CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF STUDY

A drilling fluid, or mud, is any fluid that is used in a drilling operation in which that fluid is circulated or pumped from the surface, down the drill string, through the bit, and back to the surface via the annulus (Amoco Production Company, 2001). The drilling-fluid system is commonly known as the “mud system” is the single component of the well-construction process that remains in contact with the wellbore throughout the entire drilling operation. Drilling-fluid systems are designed and formulated to perform efficiently under expected wellbore conditions. Advances in drilling-fluid technology have made it possible to implement a cost-effective, fit-for-purpose system for each interval in the well-construction process.

Drilling fluids satisfy many needs in their capacity to do the following:

i. Suspend cuttings, remove them from the bottom of the hole and the well bore, and release them at the surface
ii. Control formation pressure and maintain well-bore stability
iii. Seal permeable formations
iv. Cool, lubricate, and support the drilling assembly

The most critical function that a drilling fluid performs is to minimize the concentration of cuttings around the drill bit and throughout the wellbore. Of course, in so doing, the fluid itself assumes this cuttings burden, and if the cuttings are not removed from the fluid, it very quickly loses its ability to clean the hole and creates thick filter cakes. To enable on-site recycling and reuse of the drilling fluid, cuttings must be continually and efficiently removed. The circulation system as in Figure 1 shows the drilling fluid movement and its complementary function of drilling job.

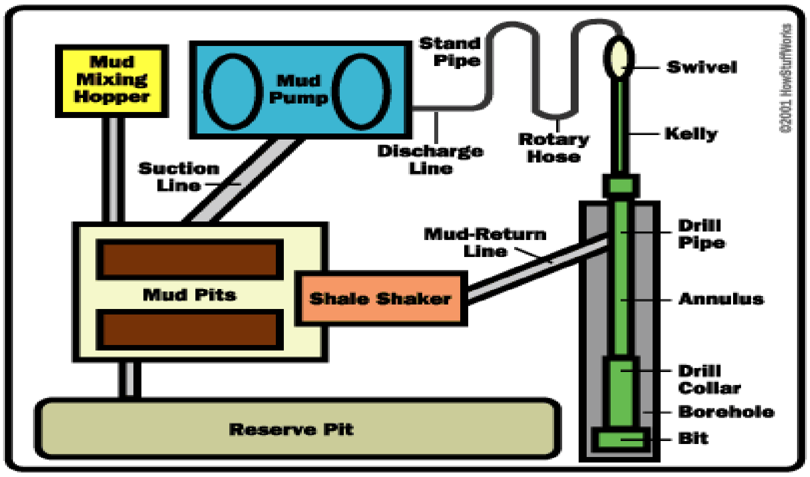


Figure 1: Typical Circulation System

1.2 PROBLEM STATEMENTS

There are equally important factors of choosing the additive for drilling fluid which are total cost and the fluid's effect on well productivity. Therefore, in order to correlate cost and effectiveness of the additive, the natural sources of additive (feldspar) which found abundant in Malaysia is determined its potential.

The main problem in production is minimizing formation damage. Drilling fluid, formation interactions and other processes will alter in situ formation characteristics must be considered in the selection of additives and fluid systems. Production zones can be partially or totally lost depending upon fluids selected to drill and complete a well. The natural local additives should be in recommendation list in order to avoid the production zones damaged.

Meanwhile the operation main problem with drilling fluids and additives are concerned on the effect of the drilling fluid log interpretation and on cuttings analysis. Therefore, characterizing and cataloging drilling fluid additives and fluid systems can greatly enhance the geologist's interpretation of reservoir potential. Most operational problems are interrelated, making them more difficult to resolve. For example, loss of circulation into a depleted zone causes a drop in hydrostatic pressure in the wellbore. When the hydrostatic pressure falls too low to hold back formation fluids, the loss incident can be compounded by an influx of gas or water, known as a flow or (when more severe) a kick.

Minimizing the environmental impact of a drilling operation as well as safety considerations both directly affect the choice of drilling fluid additives and drilling fluid systems. As more environmental laws are enacted and new safety rules applied, the choices of additives and fluid systems must also be reevaluated.

1.2 OBJECTIVES AND SCOPE OF STUDY

The main objectives of this research are:

- **To discover the properties and characteristics of quartzo-feldspathic rock.** The objective is completed by using the scanning electron microscope and X-ray diffraction. This is a first step of determining the feldspar potential as an additives in further works
- **To discover the effect of the feldspar addition on drilling fluid properties.** Oil based mud is preferably used in the higher temperature well because of its durability and the addition of feldspar effect is determined by using the current laboratory technology.
- **To determine the effect of formulated drilling fluid in high temperature and high pressure well condition.** The drilling fluid characteristic is determined by using the HPHT equipment, HPHT viscometer and HPHT filter press. This objective will conclude the previous findings in order to determine the feldspar as a type of additives that may be used in future drilling fluid technology.

The scope of work for this project is to investigate the suitability of feldspar as an additive in high temperature drilling fluid. The ideal volume percentage of feldspar in every experiment will be the benchmark in determining the best type of additive concluded from the feldspar rock.

1.4 RELEVANCY OF PROJECT

In terms of the relevancy of this project, it poses a great deal of significance to the oil and gas industry. The world nowadays is in demand of oil as the most important source of energy. With the days of easy oil that have long gone, every oil and gas companies are striving towards the hard way to produce oil and gas.

For this project, the author is applying his theoretical and practical knowledge in petroleum engineering to solve the issue of drilling fluid addities cost reduction and discovering new potential addities . The basic principle involved ranges of well from exploration, appraisal and development. Thefore, the project is important as a cost reduction and reservoir management department.

1.5 FEASIBILITY OF PROJECT

All the objectives stated earlier are achievable and feasible in terms of this project duration and time frame. The author are confident to complete the laboratory in the given time. The precise and compact experiment for determining the feldspar potential in drilling fluid is conducted by considering three main drilling fluid properties which are density, viscosity and filtration.

CHAPTER 2: LITERATURE REVIEW

2.1 FELDSPAR; AS THE EXPERIMENTING ADDITIVE

Feldspar is the most common rock-forming mineral about 60% of the earth's crust (Kauffman and Van Dyk, 1994). The mineral name feldspar is derived from the German words feld and spar. From the Germany word "feld" is a meaning of "field" and "spar" is a terminology for light colored minerals that break with a smooth surface.

Feldspar is commonly found in rock-forming mineral. It is a group of minerals with a general chemical formula of AlSi3O8. The physical view of feldspar minerals is usually white or very light in color and has a hardness of 6 on the Mohs' Scale of Hardness and usually has good cleavage in two directions. Feldspars are primarily used in industrial applications for their alumina and alkali content. Alumina provides hardness, workability, strength, and improves resistivity to chemicals. The alkali content in feldspar acts as flux, lowering the glass batch melting temperature.

In this project, the specimen is a composition of feldspar and quartz which is called a quartzo feldsphatic rock. This composition did not change its physical appearance as it is still white in color and the Mohr Hardness Scale is 6. The abundance availability of both feldspar and quartz is the primary key potential of this project.

The rock sample located at the Main Range Province specifically at Cameron Highland, Malaysia. The Main Range Province contains major batholiths and large complex plutons of restricted compositional range comprise a suite of tin bearing S-type granites of mainly Triassic age (Bignell & Snelling 1977; Liew & Page 1985). Granitoids designated as two-phase variants have been recognized where xenocrysts and xenoliths of coarse, primary texture granite are enclosed in, and corroded by an invasive, equigranular quartzo-feldspathic matrix. These rocks form an essential part of the granite sequence in all provinces and have probably resulted from the infiltration and disruption of the host granite by late stage magmatic fluids.

