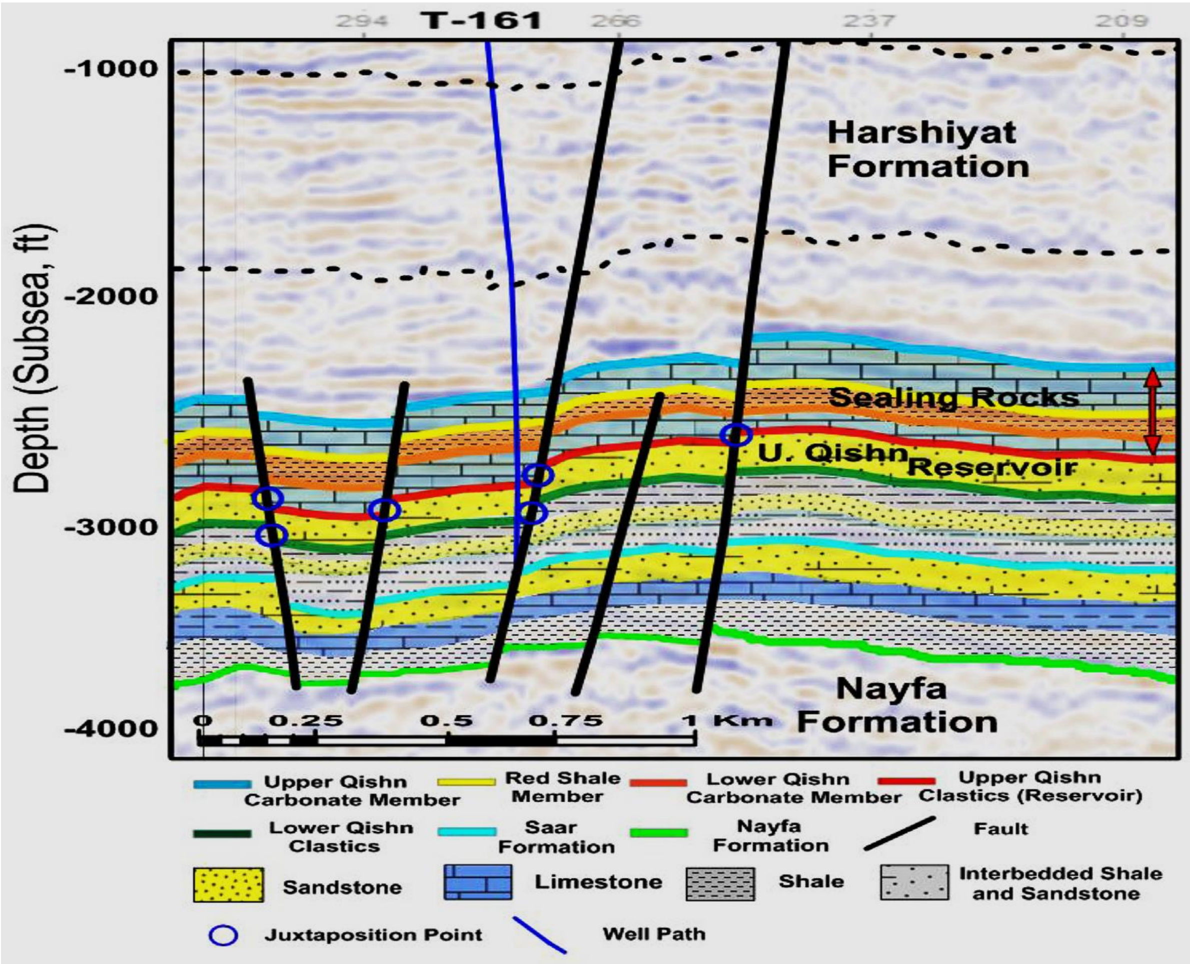

***Figure 2.12** Geo-seismic cross-section of the northern part of seismic profile CO98-2038A with a shot point range of 209–295. The Qishn reservoir is juxtaposed at the top and bottom against the limestone and shale lithology.*

2.7 Drilling summary

This phase commenced with nippling up of the Bops, which were tested as per specifications. Bit #2, 12¼" REED, R57DT with 3x24 nozzles was made up and ran in hole. Cement was tagged at 1057 ft. Drilled out cement, drilled out 13 3/8"csg shoe at 1074 ft. Drilled 12 1/4" hole from 1080 ft to 3197 ft with losses prevailing at an average rate of 6 bbls/hr. Circulated hole clean, dropped survey. POOH from 3197 ft to 2593 ft, worked on tight spots. Backreamed from 2593 ft to 1912 ft. POOH to surface. Retrieved survey, survey @ 3135 ft inclination was 2.75°. Ran in hole to 2286-ft. Break circulation, reamed down from 2286 ft to 2377 ft. Ran in from 2377 ft to 3133 ft. Washed down to bottom. Drilled ahead from 3197 ft to 5495 ft. Pumped 40 bbls Hi Vis pill, circulated hole clean dropped survey. POOH for bit change. Worked on tight spots, with a maximum overpull of 50klbs, retrieved survey, survey @5452 ft inclination was 2.5°. This bit drilled 4415 ft with an average ROP of 93.15 ft/hr

A new bit, Bit #3 REED EHP51W with 3x24 nozzles was made up. Ran in hole to shoe. Break circulation. Ran in hole from 1074 ft to 2880ft. Break circulation. Ran in hole from 2880 ft to 5290 ft. Reamed down from 5290 ft to 5495 ft. Drilled 12 1/4" hole from 5495 ft to 5737 ft. Observed tight spots from 5611ft to 5668 ft on connection. Drilled ahead from 5737 ft to 5840 ft. Pumped 40 bbls Hi Vis pill, circulated hole clean. POOH to Cut Core#1. .Backreamed from 5423 ft to 5233 ft. POOH to surface

M/up Core Head and Core Barrel. Ran in to 5768 ft. Cleaned down to bottom from 5768 ft to 5840 ft. Circulate hole clean & dropped ball. Cut Core #1 from 5840 ft to 5870 ft. .POOH Core, lay /down Core and Core assembly. Recovered Core #1, 100% Recovery

Ran in hole with 12 1/4" bit, Bit # 3RR, to 5840 ft, break circulation at 1130ft, 3090 ft, and 4980 ft. Drilled core rat hole. Drilled down from 5840 ft to 6702 ft FTD. Pumped 60bbls of Hi Vis pill, circulated hole clean. Wiper trip, POOH to 6501 ft. The hole was tight from 6652 ft to 6559ft, with a maximum overpull of 55 klbs. Back reamed from 6501 ft to 5891 ft. Pumped 50 bbls Hi Vis pill, POOH from 5891 ft to 1075 ft. RIH from 1075 ft to 6633 ft, break circulation, washed down to bottom. Pumped 50 bbls Hi Vis pill circulated hole clean. dropped survey. POOH for logging. Retrieved survey, survey @ 6652 inclination :was 1.5°

Well was logged by Schlumberger Wireline. Schlumberger logged 12 ¼" hole. Two set of Logs were Run. Log #1: PEX-NGS-BHC. Log #2 as RFT-GR. Attempted 32 points, 27 .were normal & 5 were dry

A Clean-out Trip was done. Tubular was laid down. Rigged up to run 9 5/8" casing. The 9 5/8" casing was lowered with the shoe set at 6702ft and cemented as per program.

2.8 Conclusions

This paper has investigated the structural setting and the reservoir properties of the Qishn reservoir at the Tawila field using combinations of seismic reflection and logging analyses. The main conclusions from this work are:

- The northern area of Tawila field has been subjected to structural deformation, whereas the southwestern area is intersected to lesser extent by isolated normal faults. Few structural elements were detected in the central area.
- Interpretation of the 2D seismic data has identified four main fault groups: Fartaq–Saar, Qishn–Saar, Tertiary–Fartaq, and Tertiary–Saar.
- A major E–W normal fault system with large vertical throw was observed in the northern part of the study area cutting through the entire sequence of strata. The deep-seated layers were subjected to numerous E–W normal faults that intersected the Qishn Carbonate units and underlying formations. The Tertiary–Fartaq fault system، running ENE–WSW, is dominated in the southern parts of the study area with limited effect, whereas the Tertiary–Saar fault system is responsible for the major normal E–W faulting that affected the entire succession in the northern parts.
- The UQRM is divided petrophysically into three main units: S1, S2، and S3. No hydrocarbons were found in the S1 unit which has dispersed shale model, whereas considerable to good hydrocarbon content associated with the structural uplift was identified in front of the S3 and S2 units, at 7%–57% and 10%–61%, respectively. The shale type in these two units is dispersed/laminated model with laminated style priority.
- The fluid distribution maps show an increase in hydrocarbon saturation toward the northeast and west for unit S2 and toward the north and northeast for unit S3, which is matched with low recorded velocity, low AI distribution, and negative RC values.
- The entrapment style of hydrocarbon is due to juxtaposition of the reservoir against the other rocks. The thick deposits of the overlying Qishn Carbonates and RSM units have provided a good regional seal.
- The structural maps show that top of the UQRM is intersected by E–W major and ENE–WSW minor faults forming a prospective closure (horst) of good hydrocarbon accumulations.
- Although the basic reservoir properties are reasonably understood, the thick shale interbeds that dissect the reservoir into different compartments appear to complicate the fluid flow between units. A more advanced petrophysical special core analysis associated with petrographic investigation is suggested to fully characterize the reservoir and to investigate the possible inner-flow among the different zones. For further activities in the field, it is recommended that the prospective structural high should be considered in exploration or development processes. This structural anomaly will be the key point in exploring hydrocarbons in nearby areas.

CHAPTER THREE

CHAPTER III

3. APPLICATIONS OF NANOTECHNOLOGY

3.1 INTRODUCTION

The aim of this chapter is to discuss and explain the definition with historical review of nanotechnology, we will also talk in a brief about the application of nanotechnology in oil and gas industry, finely we will spot of lights about the application of nanoparticles in drilling fluid as remedial and solution for many of challenges and problems in drilling process.

3.2 NANOTECHNOLOGY

3.2.1 Definition

A general definition of nanotechnology is provided in the National Nanotechnology Initiative (NNI) website which is a federal government website. The NNI definition for nanotechnology is: “Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications.”

“Encompassing Nano scale science, engineering and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale.” (NNI). Hence, nanotechnology refers to the process, act or ability to work with materials or matter at the scale of 1 to 100 nanometers.

3.2.2 Nanometres

A nanometer (American spelling: nanometer; symbol nm) is a unit of length in the metric system, equal to one billionth of a meter. The name combines the SI prefix Nano- (from the Ancient Greek νάνος, nanos, "dwarf") with the parent unit name meter (from Greek μέτρον, metron, "unit of measurement").

The ability of working at this scale brings novel benefits to numerous products and applications such as those found in the semiconductor manufacturing, material science, medicine, etc. However, what is the size of 1 nanometer? Albert Einstein estimated that the size of 1 sugar molecule was equal to 1 nanometer. One nanometer would also be equal to the linear size of 10 hydrogen atoms stacked side by side (Roueckes et al., 2002). It is the same as one-billionth of a meter – a single bacterium is a few hundred nanometers in diameter and a DNA strand is approximately 2-12 nanometers across (NNI, 2007). The un-aided human eye can see down to about 10,000 nanometers.

3.2.3 Nanometric Lubricant.

A new kind of nano-emulsion was prepared through a one-step method. The experimental results showed that the nano-emulsion had good long-term stability, and its droplet size almost would not increase in six months. This emulsion demonstrated good inhibiting ability to clay swelling, as shown in **Figure 3.1** Compared with 7% KCl; it had stronger inhibiting ability when its concentration was over 0.5%. Meanwhile, the nano-emulsion had good lubrication. **Figure 3.2** indicated that the friction coefficient of nano-emulsion was slightly smaller than mineral oil. Besides, this emulsion had no influence on other properties of drilling fluids. It was an environment-friendly drilling fluid additive, and could be used under complicated geological conditions. Most importantly, the nanometric lubricant had high yield, low cost, and could meet the requirement of environmental protection, so it would have extensive application prospect in drilling industry.

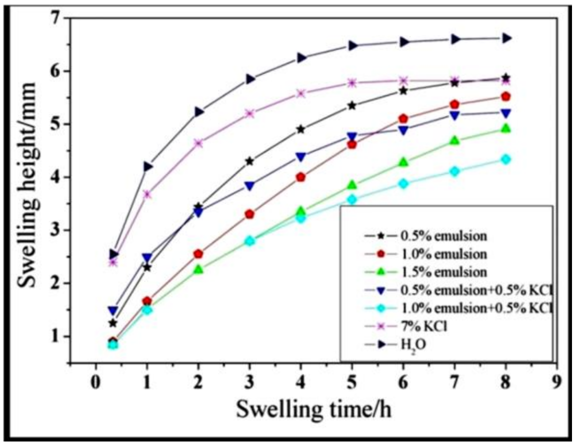

Figure. 3.1 The effect of various concentrations of nanometric lubricant on clay swelling

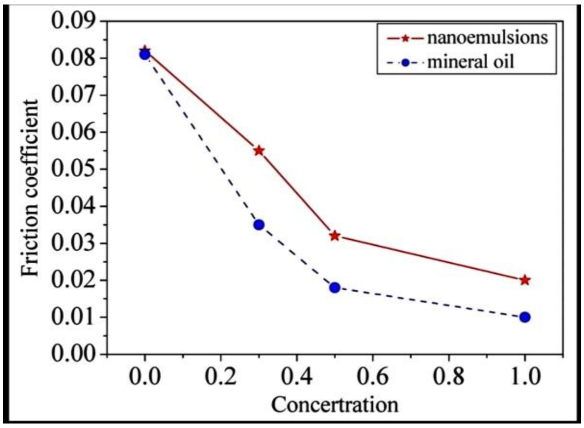

Figure 3.2 Comparison of friction coefficient between nanometric lubricant and mineral oil .

3.2.3 History of Nanotechnology.

In contemporary times, manufacturing tolerances of parts have approached nanometric dimensions, especially in the manufacturing of semiconductor devices. However, the term "nanotechnology" was not coined until 1974 by Professor Norio Taniguchi, whose work and research was in the area of high precision machining (Wikipedia). Professor Taniguchi of Tokyo Science University used the word "nanotechnology" to describe the science and technology of processing or building parts with nanometric tolerances.

Essentially, Professor Taniguchi's theoretical concepts involved the use of electron, ion beam, and laser beam processes for machining tolerances at the nanoscale. A historical overview of nanotechnology & nanoparticle is shown in **table 3.2.**

Table 4.2: Historical Overview

1959	Feyman	Feynman gives afterdinner talk describing molecular machines building with atomic precision.
1968	Stabber, etal.	Synthesis of monodisperse silica, described before in 1956 by Koibe in PhD thesis.
1974	Taniguchi &Norio	uses term "nano-technology" in paper on ionsputter machining
1981		First technical paper on molecular engineering to build with atomic precision STM invented.
1985	Smalley&cure	Buckyball discovered e.g. C_{60} carbon.
1986	Binnig& Quate	Construction of an atomic force microscope AFM.
1989	Eigier &schweizer	IBM logo spelled in individual atoms.
1991	Iijima	Carbon nanotube discovered.
1997		First company founded: Zyvex
2000		President Clinton announces U.S. National Nanotechnology Initiative.
2011		First programmable nanowire circuits for nanoprocessors DNA molecular robots learn to walk in any direction along a branched track Mechanical manipulation of silicon dimers on a silicon surface.

3.3 APPLICATIONS OF NANOTECHNOLOGY IN OIL & GAS INDUSTRY.

Nanotechnology has huge applications in different segments in the oil and gas industry such as in exploration, drilling, completion and work-over, production, and enhanced oil recovery (EOR). There are numerous areas in which nanotechnology can contribute to more-efficient, less-expensive, and more environmentally sound technologies than those that are readily available. Nanotechnology holds great promise, both for mapping out and manipulating fossil-fuel reserves, because of the small scales that characterize the cracks and pores where oil is stuck.

Nanotechnology contributes in Nano-prospecting, nanophysics in oil and gas E&P, reservoir surveillance and enhanced oil recovery. Nanotechnology also contributes in UpStream sectors such as exploration sensors, high performance materials, drilling-chemical and abrasion resistant coating, production tubular, Nanoscale chemicals to control fluid losses, novel materials responding to water presence, production-fluid flow sensors, fluid type recognition sensors, Nano-membranes, reservoir engineering-rock porosity sensors, well logging-wireless sensors.

3.3.1 Nanotechnology in Oil Exploration.

It is very well known that the first step of oil recovery process is to find out the hydrocarbon resource. Nanotechnology can be used in seismic characterization, interpretation, and formation evaluation. Nanosensors recently have attracted attentions of petroleum geologists to find out hydrocarbon reserves. In this case nanoparticles can be used as they have specific optical, magnetic, electrical properties compared to the bulk one. Therefore, they are preferred to use as a tool for preparation of imaging sensor. Actually nanosensors are used in the form of nanodust to gather physical and chemical data from reservoirs for the characterization, fluid flow type and their behaviors under reservoir conditions.

Nanosensors, ranging from 1-100 nm, have captured the attention and imagination of petroleum geologists. Nanoparticles with noticeable alterations in optical, magnetic, and electrical properties compared to their bulk counterparts are excellent tools for the development of sensors and the formation of imaging contrast agents (Ramanan, 2006).

There are now several active and promising programmers to develop nanosensors compatible with temperature and pressure ratings in deep wells and hostile environments. In addition, nanotechnology has the potential to help develop geothermal resources by enhancing thermal conductivity, and Nano-based materials could be used for geothermal production. Nanoscale metals have already been used to delineate ore deposits for geochemical exploration.

Exploration can be defined as a searching for hydrogen deposits under the surface of the earth using different methods, and this process can be done by petroleum geologists. Due to the facts that the extraction of oil resources decays with time and the accessibility to the easily recoverable oil resources has been diminished significantly, more complicated techniques are required in order to enhance the field characterization performance and ultimately increase the amount of oil recovered. The extraction of oil and gas can be maximized by having sufficient information and a clear understanding of the targeted reservoir properties. Despite using any of the current sophisticated methods for oil recovery like thermal techniques, gas injection, water-flooding, and chemical flooding, a huge quantity of oil and gas will ultimately not be extracted. Besides the inefficiency of these methods of oil recovery, these conventional processes are not favorable economically (Himes et al. 2006; Jones 2015). Since the operations in the deep wells are carried out in a very harsh environment, conventional electrical sensors are not normally able to be sustained in such difficult conditions. The available techniques provide limited information, shallow penetration, and are not able to fulfill the reservoir's characterization requirements. Clearly, there is a necessity to use unconventional techniques and exceptional materials to overcome these technical challenges and to effectively explore unconventional oil and gas reservoirs. In addition, these techniques and materials should meet environmental regulations and address safety issues.

Researchers are trying to improve a new generation of sensors which are small and hard enough to sustain under harsh conditions and to provide accurate temperature, pressure, and oil and gas flow rate measurements. They also are able to penetrate deep into the wells and obtain a clear picture of the interaction between rocks and hydrogen deposits without being interrupted by the presence of electromagnetic fields. In addition, a high level of reservoir characteristics performance requires advanced computational and imaging techniques.

In nanotechnology, different synthesis methods can be used to produce effective nanomaterials which can contribute to making unique sensors and imaging contrast agents. The optical, magnetic, and electrical properties of these nanomaterials can be changed greatly when compared with their bulk counterparts. Besides, they can form percolated structures electrically and geometrically at low volume fractions. A combination of the nanoparticles and smart fluids can generate a very effective sensor that can work properly in very difficult conditions and provide accurate measurements of temperature, pressure, oil flow rate, and stress in deep wells. Nanomaterial has great potential for use as markers for imaging when it is combined with advanced computational techniques and magnetic probes. The reservoir characterization and the pore sizing can be enhanced when the nanomaterial segregates into various fluid regions by chemical techniques. The pore size, high surface area, and mobility of the nanoparticles are absolutely essential in such imagining. Researchers are developing nanosensors which have the ability to provide information and data about fluid-type recognition, fluid-flow monitoring, and which are able to penetrate into deep wells and perform reservoir characterization. Furthermore, hyperpolarized silicon nanoparticles also have potential applications in oil imaging and exploration. A nano-CT machine could also play an important role in providing data on the pore-size distribution and images for shale and gas sand. The goal of nanotechnology in this field is to develop a nanorobot which is capable of comprehensively mapping and measuring the effective characteristics of the reservoir.

3.3.2 Upstream Production Sectors and Nanotechnology

a) Manifolds/Gathering

The well streams are brought to the main production facilities over a network of pipelines and manifold net systems. The aim of the pipelines is to allow for production setup or well sets. Thus, the best reservoir utilization well flow composition, such as gas, oil, and water, is selected from the available wells. For gas gathering systems, the individual gathering lines are metered into the manifold. However, for multiphase flows or combinations of gas, oil, and water, the inflated cost of the multiphase flow meters leads to the use of software flow rate estimators, where well test data is used to calculate the actual flow.

Stimulation In viscoelastic surfactant stimulation fluid, high-molecular-weight cross-linked polymer fluids are being used to stimulate oil and gas wells. The advantages of such fluids are their exceptional viscosity, thermal stability, proppant transportability, and fluid leak-off control. On the other side, the disadvantages of such materials include the amount of polymer residue they leave behind which can damage formation permeability and fracture conductivity.

Therefore, the nanoparticles could be good alternatives because of their high surface morphology and high surface reactivity. These materials can stabilize fluid viscosity at high temperatures and produce a pseudo filter cake of viscous viscoelastic surfactant stimulation fluid which reduces the rate of fluid loss and improves fluid efficiency.

Scale inhibition The formation of scales inside the production tubing can be inhibited by using nanomaterials with a hydrophobic surface such as epoxy paint surfaces which can reduce the chances of scale deposition. An example of this type of material is nano SO2/epoxy adhesive solution. Another example is nanomaterial coated with a low surface energy polymer, called aminopropyl.

b) Separation

In the case where the well produces a combination of gas, oil, and water, with various contaminants, then it is necessary to install the separation processes. The production separators are available in various forms and designs, with the classic variant being the gravity separator. Where the wells have pure gas production, for example, then the gas is taken directly for gas treatment and compression.

c) Gas Compression

In the case where the gasses from the separators have lost a significant degree of pressure, then the gasses should be recompressed for transportation. To facilitate this, turbine compressors gain their energy by using up a relatively small proportion of the natural gas which they compress. The turbine can serve to operate a centrifugal compressor, containing a type of fan which compresses and pumps the natural gas through the pipeline. Note that gas from a pure natural gas wellhead has sufficient pressure to feed directly to a pipeline transport system, thus there is no need for it to be recompressed.

d) Oil and Gas Storage and Export

The final step before the oil or gas leaves the platform consists of

(i) Storage

(ii) Pumps

(iii) Pipeline terminal equipment

In production sites, the oil and gas is piped into a refinery terminal. Gas can be difficult to store locally, consequently, underground mines, caverns, and salt deposits are used to store gas. The gas pipeline is fed from the high-pressure compressors.