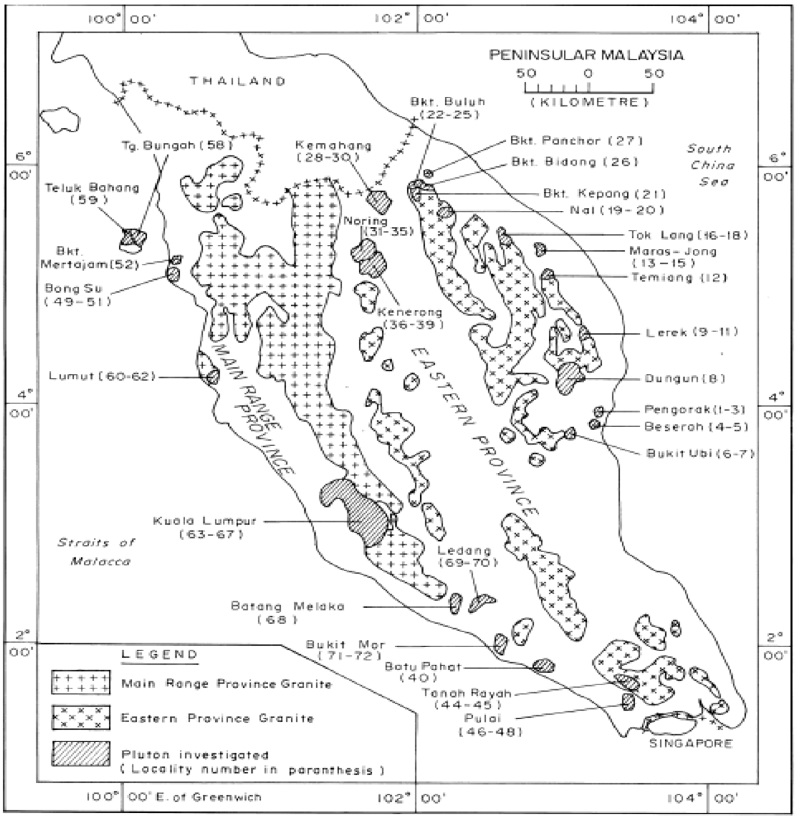


Figure 2: Main Range Province in Peninsular Malaysia

Figure 3: Quartzo-feldsphatic rock sample collection locality

2.2 DRILLING FLUID; AS THE FOCAL OPTIMIZATION PROPERTIES

The drilling fluid is as important in determining drilling costs as all other man-controllable variables combined. Considering these factors, an optimum drilling fluid is a fluid properly formulated so that the flow rate necessary to clean the hole results in the proper hydraulic horsepower to clean the bit for the weight and rotary speed imposed to give the lowest cost, provided that this combination of variables results in a stable borehole which penetrates the desired target. A fluid should enhance penetration rates, reduce hole problems and minimize formation damage (Baker Hughes, 2004).

Oil-based mud is compatible to drill troublesome shales and to improve hole stability. OBM could be selected for special applications such as high temperature and high pressure wells, minimizing formation damage, and native-state coring. Moreover, OBM are also applicable in drilling highly deviated holes because they are characteristically high lubricity and ability to prevent hydration of clays. Another reason for choosing oil-based fluids is, their resistant to contaminants such as anhydrite, salt, CO2 and H2S acid gases which commonly found in problematic reservoir. The cost is a major concern when selecting oil-based muds but, because of oil muds can be reconditioned and reused, the costs on a multi-well program may be comparable to using water-based fluids. Today, with increasing environmental concerns, the use of oil-based muds is either prohibited or severely restricted in many areas. The costs of containment, hauling, and disposal can greatly increase the cost of using oil-based fluids.

2.3 TYPES OF DRILLING FLUID ADDITIVES

According to Schlumberger Oilfield Glossary, drilling fluid additives are defined as a material that added into a drilling fluid to perform one or more specific function. They are a categorized and names as its functions to drilling fluid, such as viscosifier, loss circulation agent, lost circulation material, viscosifier, dispersant and reducer (Adam T, Bourgoyne Jr, 1991).

2.3.1 **Viscosifiers**

The viscosifier products is classified with its suitability in clearwater brines, water-based muds, and oil-based muds. The viscosity of a fluid is dependent upon size, shape, interparticle force and number of particles and based fluid viscosity. Fluid viscosities are measured in several different manners at the rig site. The most common procedures utilize the Marsh funnel and the viscosity-gel (VG) meter. These tests evaluate different fluid properties.

2.3.2 **Viscosity Reducers**

A high viscosity will result several drilling problems which are caused by excessive colloids, undesirable drill solids, or contaminants. High viscosities will result excessive yield points and gel strengths, which cause an increase in the equivalent circulating density and may require high pump pressures to break the circulation. These conditions can result in lost circulation and other wellbore problems.

2.3.3 **Thinners and Dispersants**

Chemicals that cause mud thinning disperse the clay platelets by reducing the interparticle attraction forces and, in some cases, by creating repulsion forces. Thinners satisfy the broken valence bonds at the edges of the clay platelets, reducing the attractive forces between the clay platelets and stacks of particles. The reduction or elimination of these forces is commonly referred to as dispersing a mud system. Most thinners can be classified as organic materials or as inorganic complex phosphates. The organic thinners include lignosulfonates, lignins, and tannins. Lignosulfonates with several metal compounds have been used successfully in a wide range of applications.Organic thinners can be used in higher-temperature wells and exhibit good filtration control properties. Inorganic thinners Include sodium acid pyrophosphate (SAPP), tetrasodium pyrophosphate, sodium tetraphosphate, and sodium hexametaphosphate. Inorganic thinners are effective in very small amounts but are restricted to freshwater clay muds, low temperatures, low chlorides, low calcium/magnesium, and low pH values.

2.3.4 **Fluid Loss Agents**

All muds lose fluid to the formations. Fluid reductionm agents were developed to form thin, tough, semipermeable wall cakes. The hole becomes more stable, and productive zones are protected to some degree if invasion of drilling fluid filtrate is controlled. The deposition of solids too large to pass through the membrane pores minimizes the continuation of fluid loss. Permeability of a filter cake is dependent upon size and distribution of particles on the wall cake.

2.3.5 **Loss Circulation Material**

Many types of LCM are available to address loss situations. Sized calcium carbonate, mica, fibrous material, cellophane, and crushed walnut shells have been used for decades. The development of deformable graphitic materials that can continuously seal off fractures under changing pressure conditions has allowed operators to cure some types of losses more consistently. The application of these and similar materials to actually strengthen the wellbore has proved successful (Aadnoy, B, 1996). Hydratable and rapid-set lost-circulation pills also are effective for curing severe and total losses. Some of these fast-acting pills can be mixed and pumped with standard rig equipment. Others require special mixing and pumping equipment.

2.3.6 **Spotting Fluids**

Most spotting fluids are designed to penetrate and break up the wall cake around the drillstring. A soak period usually is required to achieve results. Spotting fluids typically are formulated with a base fluid and additives that can be incorporated into the active mud system with no adverse effects after the pipe is freed and/or circulation resumes.

2.4 HPHT WELL CONDITION

According to United Kingdom Shelf Operation Notice, HPHT well is defined as any well where its undisturbed bottomhole temperature is greater than 300°F and the pore pressure exceed 0.8 psi/ft or pressure control equipment is greater than 10000 rated working pressure is required (McMordie W. C, 1995). The identification of HPHT operating environments, safe operating envelopes, and technology gaps, new classifications have been developed. The classifications segment HPHT operations into three tiers. Tier I refers to the wells with reservoir pressures up to 350°F (177°C). Nowadays, most HPHT operations have taken place under Tier I conditions. Tier II are called as the ultra HPHT wells, which are characterized by reservoir pressures of up to 20,000 psi (1379 bar) and temperatures of up to 400°F (204°C). Many upcoming HPHT deepwater gas and oil wells, particularly in the Gulf of Mexico, fall into the Tier II category. Tier III encompasses the extreme HPHT wells, with reservoir pressures of up to 30,000 psi (2068 bar) and temperatures of up to 500°F (260°C). Tier III is the HPHT segment with the most significant technology gaps. Several deep gas reservoirs on North American land and the Gulf of Mexico shelf fall into this category (Schremp, F.W. and Johnson, V.L,1995) Figure shows the category of HPHT well.

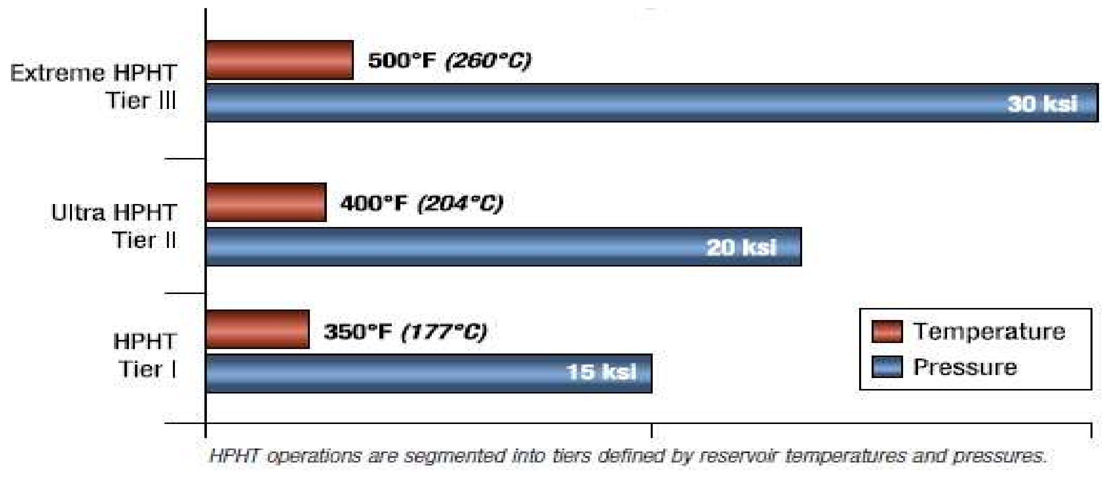


Figure 4: HPHT Regimes

2.5 ENGINEERING THEORY

The American Petroleum Institute (API) has set forth numerous recommended practices designed to standardize various procedures associated with the petroleum industry. The practices are subject to revision from time-to-time to keep pace with current accepted technology (API RP 13-B, 1997). One such standard is API Bulletin RP 13B-2, "*Recommended Practice Standard Procedure for Field Testing Oil-Based Drilling Fluids*". This Bulletin described the following drilling fluid measurements as necessary to describe the primary characteristics of a drilling fluid:

i. Density – for the control of formation pressures
ii. Viscosity and Gel Strength – measurements that relate to a mud's flow properties
iii. Filtration – a measurement of the mud's loss of liquid phase to exposed, permeable formations
iv. Sand – the concentration of sand (solid particles < 74μ) being carried in the mud
v. Methylene Blue Capacity – an indication of the amount of reactive clays present in the mud
vi. pH – a measurement of the alkaline and acid relationship in the mud
vii. Chemical Analysis – qualitative and quantitative measurement of the reactive chemical components of the mud