On the other hand, on platforms with no pipelines, oil is then stored in onboard storage tanks to be transported using a shuttle tanker. The oil is stored in storage cells around the shafts on concrete platforms and in tanks on floating platforms. A separate storage tanker can be used for some floaters. Ballast handling is necessary to balance the buoyancy when the oil volume varies. For onshore, fixed roof tanks are usually used for crude and floating roofs for condensate. In addition, rock caverns are used. Oil pipelines are usually driven by separate booster pumps. For long pipelines, intermediate compressor stations and pump stations are recommended to be used due to the distance involved in crossing mountain ranges.

3.3.3 Nanotechnology in Production

Bhatia and Chacko, suggested the injection of air-suspended self-heating Ni-Fe nanoparticles (50 nm) in the hydrate formation through horizontal well. These particles will penetrate deep into the class I, II and H hydrate reservoir by passing through the cavities (8695 nm). The self-heating of Ni-Fe particles in a magnetic field is caused by hysteresis loss and relaxation losses.

These particles cause a temperature rise up to 42˚C information leading to disturbance in thermodynamic equilibrium and causing the water cage to decompose and release methane. In this technique, the pressure of the fluids in contact with hydrate is lowered, pushing the hydrate out of its stability region and leading to its decomposition.

Bhatia and Chacko, discovered that the less expensive, readily available eggwhite (Ovalbumin) can catalyze the reaction which results in large scale formation of these nanoparticles. The main advantage of this technique is the very low dosage requirements (small quantity required for $1m^3$ of Hydrate decomposition).

3.3.4 Nanotechnology in Enhanced Oil Recovery.

Interfacial tension reduction in oil recovery is an important issue. The ultimate aim of enhanced oil recovery by surfactant flooding is to increase the capillary number by reducing interfacial tension of oil-water systems. Therefore, it is obviously essential to reduce interfacial tension using proper surfactants in oil recovery technique.

For this purpose, studied the application of nanofluid for enhanced oil recovery. They reported that nanofluids comprising aqueous suspensions of nonferrous metal nanoparticles (size 70-150 nm) dispersed in an aqueous solution of anionic surfactant (sulfanole-alkyl aryl sodium sulfonate), which resulted in an increase in the efficiency of the oil displacement by 35%, compared to that obtained using a surfactant solution alone in a homogeneous porous media and 17% in a heterogeneous porous medium at a temperature of 25° C.

They concluded that the enhanced oil recovery is due to reduction in interfacial tension between oil and aqueous phases and change in the flow characteristic of nanofluids moving from a Newtonian to non-Newtonian state. Hendraningrat et al, (2013) investigated the efficiency of hydrophilic silica nanoparticles suspension for enhanced oil recovery. They reported that nanofluids can reduce IFT between water and oil phases and make the solid surface more water wet. Nanofluids can increase the oil recovery about 4-5% compared to brine flooding.

3.5 APPLICATIONS OF NANOTECHNOLOGY IN DRILLING INDUSTRY.

3.5.1 Upstream Drilling Sectors

3.5.2 Wellheads and Drilling

The oil well exploration is followed by the drilling of a natural gas or oil well. Then, there should be a verification of whether the available natural gas is commercially suitable in terms of quantity. At this stage, the well can be completed to allow petroleum to be extracted to the surface. Wellheads can be defined as components at the surface of an oil or gas well that provide the structural and pressure-containing interface for the drilling and production tools. Wellheads are used to provide the suspension point and pressure seals for the casing strings which run from the bottom of the hole-sections to the surface pressure control equipment. In this stage, the well hole is strengthened with casing, the pressure and temperature are evaluated for the formation, and the proper equipment is installed to ensure an efficient flow of natural gas from the well which is controlled with a choke. Nanotechnology offers innovative techniques for drilling processes which depend on waterbased fluid. These methods could make a dramatic change in the drilling process performance, are low in cost, and can be applied using straightforward methods. Besides, nanotechnologybased solutions have less impact on the environment since the fluid used does not contain toxic chemical materials, which is the case with conventional fluid drilling. Nanomaterials can be applied to plug pores in the shale formation, which prevents the formation of a filter cake, which is usually responsible for fluid loss reduction and the formation of fractures. Nanoparticles can be added to the used drilling fluid to minimize the thickness of the filter cake by reducing the permeability of the shale formation. As a result, nanotechnology is a potential solution which could play an important role in increasing the drilling process quality and enhancing the wellbore stability.

Various nanotechnology techniques can be implemented to enhance the downhole tool performance including the polycrystalline diamond compact bits. A nanodiamond is an interesting option to increase the PDC abrasion resistance and to boost its durability. One method to increase PDC diamond density and to decrease the metallic binder is that nanodiamond may reduce the localized microstructural stress when its coefficient of thermal expansion CTE is compatible with that in the micron diamond.

Bit balling Nanomaterials drilling mud with the hydrophobic film forming capability on the bit and stabilizer surfaces is used to eliminate the bit and stabilize balling. Due to their high surface area, nanomaterials fluid could be used for drilling

in shale which is very reactive, highly pliable, and tenacious.

Due to the fine and very thin film forming capability of nanomaterials, the nanomaterialsbased fluid may

1. Allow a reduction of the frictional resistance between the pipe and the borehole wall as a result of formation of a thin lubricating film in the wall-pipe interface.

2. Facilitate formation of an ultra-thin bed of a ball-bearing type surface between the pipe and the borehole wall which allows easy sliding of the drill string along the nanomaterial-based ball-bearing surface. Removal of toxic gasses H2S can diffuse to drilling fluid from formations during drilling of gas and oil wells.

H2S is to be eliminated from the mud to prevent corrosion of pipelines and equipment. For example, zinc oxide nanoparticles and bulk zinc oxide have the potential to remove H2S from water drilling mud.

3.5.3 Logging While Drilling

Logging while drilling (LWD) is a method for the extraction and collection of data and information during the drilling process. It measures the formation properties, well geometry, and the drilling process properties. It makes measurements while the tools are drilling which provides directional surveys and drilling mechanics data. Compared with wireline measurement, LWD has similar measurement capabilities, although it differs in numerous other aspects. LWD can work in harsh environments. On the other hand, wireline measurements are small, delicate, powered through cable, offer high-speed performance, and are affected by the entirety of the challenging environment. The main advantage of these processes is monitoring and controlling the operations while the drilling is taking place. There are many available LWD measurement techniques such as natural gamma ray (GR), borehole caliper, resistivity, and sonic and neutron porosity. Nowadays, the majority of the neutron porosity that is implemented in LWD uses He-3 detectors in order to detect neutrons in the whole. The main advantages of He-3 detectors are that they are mechanically robust, operate at high temperatures, and fulfill the well logging requirements; however, their available quantity is very limited and they could be depleted in the next few years. However, a good alternative for the He-3 detector is the Li-6 scintillation detector, which can be used as an LWD tool. This detector can be improved using nanotechnology techniques in order to work more efficiently and substantially. Nanostructured glass-ceramics of Li-6 scintillations can work far better than the current Li-6 scintillation materials. Nano-logging can be the main contributor in this field and can improve the next generation of LWD tools, especially in neutron porosity logging.

3.4 Nanotechnology in Drilling Fluids.

Nano-fluid is a fluid with at least one component in the size range of 1-100 nm. Typical nanoparticles can be metals, metal oxides, carbides or fullerenes. These nanoparticles give desired properties to the fluid, like enhanced thermal conductivity, enhanced tribological

effects, and enhanced chemical or rheology improvements.

The surface area of the nanoparticles may play a major role in these effects along with the surface chemistry. In **Figure 3.3** it can be observed how much the surface area is increased over the same volume with different particle sizes and may indicate why the nanoparticles are so special.

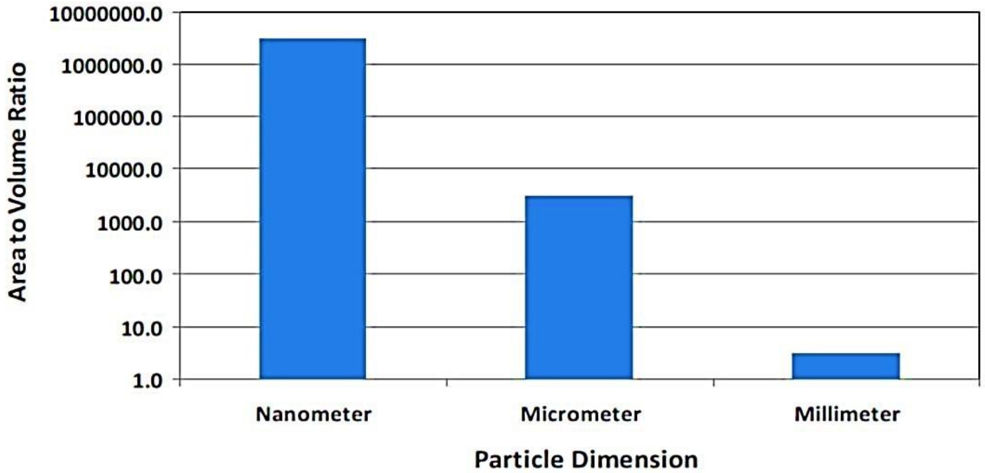

Figure 3.3 ***Surface area VS Particle size (Frode, 2013).***

The drilling fluid circulation has to be maintained throughout the drilling process during which it has to perform certain tasks like hole cleaning, maintaining effective lubrication between the bore-hole and drill-string, cooling of the bit, etc. These functions have to be performed consistently throughout the operation regardless of the type of formation and operating conditions. These functions are purely dependent on the rheological properties of the drilling fluids, particularly, viscosity, density and gel strength.

Lack in performing any of these functions leads to severe drilling problems like: lost circulation, high torque and drag, instability with changing conditions, and stuck pipe events (Adriana et al., 2009). These problems, if happen, lead to huge financial losses since there will be a need for expensive additives, huge non-productive time in resolving the problem and in the worst cases, may lead to abandonment of the well.

Specially designed nanoparticles have various applications in clay stabilization, viscosity enhancement of drilling fluids, fluid loss control, sloughing (wall collapse) control, stability of well bore, torque and drag friction, hydraulic fracturing, and cementing.

Table 4.2 Summary of Nanopartideand their application in drilling fluid.

Nanoparticles	Sizes (nm)	Characteristics	Applications in Drilling Fluid
Nanosilica	Between 5 to 100	Small and tiny sized	- Fluid loss control - Wellbore stability - Reduce pipe sticking - Pipe sticking
Carbon -based	Between 15 to 100	Low surface energy	- Prevents bit balling - Prevents corrosion
Nickel-based	Below 100	Fine texture and structure	- Reduce torque and drag
Zinc Oxide	Between 14-25	Higher reactivity than hydrogen sulphide	- Remove hydrogen sulphde from crude oil
	Below 100	Good heat transfer coefficient. High total surface area.	- Transfer heat from reservoir to surface efficiently - Reduce solid content in mud

a) Economics of nanoparticles.

Low cost is one of the most promising features of Nano drilling fluid along with the other technical benefits. Small concentration of nanoparticle can yield extraordinary results in terms of performance. This is due to their high surface area which makes them highly reactive.

b) Nanoparticles to control fluid loss.

One of the most popular drilling problems is loss circulation It is a partial or complete loss of the drilling fluid to the formation. This situation occurs due to naturally fractured, crevices and channels. The loss of circulation leads to increase the cost and time required for drilling to reach the target depth. The loss of circulation also causes loss of pressure control. The use of micro and macro particles have shown limited success.

The utilization of nanoparticles led to reduce loss circulation by raising carrying capacity sufficiently to carry the cuttings efficiently and to maintain drilling fluid density and pressure over a wide range of operational conditions.

c) Wellbore Instability.

It is known, each year, millions of dollars are spent due to wellbore instability problems which are happening from exposure of shale to drilling fluid (Nabhani & Emami, 2012). The drilling fluids that contain nanoparticles have the power to depreciate wellbore instability (Singh & Ahmed, 2010). The nanoparticles size is less than the pore throat sizes of rocks that lead to plug the pore throats. According to Suri and Sharma (2004), the particle size should not be higher than one-third of the pore throat to build a bridge and plug the pores.

d) Nanoparticles to Reduce Fines Migration.

Fines migration within reservoirs can significantly decrease reservoir permeability and affect well production/injection performance. The mechanisms include surface deposition or attachment, pore-throat bridging or straining, internal cake formation and infiltration sedimentation (Nguyen et al., 2007). Nanotechnology has been used as drilling additives to solve this problem. Nanoparticles with extremely high surface area of approximately 200 m^2/g are suitable to help fixate mobile formation fines. The socalled nanoparticles used to treat fines migration are in the order of 1-100 nanometers in size, with the preferred product having an average size of 35 nanometers.

Because the size of a nanoparticle is relatively small when compared to porethroat sizes, they have negligible effects on the pore-throat structures and permeability of reservoir formations. However, when suspension or colloidal fluid passes through the special coated or surface modified nanoparticles-treated sand pack, the surface forces of nanoparticles retain mobile fine particles and prevent them from further traveling through permeable medium. Laboratory experiments demonstrate that a small concentration of nanoparticles used in sand packs can greatly help prevent fines migration.

e) Nanoparticles to reduce pipe sticking.

Sometimes the drill pipe stuck to the wall of the borehole due to cutting accumulation when drilling fluid circulation stops or because the filtrate loss in the wall of the wellbore (Palaman & Bander, 2008). The Nano-fluids can play a role in recovering the stuck pipe. Nanomaterials based drilling mud have the potential to decrease the sticking tendency of mud cakes by making a thin film covering the drill pipe that lead to cutting down the pipe sticking problem. Also, Nano-fluids have excellent carrying capacity, thus reducing the pipe sticking by cleaning the wellbore from cuttings (Nabhani & Emami, 2012).

f) Nanoparticles for Bit Balling.

According to (Amanullah & Al-Tahini, 2009), nano material-based drilling mud with hydrophobic film forming capability on the bit and stabilizer surfaces is expected to eliminate the bit and stabilizer balling totally. Due to high surface area to volume ratio and very low concentration requirement compared to macro and micromaterialbased fluids, Nano-based fluid could be the fluid of choice for drilling in shale which is very reactive, highly elastic, and viscous and thus can stick easily to the bit, stabilizers, tool joints, etc. As it prevents the reduction in ROP and in total operating cost.

g) Nanoparticles to Reduction Torque and Drag.

There is a noteworthy boost in torque and drag difficulties due to the clash between the drill string and the borehole. Micro and macro materials-based drilling muds have limited ability to overcome torque and drag problems (Wasan & Nikolove, 2003). Due to fine and very thin film forming capability of nanomaterials, Nano-based fluids can provide a significant reduction of the frictional resistance between the pipe and the borehole wall due to the formation of a continuous and thin lubricating film in the wall-pipe interface, thus the application of nanoparticles leads to a significant reduction of the friction between the pipe and the borehole (Donald & Frank, 2007).

Moreover, the tiny spherical nanoparticles may create an ultra-thin bed of ball bearing type surface between the pipe and the borehole wall and thus can allow easy sliding of the drill-string along the Nano-based ball-bearing surface. This highlights the extraordinary role of Nano-based smart fluid in reducing the torque and drags problems of horizontal, extended reach, multilateral and coiled tubing drilling.

h) Nanoparticles to Removing Toxic Gases.

Nanoparticles can be employed in drilling fluids to rid of toxic and corrosive gases, like hydrogen sulphide. This gas should take away from the drilling fluids in order to cut environmental contamination as well as to protect the health of drilling staff and to prevent corrosion of drilling equipment's (Singh & Ahmed, 2010). Sayyadnejad et al. (2008) have found that the addition of 14 to 25nm zinc oxide particles into drilling muds removes hydrogen sulphide completely while bulk zinc oxide removes only 2.5% and take more time.

i) Increase in Shale Stability.

Shale formations are very complicated when it comes to solving the wellbore problems associated with them. Several chemical and mechanical actions are responsible for instability of reactive shale. Interaction between shale and mud can be minimized by using nanofluid because of its ultra-fine particle size. It can also enhance the shale's resistance to fracture and collapse. Chemical reaction associated with shale-mud interaction can also be controlled using nanoparticles as it has several numbers of functional groups (Irfran & Zhixin, 2017).

3.5 Nanometer Shale Inhibitor

Maintaining borehole stability is of great importance to drilling operations. But most of conventional water-based drilling fluids can easily generate fluid penetration into shale formations, which will cause borehole instability problems, resulting in wellbore collapse, borehole shrinkage, and pipe sticking.

a) Shale Permeability and Porosity

The filtration rate of shale sections is very low compared to sand sections under the same differential pressure and the drilling fluid cake is more difficult to be formed on shale sections.

b) Shale Pore throats

The drilling fluid cake forming with ultralow filtration requires the match between the pore throat size and the shielding/ plugging particle size. A mud cake cannot be formed for shale formations because conventional drilling fluid particle sizes are much larger than the shale pore throat size.

c) Micro-cracks of Shale

Micro-cracks are mostly in a closed state under the high confining pressure before the shale is drilled into. Because of the strong conductivity of cracks, if not blocked, the drilling fluid will be driven straight along the cracks rapidly into the formation. Then the supporting effect of the drilling fluid column pressure quickly disappears and causes a high collapse pressure. Therefore, the presence of cracks in shale influences the borehole stability. Oil-based drilling fluids are used primarily due to their drilling performance and low reactivity with the shale formation while maintaining wellbore stability; however environmental agencies, from EPA to local authorities, are ensuring that the operators in the gas plays regulate their drilling operation by adhering to certain protocols and activities. Improvements in drilling performance and reduction of salt use could significantly reduce waste expenses and increase the use of water-based fluids in shale formations. A good solution based on water-based drilling fluids to shale instability problems was proposed. Two different silica nanoparticles were added to water-based drilling fluids, and their influence on shale stability was evaluated.

The experimental results indicated that these nanoparticles reduced the permeability of the shale significantly, and fluid invasion into the shale decreased dramatically. The reason for this was that these nanoparticles were small enough to penetrate and seal the pore throats in shale, and built an internal mud cake, resulting in the reduction of fluid penetration into the shale. Using these nanoparticles-based drilling fluids to seal the shale was a very powerful and economical approach for enhancing borehole strength in problematic shale formations. In the future, this drilling fluid system might hold potential application prospect to resolve shale instability problems.

3.6 Nanocomposite Bentonite.

Using acrylamide as intercalated agent, a new kind of nanocomposite bentonite was synthesized by in-situ intercalation polymerization.

XRD indicated that the intercalated agent had entered into the crystallite layers of bentonite, and the interlayer space of bentonite had increased greatly. TEM showed that acrylamide had good intercalated capacity for bentonite, and the bentonite lamella became smaller and looser. Due to unique intercalated structure, the nanocomposite bentonite had better heat resistance, pollution resistance and cuttings carrying capacity as compared with regular sodium bentonite. This nanocomposite bentonite was added to drilling fluids, and its influence on the properties of drilling fluid system was evaluated. The results indicated that it could improve the rheological properties of drilling fluids, and enhance the thermal stability and inhibiting ability of drilling fluid system, too. In addition, it had good compatibility with drilling fluid system, and it could offer better functionality than regular bentonite without the requirement of other expensive additives, which was critical to deep drilling.

3.7 Nanotechnology in Refining Processes

Nanotechnology is making a significant contribution to the oil refining and petrochemical industry, with potential solutions for the related challenges. For example, several forms and types of nanomaterials are being used as catalysts for several types of refinery and developing industry in various units.

One example is the development of mesoporous catalyst materials such as zeolite and alumina loaded with diverse types of nanoparticles as catalysts. Another example is the use of nanotechnology in removing harmful toxic substances such as nitrogen oxides, sulfur oxides, and related acids and acid anhydrides from vapor by using distinct types of nanofilters and nanoparticles. The removal of mercury from oil and gas is considered to be another challenge, where nanomaterials can play a key role in solving these types of the problem by using, for example, nanoparticles of metal oxides such as copper oxide. Nanotechnology further provides solutions for carbon capture and long-term storage. The removal of sulfur compounds from oil is another problem that is being investigated by scientists and engineers. Various nanomaterials are being developed and evaluated for such applications.

In the following chapters, the role of nanotechnology in solving different oil and gas-related problems is discussed along with several types of nanomaterials that are used for such applications.

3.8 SUMMARY.

The application of nanotechnology in oil and gas industry has a wide range in many sectors, one of these sectors is drilling process where the nanotechnology can play an important role as a remedial or a prevent action for a lot of drilling problems. Nanoparticle addition into drilling fluid provide a novel benefit, especially on filtration problem, since the addition of Nano give a satisfied reduction in the volume of mud loss during drilling process.

CHAPTER FOUR

CHAPTER IV

4. METHODOLOGY

4.1 INTRODUCTION.

In this chapter the methodology upon which effect of Nano silver additives on the main parameters of water-base-mud drilling which are mud cake thickness and water loss were investigated. The water-base-mud was prepared in lab by Hamilton Beach Mixer. Nano silver was prepared added to the mud drilling. The experiment related to the amount of water loss and mud cake thickness was done with the filter press device. In the filter press device air was used as a pressure factor on the mud drilling. The pressure of the device was set on 100 psi for 30 minutes and room temperature. Water-base-mud testing also including density and rheology tests.

4.2 MAKING OF FLUID.

The fluid used in the experiment is water-based mud. It is consist 350 ml water, 25gm (5.4% wt.) betonies and 80gm (17.5% wt.) barite. Fluid's density (10ppg). These components mixed in the mud mixer for 15min. After that and with the same component of mud, we prepared four muds for mixing with various concentration of Nano silver.

4.3 NANO SILVER SOLUTION PREPARATION.

4.3.1 Components.

Starch, D-Glocus, Sodium Hydroxide and Silver nitrate showing in **Figure 4.1**.