2.5.1 **Density**

The density of any fluid is related to the amount and average specific gravity of the solids in the system. Fluid density units are commonly expressed in lbm/gal (lbm/ft3 in also is used) and in specific gravity or g/cm3 when converting to metric system. The density of any fluid should be dictated by formation pressures. The density must be sufficient to promote wellbore stability. The control of density is critical since the hydrostatic pressure exerted by the column of fluid is required to contain formation pressures and to aid in keeping the borehole open. The pressure exerted by the fluid column should ideally be only slightly higher than that of the formation to insure maximum penetration rate with minimal danger from formation fluids entering the well bore (Isambourg, P, 1998)

2.5.2 **Rheology**

Rheology is defined as physics of the flow and the deformation of matter. Rheology and the associated annular hydraulics relate directly to borehole stability and how effectively the borehole is cleaned. An understanding of rheology is essential if wellsite engineering of the drilling fluid is to cost effectively complement the objective of drilling the well. Rheology and hydraulics of drilling fluids are not exact sciences, but are based upon mathematical models that closely describe the rheology and hydraulics of the fluid and do not conform exactly to any of the models. Consequently, different methods are used to calculate rheology and hydraulic parameters (Gray, G. R. and Darley, H. C. H, 1979).

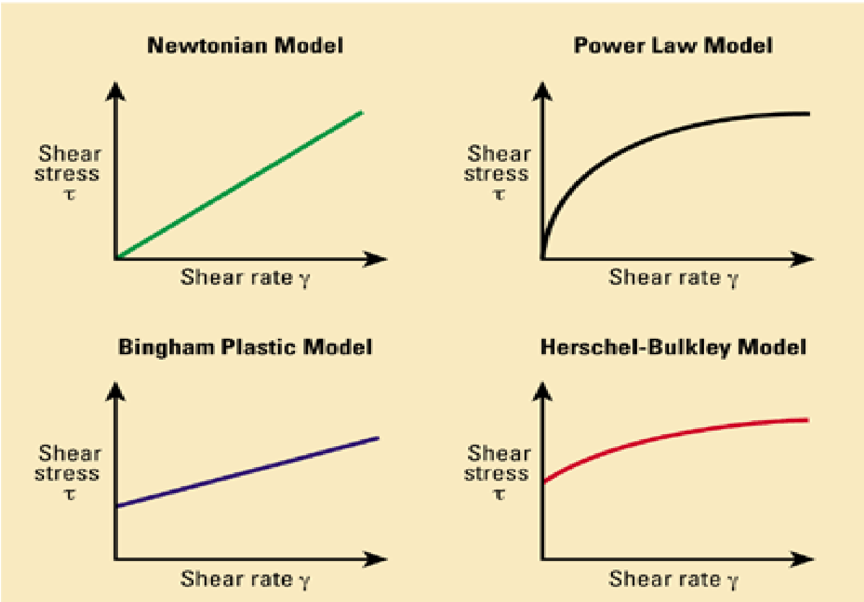


Figure 5: Rheological Model

2.5.3 **Shear Stress**

It defined as an applied force (F), acting over an area (A), causes the layers to slide past one another. However, there is a resistance, or frictional drag, force that opposes the movement of these plates. This resistance or drag force is called as shear stress (τ). In equation form,

$$\tau = F/A,$$

Where τ = shear stress
F = force
A = area of surface subjected to the force.

The shear stress typical units is lbf/100 ft2. Additionally, the fluid layers move past each other easier than between a pipe wall and fluid layer. Therefore, we can consider a very thin layer of fluid next to the pipe wall as stationary (Schlumberger. Completion Fluids 2012).

2.5.4 **Shear Rate**

The difference in the velocities between two layers of fluid divided by the distance between the two layers is called the shear rate (γ). The equation is as below:

$$\gamma = \frac{\text{velocity difference}}{\text{distance}}$$

With typical units of or, reciprocal seconds.

$$\frac{\text{ft/sec}}{\text{ft}} = \frac{1}{\text{sec}} = \text{sec}^{-1}$$

The relationship between shear stress (τ) and shear rate (γ) defines the flow behavior of a fluid. For some fluids, the relationship is linear. If the shear rate is doubled, then the shear stress will also double. Such fluids are called Newtonian fluids. Examples of Newtonian fluids include water, alcohols, and light oils. Very few drilling fluids fall into the Newtonian category (Lomba,R.F.T, 2002). Fluids which have flow characteristics such that the shear stress does not increase in direct proportion to the shear rate are called non-Newtonian fluids. Most drilling fluids are of this type.

2.5.5 **Viscosity**

For a Newtonian fluid, the relationship between viscosity, shear stress and shear rate is defined as the viscosity (μ) of the fluid where,

$$\mu = \tau / \gamma$$

Where τ = shear stress
γ = shear rate
μ = viscosity.

As previously described, the relationship between shear stress and shear rate is directly proportional for a Newtonian fluid. The viscosity remains constant and is the only parameter needed to characterize the flow properties. The metric unit typically used for viscosity is the *poise*, defined as the force in *dynes* per square centimeter required to produce a difference in velocity of one centimeter per second between two layers one centimeter apart. A *centipoise* is one hundredth (1/100) of poise. For non-Newtonian fluids, the relationship between shear stress and shear rate is defined as the effective viscosity. However, the effective viscosity of a non-Newtonian fluid is not constant. For most drilling fluids, the effective viscosity will be relatively high at low-shear rates, and relatively low at high-shear rates. (Briscoe B. J. 1998)

2.5.6 **Filtration**

Two types of filtration are considered in this section, static and dynamic. Static filtration occurs when the fluid is not in motion in the hole (OFI Testing Equipment. Dynamic HTHP Filter Press, 2012). Dynamic filtration occurs when the drilling fluid is being circulated. Dynamic filtration differs from static filtration in that drilling fluid velocity tends to erode the wall cake even as it is being deposited on permeable formations. As the rate of erosion equals the rate of build up of the wall cake, equilibrium is established. In static filtration, the wall cake will continue to be deposited on the borehole (Sacramento California, 1983).

The theoretical change in filtrate, due to reduction of the viscosity of the filtrate as temperature is increased, can be expressed by the following equation:

$$f_1 - f \times \frac{\sqrt{\mu}}{\sqrt{\mu_1}}$$

where,

f = filtrate at a known temperature

f_1 = filtrate at an elevated temperature

μ = viscosity of water at known temperature

μ_1 = viscosity of water at an elevated temperature

Temperature		**Viscosity of Water (Centipoise)**	**Temperature**		**Viscosity of Water (Centipoise)**
°C	°F		°C	°F	
0	32	1.792	40	104	0.656
10	50	1.308	60	140	0.469
20	68	1.005	80	176	0.356
30	86	0.801	100	212	0.284

(Data from Rogers, W. F.; Composition and Properties of Oil Well Drilling Fluids, Third Edition)

Table 1: viscosity of water and the temperature effect

CHAPTER 3: METHODOLOGY

3.1 RESEARCH METHODOLOGY

The assessment on the effectiveness of feldspar will be done in oil-based drilling fluid. The experiment of mud properties also conducted such as mud density, viscosity, rheology and filtration of mud. Project methodology flow is as below:

1. **Prelim Research**
   - Conduct literature review on feldspar rock properties, types of additive in drilling fluid and current technology developed in HPHT wells

2. **Hardware/ Experimental Setup**
   - Material Identification:
     i. To design oil-based mud: Saraline 185v, API barite & other additives
   - Hardware needed is: HPHT Filter Press, Ofite 1000 HPHT Viscometer, SEM, XRD, Roller Oven, multimixer, hammer and siever

3. **Experimental Work**
   - Experiment 1: Prepare the rock sample from raw condition
   - Experiment 2: Study and determination of feldspar rock properties
   - Experiment 3**:** Study and determination of additive using OBM

4. **Analysis of Result**
   - Gather data and correlate through statistical approach

5. **Discussion of Analysis**
   - Discuss the findings from the results obtained and make a conclusion out of the study, determine if the objective has been met

6. **Report Writing**
   - Compilation of all research findings, literature reviews, experimental works and outcomes into a final report

3.3 KEY MILESTONES AND GANTT CHART

The Final Year Project II key milestones have been proactively plaaned and organized as below

Week 1 : Acquiring the list of available mud additives on laboratory
Week 2 : Acquiring the lab booking
Week 3 : Specimen preparations
Week 4 : Formulating mud
Week 5 : Mud mixing and instant rheology test
Week 7 : Acquiring the result of feldspar properties test
Week 8 : Submission of Progress Report
Week 9 : Acquiring the filter press test result
Week 10 : Acquiring HPHT viscometer result
Week 12 : Pre-EDX, submission of draft Final Report & Technical Paper
Week 13 : EDX & Submission of Final Report
Week 14 : Oral presentation

The project timeline (Gantt chart and project milestones) are stated in Appendix, Table 4, 5 & 6.