Figure 4.1: ***Components of Nano silver.***

4.3.2 Procedures of Preparation.

1. Taking 0.064gm of starch in the first flask, 0.0173gm of D-Glocus in the second flask, 0.096gm of Sodium Hydroxide in the third flask and taking 0.0082gm of Silver nitrate in the fourth flask. The balance that used showing in **Figure 4.2.**
2. Adding 32 ml of ionized-water into the starch flask, 0.48 ml into the D-Glocus flask, 2.4 ml into the Sodium-Hydroxide flask and 16 ml into the Silver-nitrate flask.
3. Putting the solution of starch on the magnetic-stirrer device (showing in Figure 6.3) at 70ºC and 400 rpm for 15 minutes, then adding the solution of Silver nitrate into it and still 10 minutes on the magnetic-stirrer, then adding both of D-Glocus and Sodium-Hydroxide solutions into them and waiting for one hour on the magnetic-stirrer device.

4.4 NANO ADDITIVE

The Nano silver that prepared (showing in **figure 4.4**) used in the experiment in different concentration as flowing:

1. Nano silver with 7.75ml (2% vol).

2. Nano silver with 15.8ml (4% vol).

3. Nano silver with 42.17ml (10% vol) 4. Nano silver with 67ml (15% vol).

Figure 4.2 **:** ***Balance***

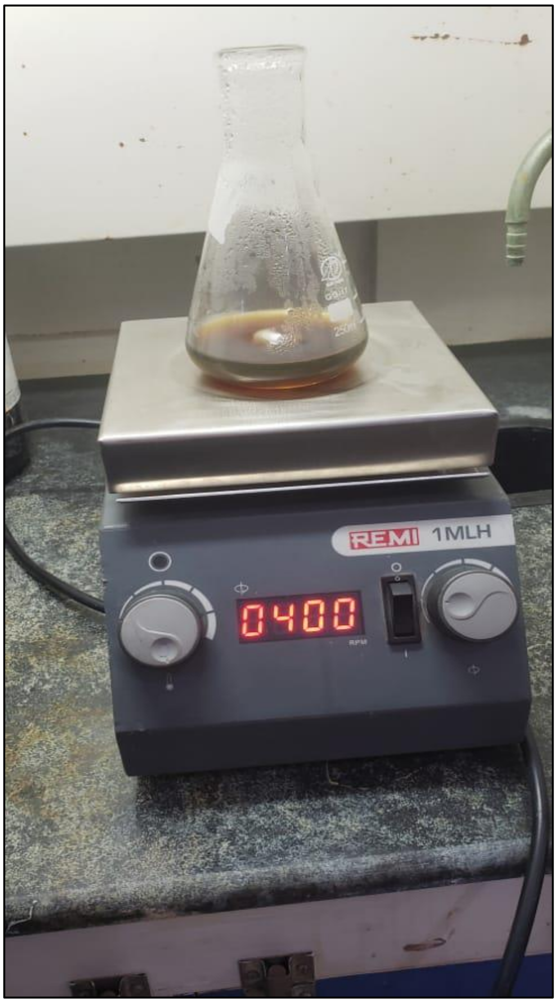

Figure 4.3 **:** ***Magnetic -stirrer device***

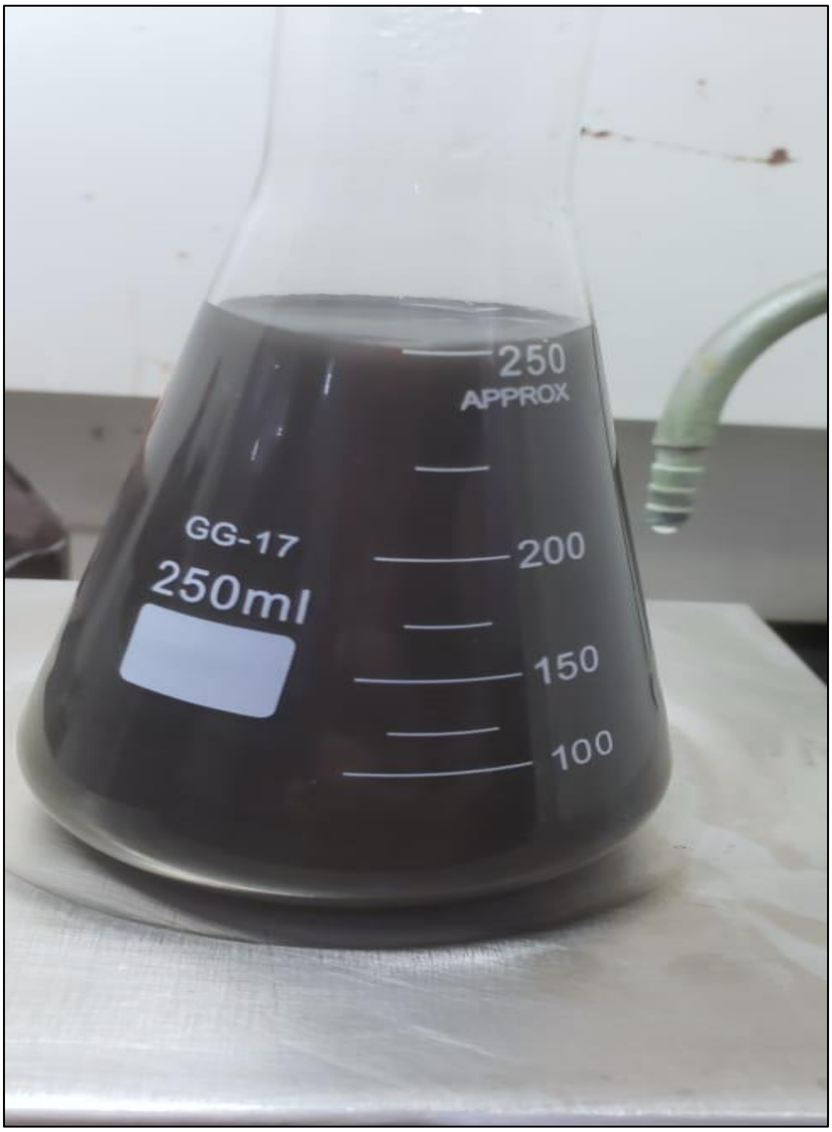

Figure 4.4: ***Nano* s*ilver***

4.5 DENSITY TEST.

The Mud Balance as shown in **figure 4.5** is used to determine density of the drilling fluid. The instrument consists of a constant volume cup with a lever arm and rider calibrated to read directly the density of the fluid in ppg (water 8.33), pcf (water 62.4), specific gravity (water = 1.0) and pressure gradient in psi/1000 ft. (water 433 psi/1000 ft.)

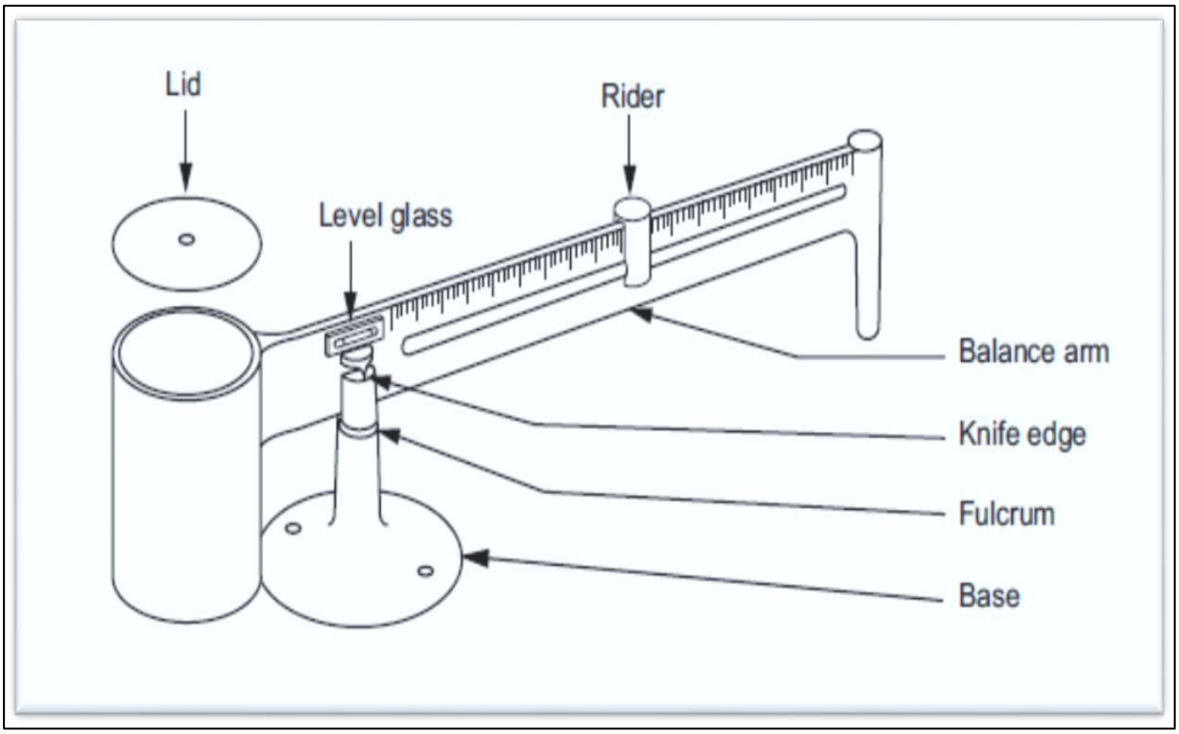

Figure 4.5: Mud balance

4.6 RHEOLOGY TEST.

Rheology test in the experiment done by viscometer (shown in **figure 4.6**). The viscometer is instrument with the ability to test at six speeds (3, 6,100,200,300 and 600) RPM. The speed determined by a combination of speed switch setting and viscometer gear knob placement.

To select the desired speed, set the speed switch located on the right side of the base to the high or low speed position as desired. Then turn the motor on and move the viscometer gear shift knob located in the center of the top of the instrument to its desired position**.**

4.7 Nano silver Effect on Gel/Polymer Drilling Fluids

To run API Filtration test & Rheology test, we have to use the Gel/Polymer Mud sample previously mixed and add the following additive to control the fluid loss and improve the quality of filter cake then add 2 % of Nanosilver to see fluids properties enhancements:

1. 2 ppb (2 grams) Trupac-LV to decrease fluid loss and 15 ppb (15 grams) $CaCO_3$ fine to enhance quality of filter cake and mix well.
2. Run API Filter press test as per instructions, pH & Rheology, then record the results in the below table.
3. Pour the filtrate and peel the filter cake into the sample and agitate with the mixer.
4. Add 2 ml (2%) of NanoSilver to decrease fluid loss, enhance quality of filter cake and improve Rheology then mix well.
5. Run API Filter press test as per instructions, pH & Rheology, then record the results in the below table.

Fluids additives / **Parameters**	**Gel/Polymer Mud + F.L.C.+CaCO3**	**Gel/Polymer Mud + F.L.C. +CaCO3+ NanoSilver**
Fluid loss, ml/30 minutes	7.2	6.6
Filter Cake size, 1”/32	1	1
Filter Cake quality	Medium hard	Hard and slick
pH mud sample	9	9
pH filtrate	8.5	8.5
600/300	92/74	90/74
PV /YP	18/56	16/58
10 sec. gel/10 min. gel	39/75	33/65

Conclusions:

Figure 4.6 **:** ***FANN viscometer***

4.7 FILTRATION TEST.

The filtration test in the experiments done by API filter press (shown in **figure 4.7**). The pressure source delivered air with a pressure of 100psi. The experiments were always started with thorough cleaning and drying of the base cap, rubber gasket, screen and the filter cell. The cell was then sealed to the base cap and filled with mud.

After that the cell was carefully placed into the frame and the regulator from the pressure source. This was the most critical step as the cell sometimes was leaking. If that were the case the cell was disassembled and the experiment was started over again. If the cell was not leaking the timer was started and the filtrate volume was measured after 1, 2, 3, 5,7.5, 10, 15, 20, 30 minutes.

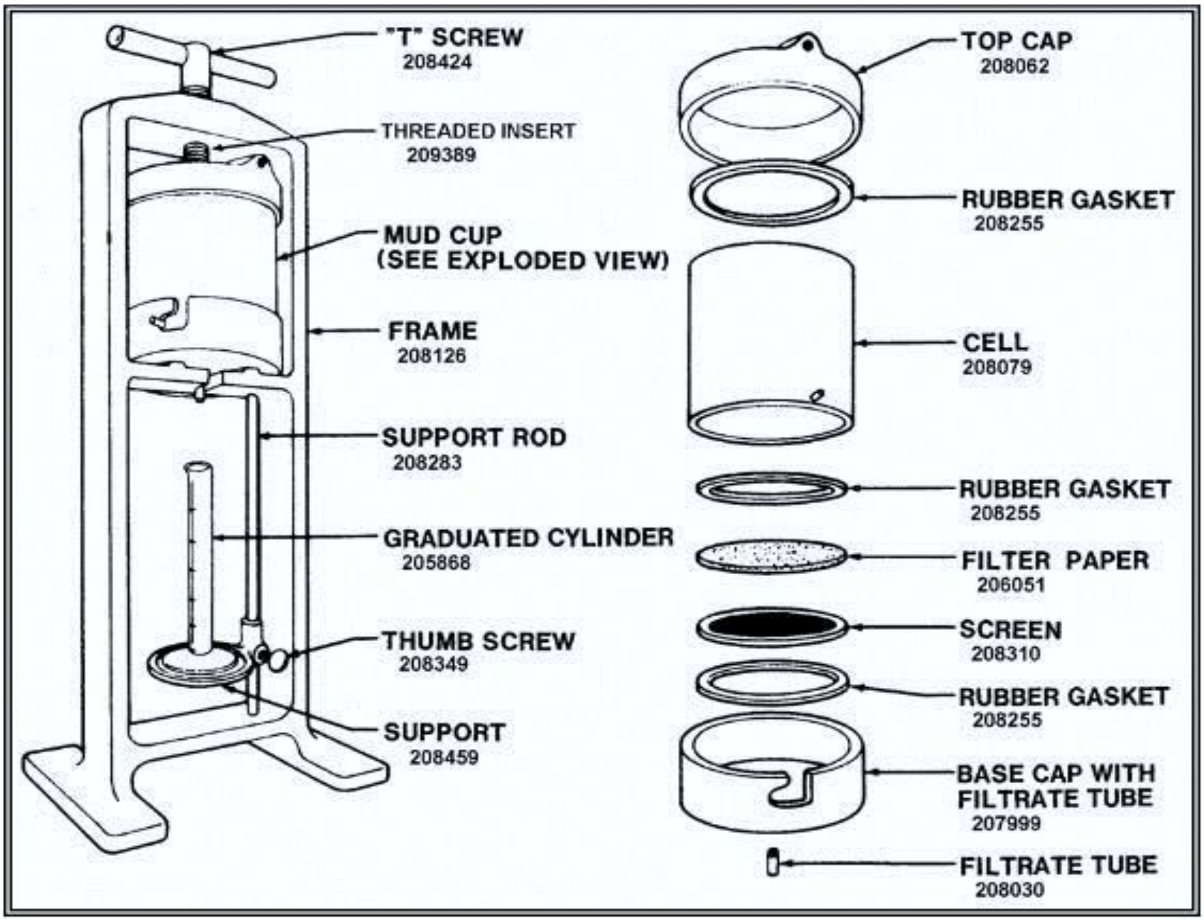

Figure4.7. ***1API filter press.***

CHAPTER FIVE

CHAPTER V

5. RESULTS AND DISCUSSION

5.1 DENSITY

Results showed that the addition of Nano-silver into WBM doesn't have a significant effect on the density of mud, since the densities of mud1, mud2, mud3, mud4, and mud5 are 10, 9.91, 9.81, 9.8, and 9.7 respectively**. Figure 5.1** show slight decrease in density as Nano-silver concentrations increase.

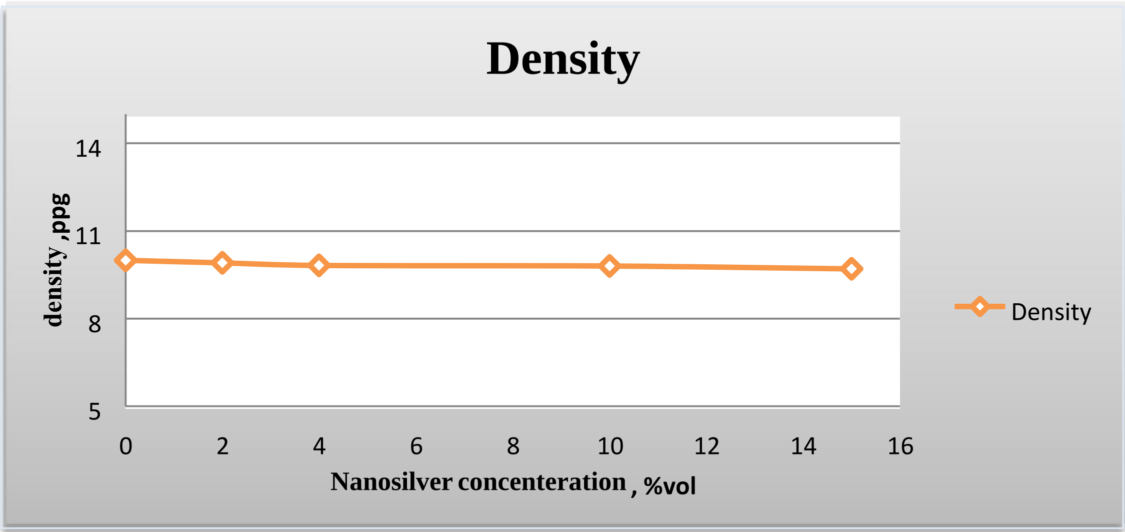

Figure 5.1: The variation of density during five types .

5.2 RHEOLOGY

The observed results for the plastic viscosity of the five types indicate also slight effect of nanoparticle's addition into water-based mud, approximately (1-1.5) cp is the variation between a pure water-based mud and the other Nano-water based mud, as well as the same plastic viscosity for Nano-water based muds.

The values of μ_p for the five types (mud1, mud2, mud3, mud4, mud5) are 3.5, 5, 5, 4, 5 respectively. **Figure 5.2** shows a graph for the variation in μ_p at different Nanosilver concentrations. The apparent viscosity values are 5.5, 5.5, 6, 5.5, and 5.5 respectively. Note, these results of u_s are not logic which may indicate that Rheometer is not working properly.

The yield point for the five types also measured and the results show a small decrease in YP as Nano-concentrations increase. 4, 1, 2, 3, 1 Ib/100ft^2 are the determined yield point's values, these results were explained in **figure 5.3.**

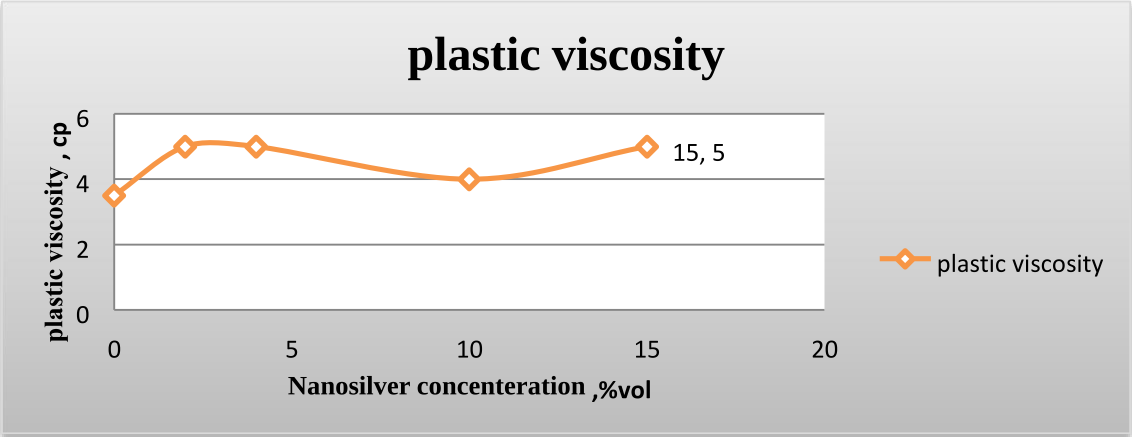

Figure 5.2 plastic viscosity variation against Nano%

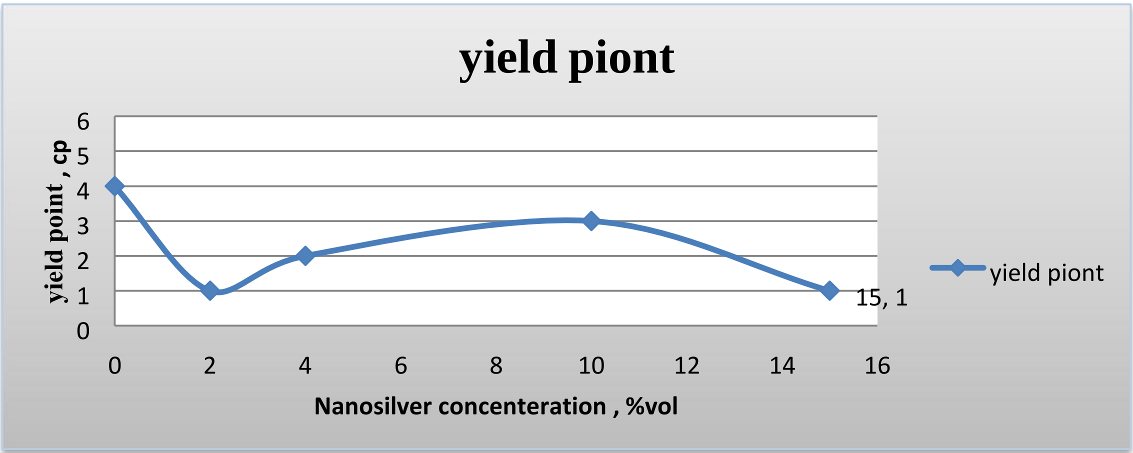

Figure 5.3: yield point variation against Nano%

5.3 API FILTRATION TEST

Results were obtained from API Filter test at 100 psig and room temperature. The largest mud filtrate was measured for the control sample (WBM without Nanoparticles). Exactly, 38 ml mud filtrate which observed for pure WBM. Surprisely, both the 2% and 4% (vol%) Nano-silver gives similar mud filtrate volume (32 ml @ 30 minute). there is some reduction in mud-cack thickness. (5/32)", (4/32)" are the measured mud-cake thickness for 2% and 4% respectively, as well as

(6/32)" is the mud-cake thickness of pure WBM**.** **Figure 5.4** show the mud-cake thickness reduction for 0%, 2%, 4% Nano-silver WBM.