3.3 PROJECT ACTIVITIES AND TOOLS

The detail project activities and the tool that will be used is explained further in order to brief the project flow.

3.3.1 **Sample Collection**

A field trip is conducted on 13th November 2011 to Cameron Highland. This field trip is purposely to collect the sample of quartzo-feldsphatic rock and bring it to the laboratory for further work. This field trip is lead by Assoc Prof Askury Abd Kadir.

3.3.2 **Sample Preparation**

3.3.2.1 **Crushing Process**

The raw sample preparation started with crushing process using the geologist hammer to break the quartzo feldsparthic rock into smaller pieces. The hammering impact is continued until the rock is visibly seen turn into powder. The powder is gathered to proceed with the next step. The hammering process is carefully done and must preserve the sample rock from mixing with unwanted substances that may cause error in the experiment session. The crushed sample is kept in dry place.

3.3.2.1 **Sieve**

The next stage of preparing sample is separate it into different size by using sieving machine. The particle is grouped together with in a similar size. The separation of particle size is essential in order to obtain a more accurate result in mud test soon.

The specimen is weighted and confirmed that it is dry. 8 of test sieves is stacked on the mechanical shaker with the larger sieve is on top and vice versa. The sample is placed on top of the sieve and covered with a lid. The test is conducted with turning on the shaker and in the duration of 15 minutes the test is ended. The retained particle is weighted in every sieve stack.

3.4.3 Rock Identification

3.4.3.1 **X-Ray Diffraction**

XRD Knowing the mineral composition of a formation to be drilled is important for determining how the drilling fluid will react with the formation and how to prevent potential drilling problems. Fluid labs use X-ray diffraction to determine the mineralogical composition of shale or cuttings. They expose a crystalline mineral sample to X-ray radiation and then compare the resultant diffraction pattern to known standards to determine which minerals are present in the sample.

3.4.3.2 **Scanning Electron Microscope**

(SEM) is a microscope that uses electrons rather than light to form an image. The SEM has a large depth of field, which allows a large amount of the sample to be in focus at one time. The SEM also produces images of high resolution, which means that closely spaced features can be examined at a high magnification. Preparation of the samples is relatively easy since most SEMs ony require the sample to be conductive. The combination of higher magnification, larger depth of focus, greater resolution, and ease of sample observation makes the SEM one of the most heavily used instruments in research areas today.

3.4.4 Drilling Fluid Formulation and Additive Test in High Temperature and High Pressure

3.4.4.1 **Drilling Fluid Formulation**

The drilling fluid should be formulated as per requirement to withstand in high temperature and high pressure condition. The author must carefully select the correct additive and mud based in order to obtain a good result especially when considering a high temperature condition. These are drilling fluid ingredients and its function which will be mixed together. The mud formulation templates is attached in appendix

Item	Functions
Saraline 185v	Synthetic based fluid
VERSAPRO	Emulsifier
VERSAGEL	Viscosifier
Lime	Provide alkaline medium
VERSATROL	Fluid loss additive
Water	Brine preparation
Calcium Chloride	Brine preparation
Barite	Weighting agent

Table 7: Drilling fluid ingredients and their functions

3.4.4.2 **Mud Mixing Procedure**

The mud formulation must go through mixing process to be considered as a readily to work drilling fluid. The author had set up a mixing timeline in order to ensure that the drilling fluid ingredients are perfectly mixed. The timeline of mixing is as follow;

Mixing time (minute)	**Additive type to be mixed**
0	Saraline 185v
5	VERSAPRO
15	VERSATROL
20	VERSAGEL HT
25	Lime
30	Brine (water & calcium chloride)
45	Barite
50	Feldspar
60	Mixing complete

Table 8: mixing item and mixing time

It is recommended to mix an OBM in 60 minutes in order to ensure it's perfectly mixed because there are a lot of additives which should be included. The brine must be prepared first by mixing water and calcium chloride. The multimixer spinning fan must be ensured clean before usage in order to avoid any unwanted substances from entering into the formulation.

The author decided to categorize the drilling fluid into the hot rolled and non-hot rolled. This matter is in order to improve the result liability. The hot rolling process is taken 16 hours time with the temperature of 165 deg C. The hot rolling process will improve the mixing process with the temperature effect. The drilling fluid formulation bonds perfectly well. This process is also to initiate a real high temperature well condition. 16

hours of hot rolling is the expiring time of drilling fluid which is circulated in the well while drilling.

3.4.5 HPHT Test

The drilling-fluids specialist in the field conducts a number of tests to determine the properties of the drilling-fluid system and evaluate treatment needs. Although drilling fluid companies might use some tests that are designed for evaluating a proprietary product, the vast majority of field tests are standardized according to American Petroleum Institute Recommended Practices (API RP) 13B-17 and 13B-2,8 for WBFs and OBFs, respectively. From appendix, Table 2 shows typical API-recommended field tests for WBFs. Table 3 shows typical API-recommended field tests for OBFs. Several tests are identical to those performed on WBFs.

3.4.5.1 **Fluid Loss Test**

If fluid loss is excessive, formation instability, formation damage, or a fractured formation and loss of drilling fluid can occur. In the HPHT field, fluid loss tests are performed routinely. Fluid loss also can be measured under dynamic conditions using the viscometer, which incorporates a rotating bob to provide fluid shear in the center of a ceramic-filter core. The fluid is heated and pressurized. Fluid loss is measured radially through the entire core, giving a sophisticated simulation of the drilling fluid circulating in the wellbore. The author using HPHT filter press to obtain the loss circulation result. The procedures of conducting experiment are as below.

3.4.5.1.1 HPHT Filter Press Procedures

i. The heating well power cord is connected to an appropriate power source. A dial-type metal thermometer is placed into the well in the heating jacket and is preheated 10°F (6°C) above the desired test temperature. A pilot light will come on when the heating jacket is at the desired temperature as selected by the thermostat control knob.

ii. All of the o-rings are assured on the valve stems are in good working condition and are not damaged during the assembly procedures. A thin film of silicone grease is placed on all o-rings. A valve stem is screwed into the test cell on the side opposite the cell cap. The valve stem is tightening completely. The sample is stirred for 10 minutes with a high-speed mixer. Carefully the sample is poured into the cell. The volume of drilling fluid is must not fill the cell closer than 0.5" (13 mm) from the o-ring groove to allow for heat expansion of the fluid.

iii. An o-ring in the cell is placed and another in the cell cap recess. A circle of filter paper is placed on top of the cell o-ring and slowly the cell cap is pushed into the cell. The arrow on the cell cap is ensured lines up with the arrow on the cell body.

iv. The cap locking screws and both valve stems is tightened. Place the cell in the heating jacket with the outlet or filter side of the cell pointed down. The cell in the heating jacket is rotated so that the pin in the bottom of the heating well seats into the hole in the bottom of the cell. This will anchor the cell inside the well and prevent the cell from rotating as the valve stems are opened and closed. The thermometer is transferred from the heating jacket to the thermometer well within the cell

v. The pressuring assembly is connected to the top valve stem and is locked it in place with the retaining pin. The back pressure receiver is placed on the bottom valve assembly and also is locked it in place with the retaining pin.

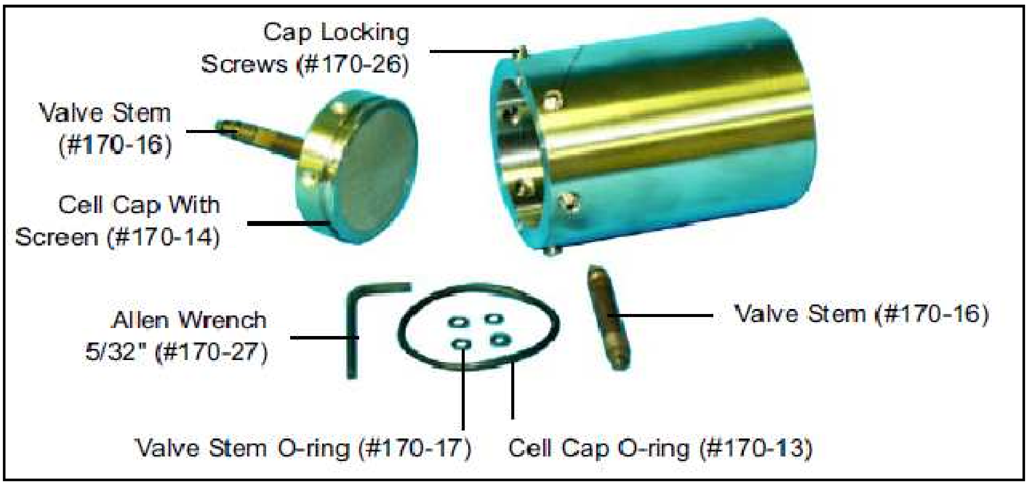


Figure 6: Filter press cell

vi. The valves are kept closed, the top and bottom regulators is adjusted to the recommended back pressure for your test. The top valve stem is loosen, and the sample is pressurized. This pressure is maintained on the fluid until the desired temperature is stabilized, as indicated by the thermometer. The heating time of the sample should never exceed one hour. The upper and lower limits of the test pressure differential are determined by the test temperature. As this temperature exceeds 212°F (100°C), the back pressure must be increased in order to prevent vaporization of the filtrate. The 500 PSI differential pressure must be maintained, so the top pressure will have to be increased accordingly.

vii. When the fluid sample reaches the desired test temperature, the pressure on the top pressure unit is increased to 500 PSI (3,448 kPa) more than the back pressure. The bottom valve stem is loosen and turned to initiate filtration.

viii. The filtrate is collected for 30 minutes maintaining the selected test temperature within 5°F (3°C). If the back pressure rises above 100 PSI (690 kPa) during the test, cautiously the pressure is reduced by opening the valve on the receiver and drawing off some of the filtrate into the graduated cylinder.

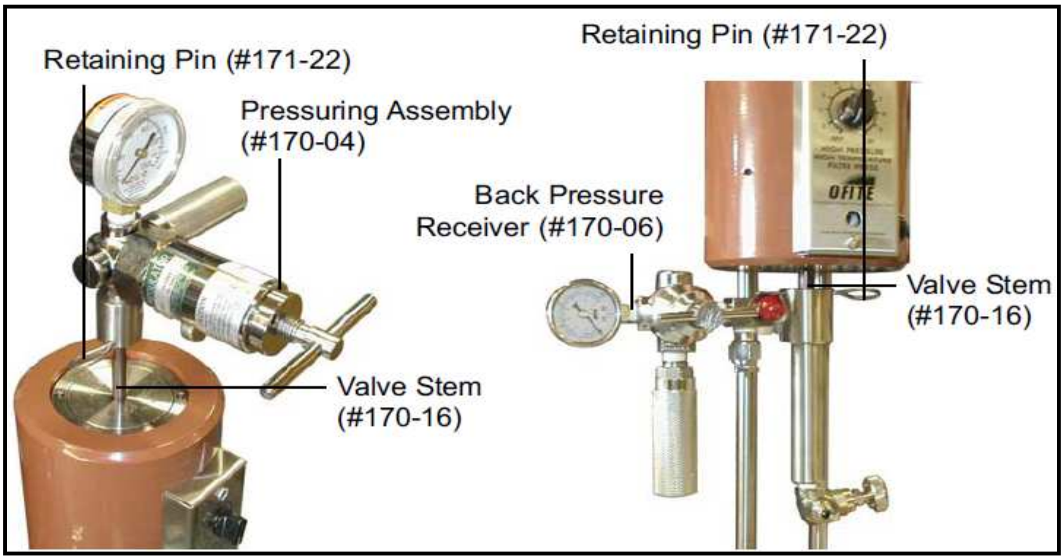


Figure 7: top and bottom heating jacket

ix. At the end of the test, the top and bottom valve stems is tighten to seal off the cell. The regulator T-screws is turned counter-clockwise to close off the flow of pressurized gas. The outlet valve on the back pressure receiver is opened to collect all of the filtrate in the graduated cylinder. The pressure from the top is released and bottom pressuring units by opening the needle and/or bleeder valves.
x. The top and bottom valve stem retaining pins and the top pressure and the back pressure assemblies are removed. Any residual filtrate collected in the receiver is drained into the graduated cylinder. The cell from the heating jacket is removed after once again checking that the cell valve stems are tightly closed. It is allowed to cool to room temperature or quick cool the cell by immersion in cool water.
xi. The total filtrate volume collected is corrected to a standard filtration test area of 7.1 in2 (45.8 cm2) by doubling the filtrate volume collected in 30 minutes. This total filtrate volume (doubled) temperature, pressure, and time are recorded.
xii. Using extreme care to save the filter paper and deposited cake, the cooled cell is placed upright with the outlet (cap side) or filter side down. The inlet valve stem is loosening to bleed off pressure from the cell body. Pressure cannot be relieved from the cell by opening the outlet valve stem as the filter cake will seal off the cell.
xiii. The six cap locking screw is loosened and the cap is separated from the cell with a slight rocking motion.
xiv. The filter cake is washed on the paper with a gentle stream of water. The thickness of the filter cake is reported to the nearest 1/32 in (0.8 mm).
xv. Apparatus is cleaned thoroughly after each use.

3.4.5.2 **Fluid Rheology Test**

Fluid rheology is an important parameter of drilling-fluid performance. For critical offshore applications with extreme temperature and pressure requirements, the viscosity profile of the fluid often is measured with a controlled temperature and pressure viscometer. Fluids can be tested at temperatures of < 35°F to 500°F, with pressures of up to 20,000 psia. Cold-fluid rheology is important because of the low temperatures that the fluid is exposed to in deepwater risers. High temperatures can be encountered in deep wells or in geothermally heated wells. The fluid can be under tremendous pressure downhole, and its viscosity profile can change accordingly. The author decided to use HPHT Viscometer to determine drilling fluid rheology. The procedures are as below.

3.4.5.2.1 HPHT Viscometer Procedure

Computer Setup

i. First, the computer's AC power setting is checked to match the available power in the region.
ii. The monitor and computer are turned on. After the computer has booted up completely, the ORCADA™ icon is checked on the desktop

Viscometer Setup

i. On the back panel, the three ¼" (6.35mm) NPT fittings are located. A water source (15 - 30 PSI / 104 - 208 kPa), nitrogen source, and drain hose is connected to the appropriate fittings. The Nitrogen is used to pressurize the sample and prevent boiling at temperatures above 212°F (100°C). The water is used to raise and lower the heater.
ii. The heater cable is screwed from the heat bath into the bottom of the cabinet.
iii. The thermocouple is plugged from the heat bath into the bottom of the cabinet.
iv. The viscometer is connected to the computer using either a 9-pin RS232 cable, a Local Area Network connection with an Ethernet cable, or Bluetooth.
v. The “Power” switch is ensured in the off position. The power cord is plugged into an AC power source.

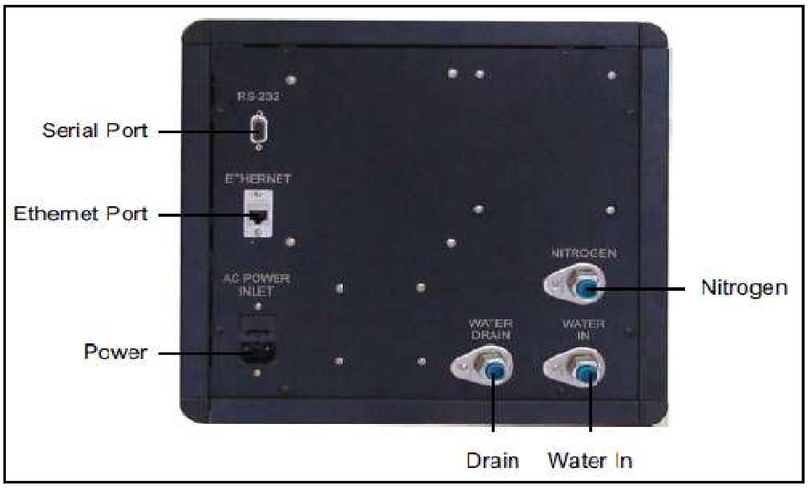


Figure 7: Ofite 1100 setup port

System Test Setup

i. The unit is turned on. The power switch is located on the front panel.

ii. If the heater is raised, it is lowered using the “Heater Lift/Lower” switch. The sample cup is already attached to the viscometer in order to protect the bob shaft during shipping. Always handle the bob shaft carefully; bending it will result in poor viscosity readings.

iii. The sample cup is loosened, the sample cup nut is unscrewed and the sample cup is turned straight down.

iv. A thin coating of high-temperature thread lubricant is placed to the bob shaft threads.

v. The bob is placed by sliding it onto the bob shaft with the tapered end down and screwed it securely into place. An R1B1 bob/rotor combination is standard for the Model 1100 Viscometer, however other combinations are available. The computer is turned on and the ORCADA™ software is opened.

vi. From the menu bar at the top of the screen, “Utilities” and then “Calibrate Shear Stress” is selected. The “Temperature” field is checked to verify that it shows room temperature. Then, that the value in the “Shear Stress Raw” fluctuates is confirmed when gently turn the bob with the hand.