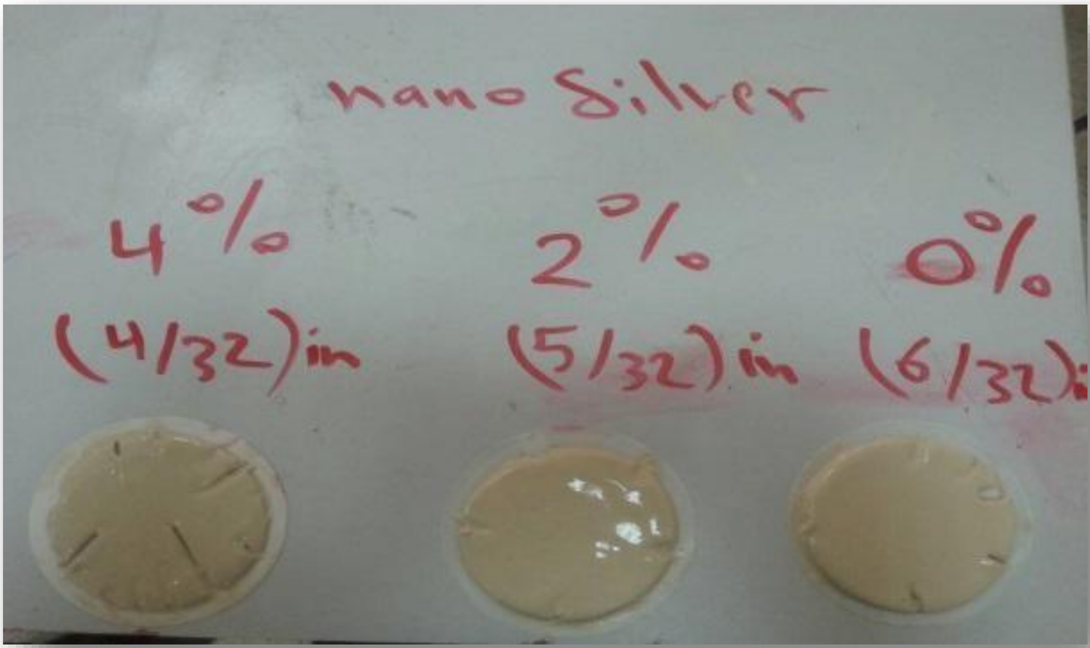

Figure 5.4: mud thickness

The API filter test was also investigated on 10% and 15% vol. Nano-fluid. A good reduction in filter lose volume was obtained compared to pure WBM and 2% Nanofluid. 34% reduction in filter lose volume was obtained at 10% Nano-fluid, as well as 36.8% reduction at 15% Nano-fluid.

Table 7.1 shows the volumes of API filter test against a measured time for the five muds, the variation in filter lose volume of all types explained on a graph in **Figure 5.5**. The mud-cake thickness of mud4 is (5/32)" while (4/32)" is the measured thickness of mud5. **Figure 5.6** show the mud thickness of mud4 and mud 5.

Table 5.1: API filter volume against time

Time (Sec)	API Filtration Volume for WBM (ml)	API Filtration Volume for 2%NanoAgNo3 (ml)	API Filtration Volume for 4% NanoAgNo3 (ml)	Time (sec)	API Filtration Volume for 10% NanoAgNo3(ml)	API Filtration Volume for 15%Nano-$AgNo_3$ (ml)
2	7.5	6	6	1	2.5	2.5
3	10	9	9	2	5	4.5
5	14.5	12	12	3	6.5	6
7.5	19	16	16	4	8	7.5
10	22	20	20	5	9.5	9
13	25	25	25	6	10.5	10
16	27	27	27	7.5	12.5	12
30	38	32	32	30	25	24

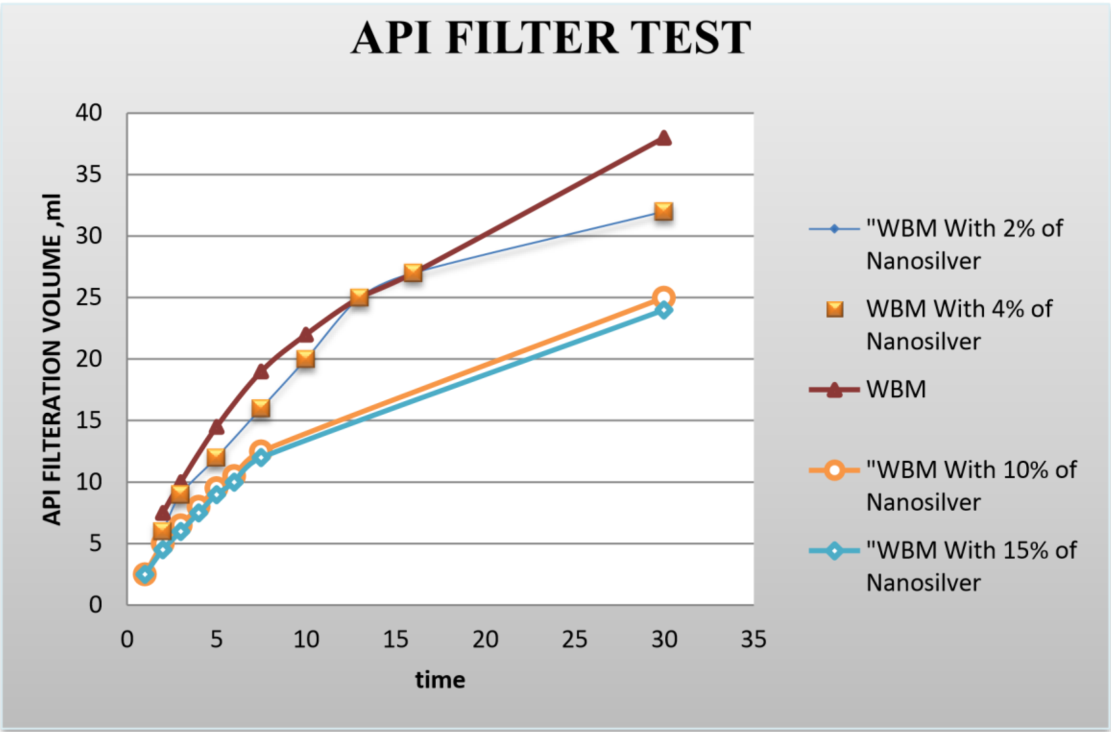

Figure 7.5: API filter volume for five muds.

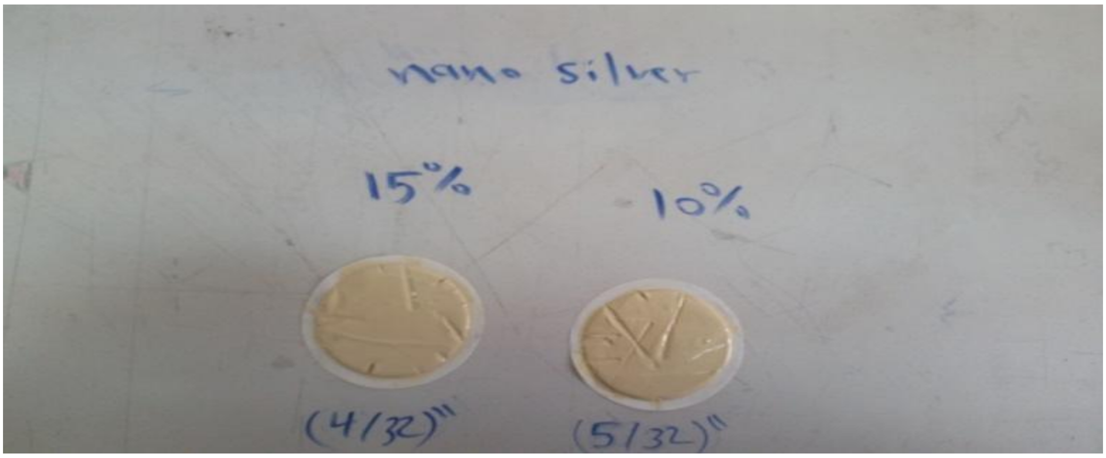

Figure 7.6: mud thickness

There was no much difference between the results of 10% & 15% Nano-silver. This may allow us to conduct that the optimum concentration of Nano-silver is approximately 10%. Any further increase in Nano-silver does not reduce mud filtrate.