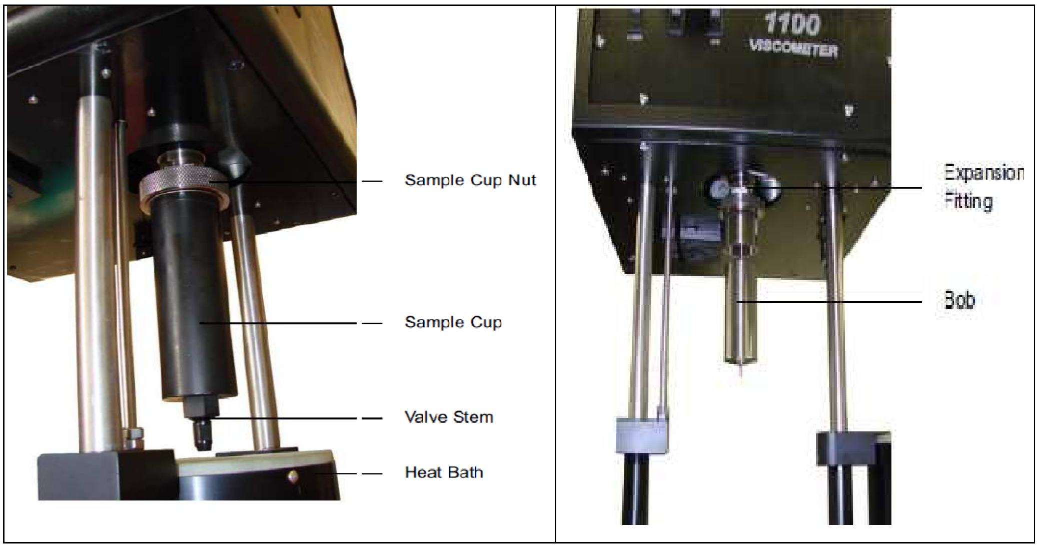


Figure 8: Ofite 1100 testing parts

Test Preparation Setup

i. The bob is installed

ii. The sample cup is filled with the proper amount of fluid based on the type of bob to be used.

iii. The sample cup is hold by hand and positions the bob in the center. The sample cup is placed up past the o-ring. The sample cup is placed in place and the sample cup nut is screwed.

iv. The heat bath is positioned under the sample cup. Then is raised it using the "Heater Lift / Lower" switch.

v. Gradually rotate the regulator knob clockwise to pressurize the sample. Gradually rotate the regulator knob to counter-clockwise at a rate no greater than 60 PSI per minute. Pressure is only necessary for tests temperatures above 200°F (95°C). The heaters will be deactivated if the sample is not pressurized enough to prevent boiling. The ORCADA™ software will indicate this with a yellow alarm light. The alarm light will turn green when the appropriate pressure is applied to the sample.

vi. Once the pressure is set and the heater is in place, the Model 1100 is ready to run a test.

Auto Mode Test

i. The viscometer for a test is prepared.
ii. A test to run is chosen from the list in the upper left-hand corner of the Main Screen.
iii. A name in the “Experiment Name” field is entered.
iv. The shear stress units are set using the drop-down menu next to the “Shear Stress” field.
v. The “Start Test” button is clicked
vi. A comment in the resulting dialog box is written.
vii. The unit is dissembled and cleaned

The non heating viscometer also is used in this project in order to gain reference points of heating effect on drilling fluid. The author is using both hot rolling and non hot rolling sample. The results are expected to be differ to each other seems the drilling fluid phase

CHAPTER 4: RESULT AND DISCUSSION

4.1 Sieving Result and Discussion

The separation into size is determined using sieving process. The sieving result is shows in the table below:

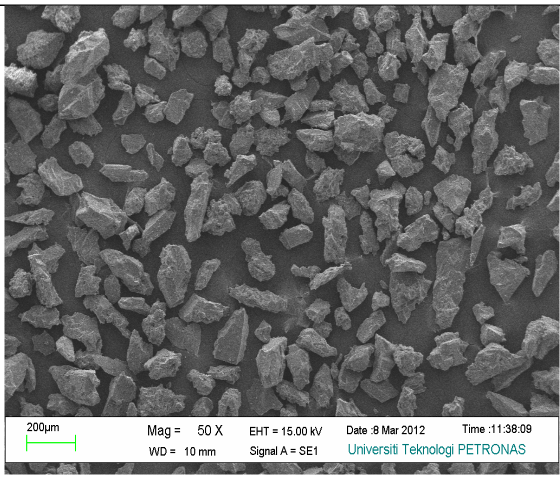
Aperture size	Mass (gram)	Distribution percentage (%)
2 mm	198.21	14.34
1.18 mm	157.00	11.36
600 µm	123.89	8.96
425 µm	142.78	10.33
300 µm	132.53	9.59
212 µm	182.60	13.21
150 µm	175.12	12.66
63 µm	170.02	12.30
Passing 63 µm	200.05	14.47
Total	1382.20	

Table 9: after sieving products

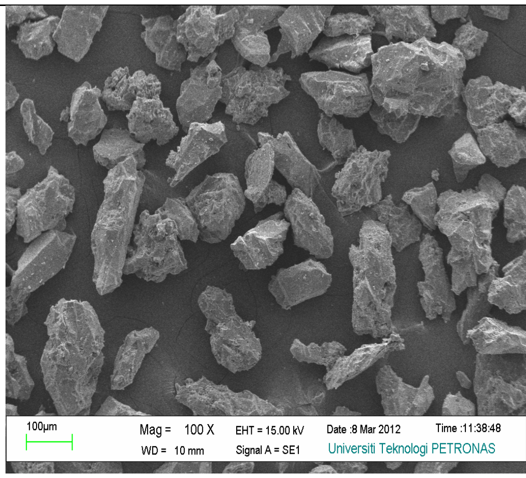
The mass distribution upon the size of aperture is about evenly distributed. The rock is kept in dry places before conducting this experiment in order to avoid any water particles that may interrupt the result. The chosen size of feldspar to be mixed in the drilling fluid is 63 µm. This is the ideal size of feldspar in the “fine type” category seems the suggested size of intermediate fine type is smaller than 150 µm. meanwhile the smaller 63 µm will be used as small fine in the filtration process.

4.2 Scanning Electron Microscope Result and Discussion

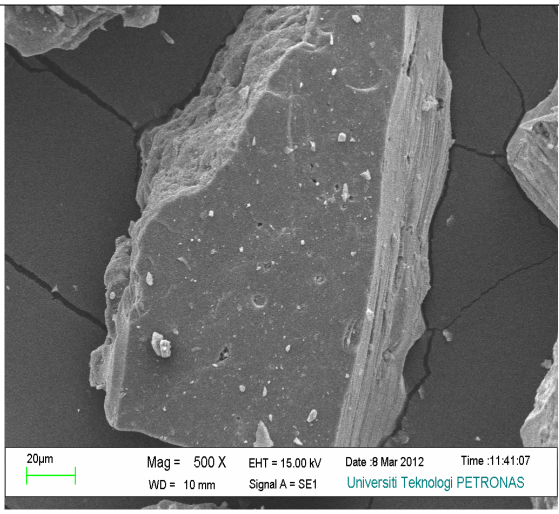
The physical property of feldspar is determined by SEM. The SEM result is shows in the table below:



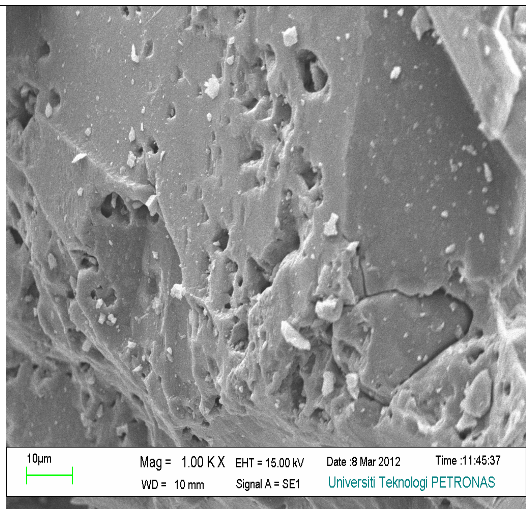
Magnification of 50 times



Magnification of 100 times



Magnification of 500 times



Magnification of 1000 times

Figure 9: SEM scanning results

The average of specimen size is 63 µm. In the magnification of 50 times and 100 times, it is discovered that feldspar shape is in oval look. The crushing process causes feldspar to break into the new shape form. In the magnification of 500 times feldspar is discovered has a fine and quite smooth layering. The crushing process causes feldspar fractured primarily between its layers because the lower fractured point is at its layer. At the magnification of 1000 times it is discovered that there are ample of small feldspar particles it is due to the feldspar natural characters which is brittle with in scale 7 of Mohr Hardness. These physical characteristics as a confirmation of two main compositions in this rock which are feldspar and quartz through their physical behavior that could only be seen using microscope. This feldspar properties is shows its ability to become a suitable additive as lost circulation material in drilling fluid.