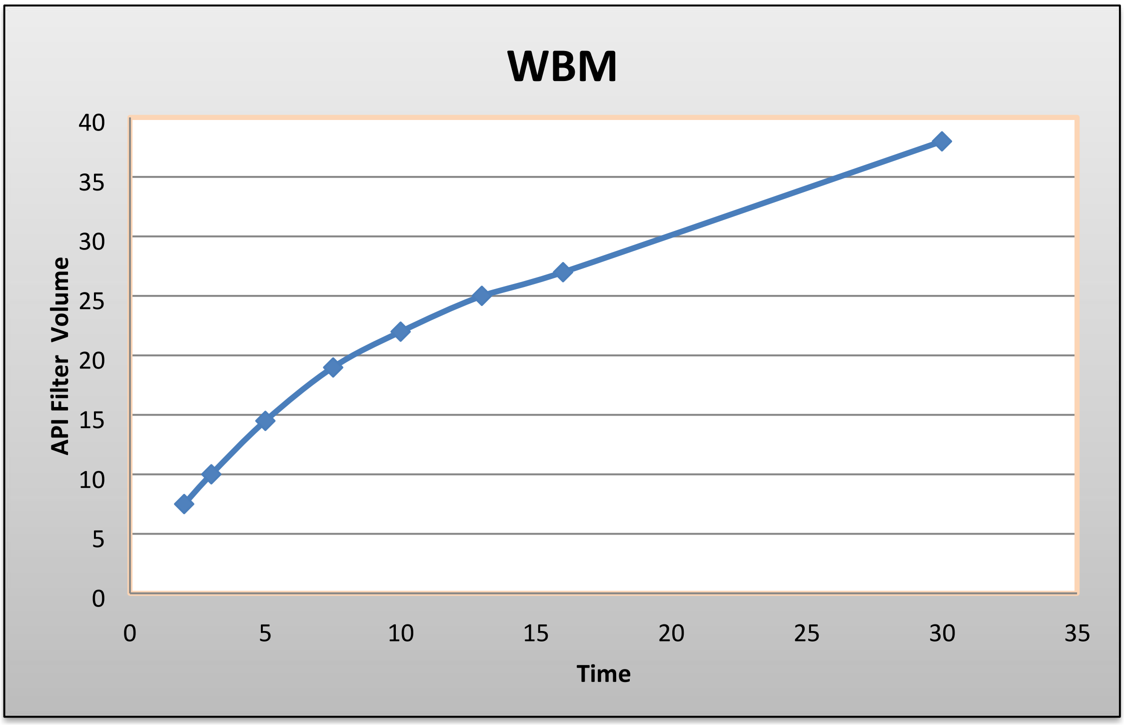

Figure 5.7: Mud Filtrate VS Time

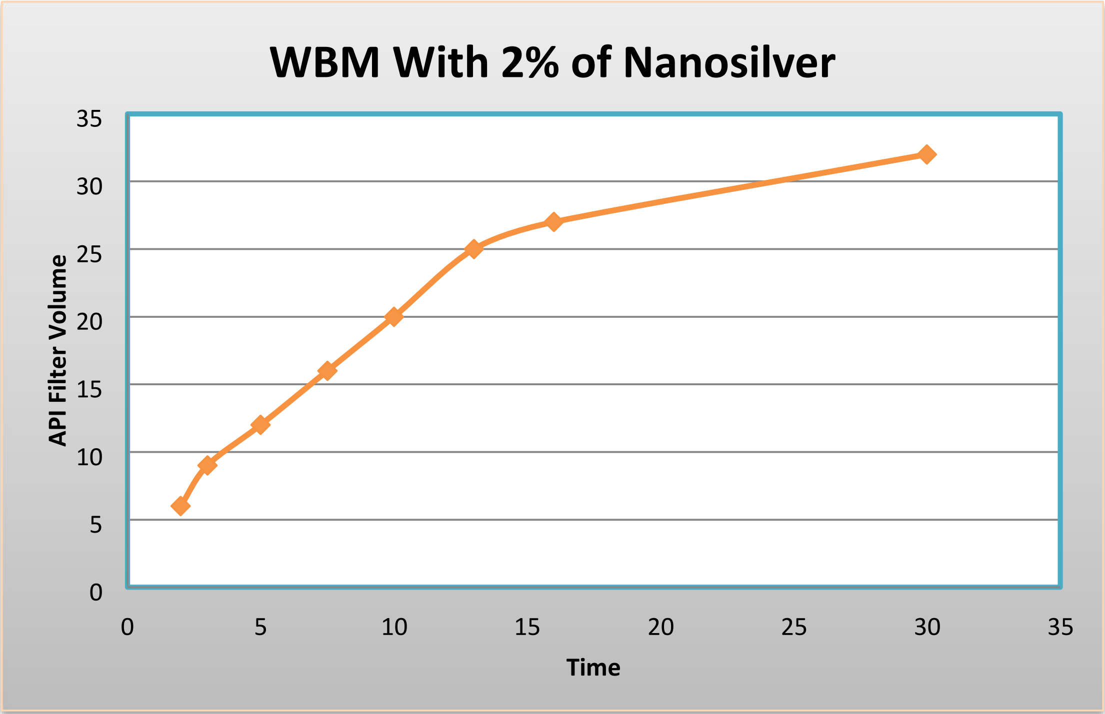

Figure 5.8: Mud Filtrate VS Time

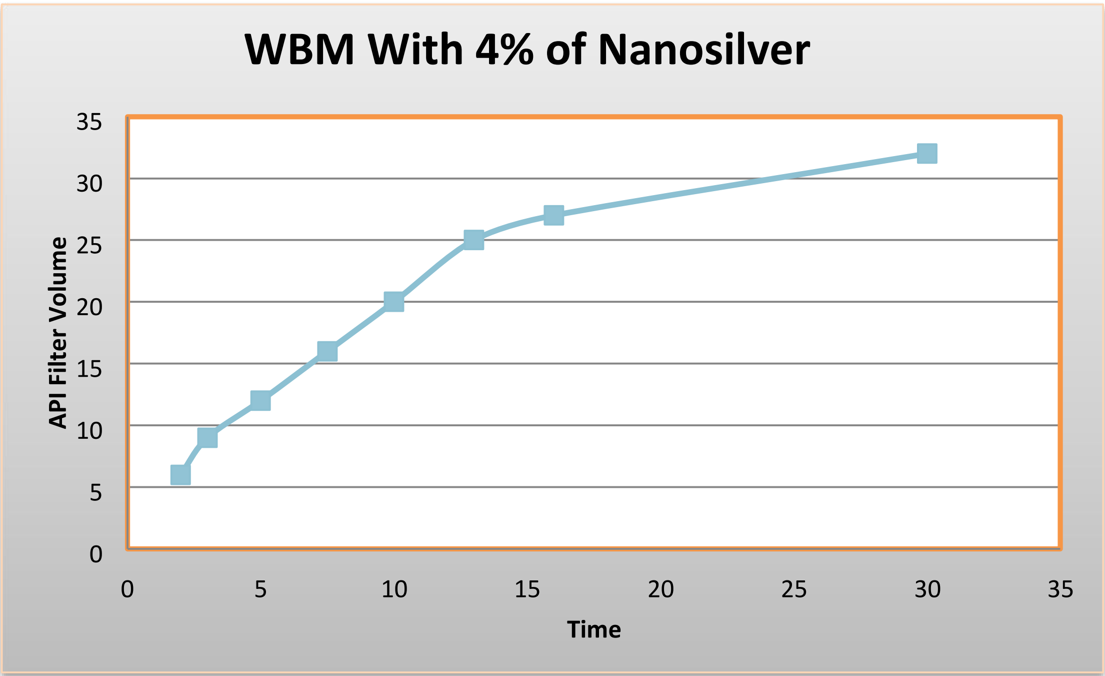

Figure 5.9: Mud Filtrate VS Time

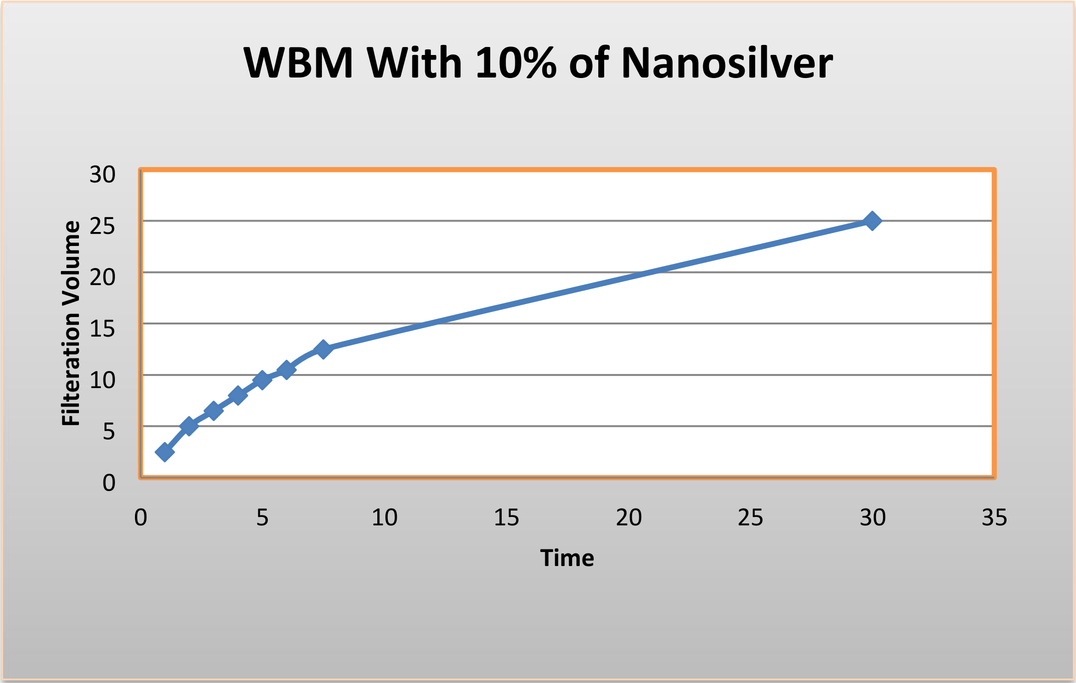

Figure 5.10: Mud Filtrate VS Time

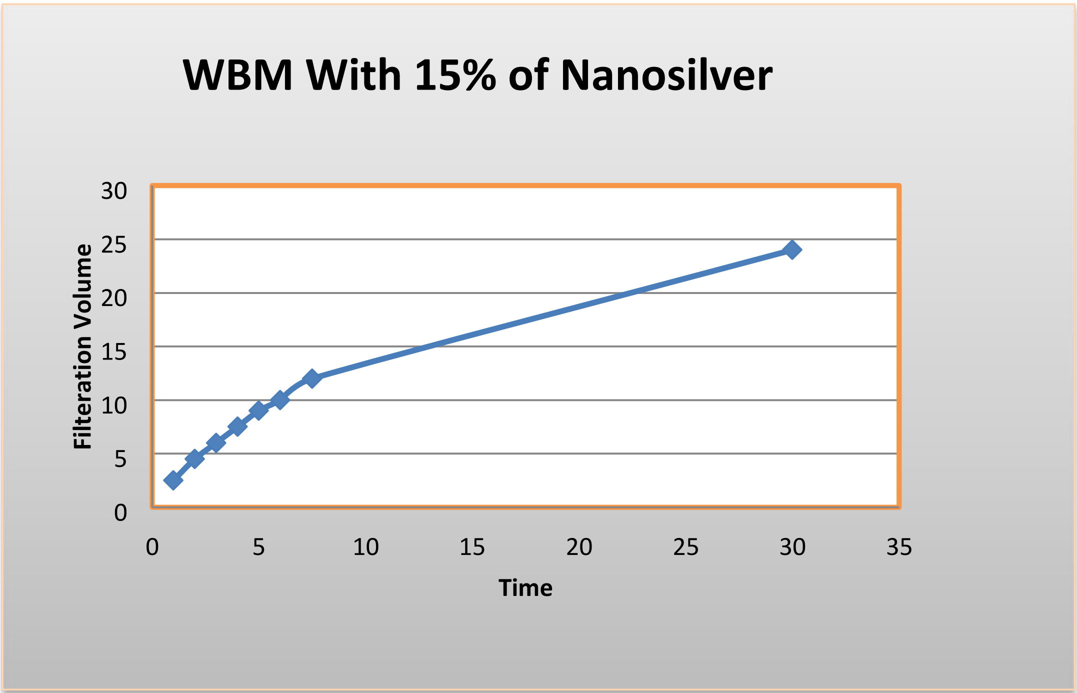

Figure 5.11: Mud Filtrate VS Time

CHAPTER SIX

CHAPTER VI

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Through our Lap experiment, we studied the effect of Nano-particle (Nano-silver) filter **on** the Rheology and loss of drilling mud. Therefore, we conclude many points:

- Nano-silver has effect on the characteristic of the drilling mud, which has little effect on Rheology and more effect on the mud filtration.
- Addition of Nano-silver into WBM does not have a significant effect on the density of mud, show slight decrease in density as Nano-silver concentrations increase.
- Addition of Nano-silver also does not have a significant effect on the plastic viscosity, (1-1.5) cp is the variation between a pure water-based mud and the other Nano-water based mud.
- The yield point for the five muds show a small decreasing in YP as Nano-silver concentrations increase.
- Addition of Nano-silver into WBM has a significant effect on the filter loss of mud. The optimum filter loss reduction was 34% at 10%vol of Nano-silver concentration.
- Any increase in Nano-silver concentration more than 10% not given valid different reduction in filter loss.
- Mud cake thickness not given large change with addition of Nano-sliver. The largest thickness achieves for the base mud without Nano-silver which given 6/32", and the optimum value was (4/32") at 4% and 10% Nano-silver concentration.

6.2 RECOMMENDATION

- The optimum concentration of Nano-silver is approximately 10%, any further increase in Nano-silver will not reduce mud filtration.
- Our lap experiment was on API Filter Press at LTLP which was less stimulation to reservoir condition, because do not have HTHP filter press.

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