4.3 XRD Result and Discussion

The feldspar phase is analyses using the X-ray Diffraction machine. The laboratory work of XRD is very essential to determine and confirm the element that composes the quartzo feldsphatic rock. The XRD machine obtained the graph of overall element that contains in the rock. The graph shows the peak range of the elements. The XRD software enabled the author to recognize and determined the combined element by narrowing the searching scope. The element is determined by comparing the peak range of element and the rock peak range. From the graph interpretation the author defined there are 3 crystallite composition in the quartzo feldspathic rock which are quartz, orthoclase and muscovite. The XRD peak range graph is as below;

Legend	
	Quartz
	Orthoclase
	Muscovite

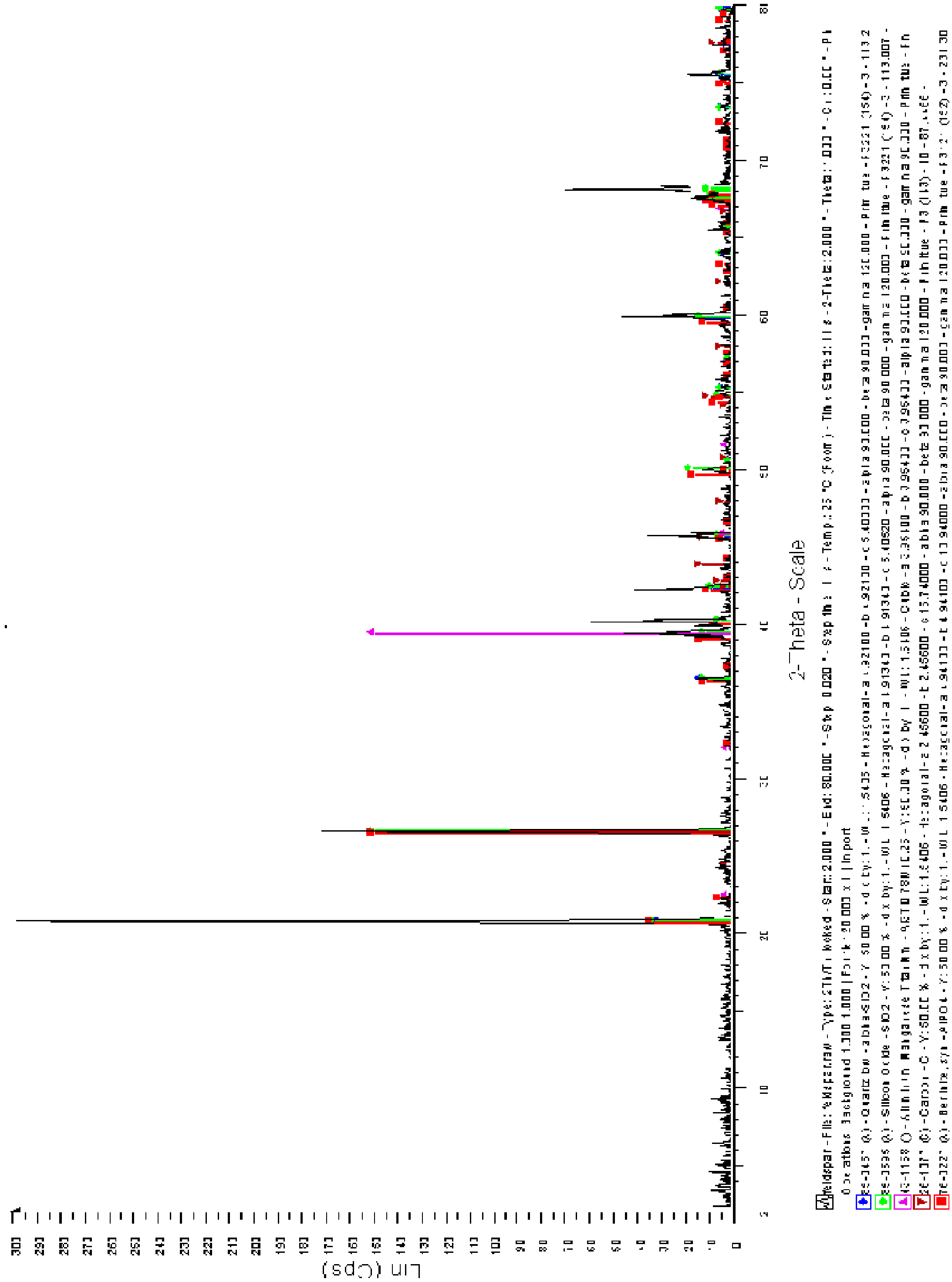


Figure 11: XRD result

4.4 Mud Formulation Result and Discussion

The mud formulation is the exactly ideal amount of mud base and additive reference on order to proceed with drilling fluid laboratory work. The correct amount of these ingredients is essential in order to obtain a good laboratory result. The author decided to formulate the mud with 10 ppg mud weight in one lab barrels. The oil water ratio is 80 to 20 considering it is an oil based mud. The manipulating factor in this formulation is the amount of feldspar which is 0, 2.5, 5, 7.5, 10, 12.5 and 15 gram in one lab barrel. The other main additives in kept constant in order to capture the trend of feldspar addition graph in determining its additives role.

The mud formulation is as below;

Lab Bbls	1		1		1		1
Mud Weight	10	10	10	10	10	10	10
OWR	80/20	80/20	80/20	80/20	80/20	80/20	80/20
Formulations	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Saraline 185V, lb/bbl	183.60	183.29	182.98	182.66	182.34	182.02	181.70
VERSAPRO lb/bbl	8	8	8	8	8	8	8
VERSAGEL HT, lb/bbl	7	7	7	7	7	7	7
LIME®, lb/bbl	4	4	4	4	4	4	4
VERSATROL , lb/bbl	8	8	8	8	8	8	8
Water, lb/bbl	59	58.90	58.80	58.71	58.61	58.51	58.41
$CaCl_2$, lb/bbl	20.9	20.88	20.85	20.82	20.78	20.75	20.71
Barite , lb/bbl	129.46	127.42	125.37	123.32	121.27	119.23	117.18
Feldspar, lb/bbl	0	2.50	5.00	7.50	10.00	12.50	15.00

Table 10: Complete mud formulation list

4.5 HPHT Filter Press Result and Discussion

The laboratory test is carefully conducted because of a high temperature and high pressure test that may cause harm to the author. The constant temperature of the experiment is 170 deg C which equal to 350 deg F with the back pressure of 500 psi. The results of HPHT filter press are as below;

Additive Volume (g)	Filter Press Volume with hot rolling (mL)		Real filter press volume without hot rolling (mL)	
	<63 μm	*>63 μm*	*<63 μm*	*>63 μm*
0.0	3.8	4.4	9.8	10
2.5	3.2	4.0	9.5	9.5
5.0	3.0	3.5	8.4	8.8
7.5	2.5	2.8	7.2	8.0
10.0	2.9	3.0	8.0	8.2
12.5	3	3.1	8.2	8.3
15.0	3.1	3.2	8.3	8.4

Table 11: HPHT filter press result

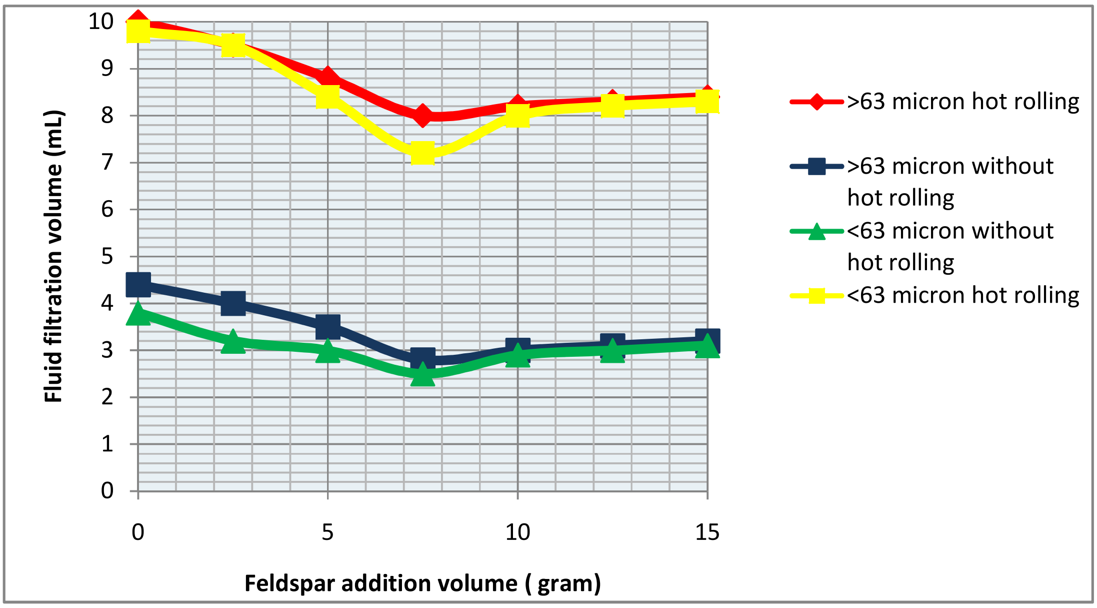


Figure 12: feldspar addition volume versus fluid filtration volume.

From the feldspar addition volume versus fluid filtration volume it is confirm that the addition of feldspar will improve the filtration effect in HPHT drilling fluid. The graph trend is declining with the inclination of feldspar addition volume. Until the feldspar amount at 7.5gram, the effect of feldspar in the drilling fluid is positive. Meanwhile, after 7.5 gram of feldspar the filtration graph is slightly incline. The inclination and declination of filtration graph show their suitable volume of feldspar as a lost circulation material additive. In this experiment, the ideal amount of feldspar in this mud formulation is 7.5 gram. The inclination of filter press liquid shows it is incompatible at a certain point (after 7.5 gram). However it could differ if the author is using a different formulation. Both hot rolling and non hot rolling mud shows the similar trend with different feldspar addition. The filtration volume of hot rolling and non hot rolling are slightly different with the hot rolling gained more filtration fluid. The hot rolling causes the drilling fluid performance to be degraded. The 16 hours of hot rolling in 170 deg C will simulate the real condition of drilling process.

4.6 HPHT Viscometer Result and Discussion

The HPHT viscometer will measure the fluid shear rate, shear stress and viscosity with different rpm. The results are as below;

feldspar volume (g)	Viscosity @ 300 rpm (cP)	Viscosity @ 600 rpm (cP)	shear rate @ 300 rpm (Dyne/cm^2)	Shear rate @ 600 rpm (Dyne/cm^2)	Shear stress @ 300 rpm (Pa)	Shear stress @ 600 rpm (Pa)
0	20	16	255.1	510.2	8.8	9.3
2.5	25.8	16.6	255.1	510.2	9.2	9.4
5	31.5	17.1	255.1	510.2	10	9.8
7.5	38.9	19.1	255.1	510.2	12.0	11.3
10	46.1	21	255.1	510.2	12.8	12
12.5	53.1	24.5	255.1	510.2	15.8	14.3
15	60	28	255.1	510.2	16	17

Table 12: mud viscosity shear stress and shear rate at 170 ºC (410 ºF) and 300 psi

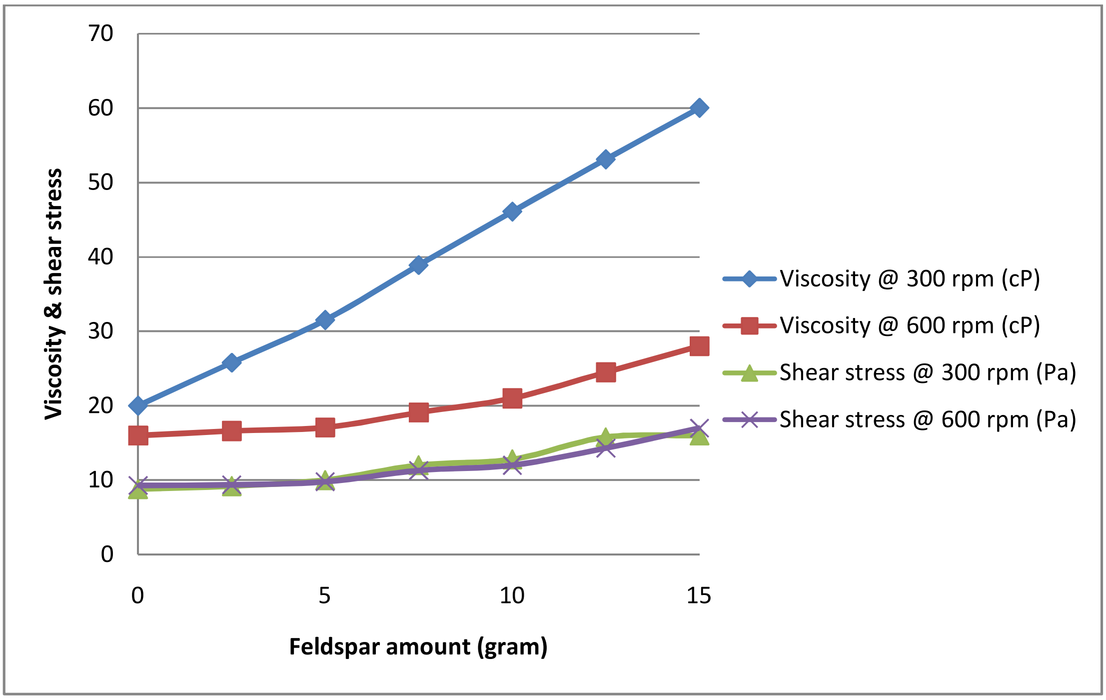


Figure 13: mud viscosity and shear stress versus feldspar amount at 170 ºC (410 ºF) and 300 psi

feldspar volume (g)	Viscosity @ 300 rpm (cP	Viscosity @ 600 rpm (cP)	shear rate @ 300 rpm (Dyne/cm^2)	Shear rate @ 600 rpm (Dyne/cm^2)	Shear stress @ 300 rpm (Pa)	Shear stress @ 600 rpm (Pa)
0	23	17	255.1	510.2	9.0	9.7
2.5	29	19	255.1	510.2	9.5	9.8
5.0	36.6	19.1	255.1	510.2	10.3	10.3
7.5	43.9	21	255.1	510.2	11.0	11.3
10.0	51.1	23.1	255.1	510.2	14	12.3
12.5	58.5	26.5	255.1	510.2	15.8	14.3
15.0	65	30	255.1	510.2	18	16.2

Table 13: mud viscosity, shear rate and shear rate at 210 ºC (410 ºF) and 500 psi

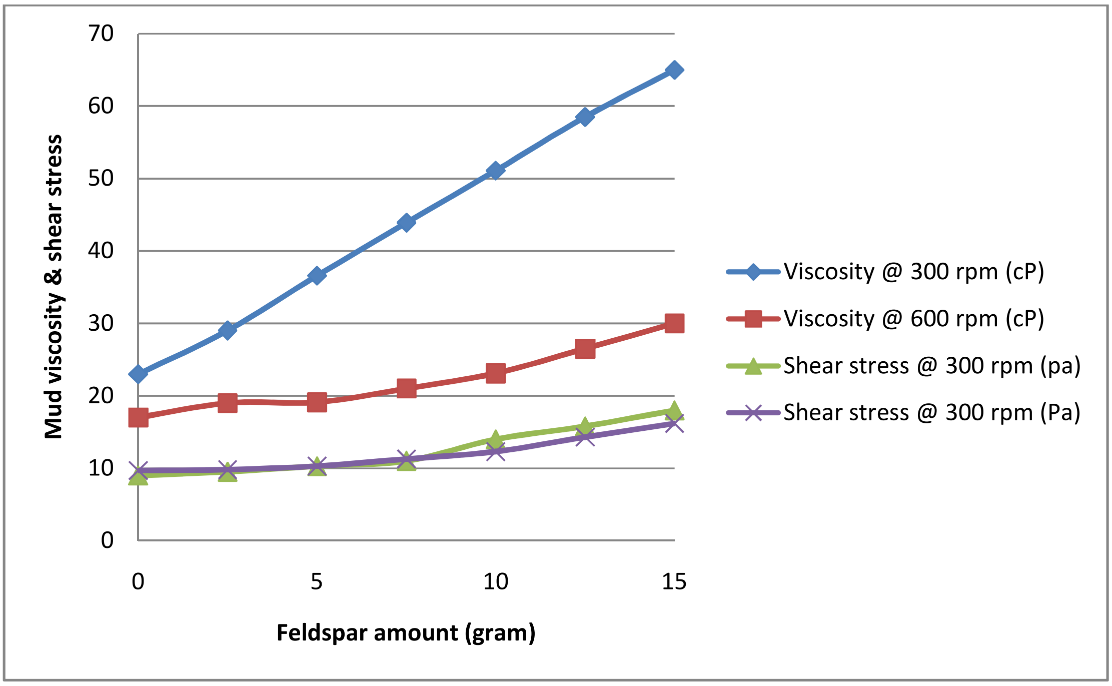


Figure 14: mud viscosity and shear stress versus feldspar amount at 210 ºC (410 ºF) and 500 psi

feldspar volume (g)	Viscosity @ 300 rpm (cP	Viscosity @ 600 rpm (cP	shear rate @ 300 rpm (Dyne/cm^2)	Shear rate @ 600 rpm (Dyne/cm^2)	Shear stress @ 300 rpm (Pa)	Shear stress @ 600 rpm (Pa)
0	45.1	26	255.1	510.2	10.0	11
2.5	42.2	24.1	255.1	510.2	9.4	10.8
5.0	41.6	22.1	255.1	510.2	9.0	10.5
7.5	48.9	24	255.1	510.2	13.1	12.3
10.0	56.1	26.1	255.1	510.2	15.5	13.3
12.5	63.6	29.5	255.1	510.2	16.8	15.3
15.0	70.6	33	255.1	510.2	19	17.2

Table 14: mud viscosity, shear rate and shear stress at 225 ºC (437 ºF) and 800 psi

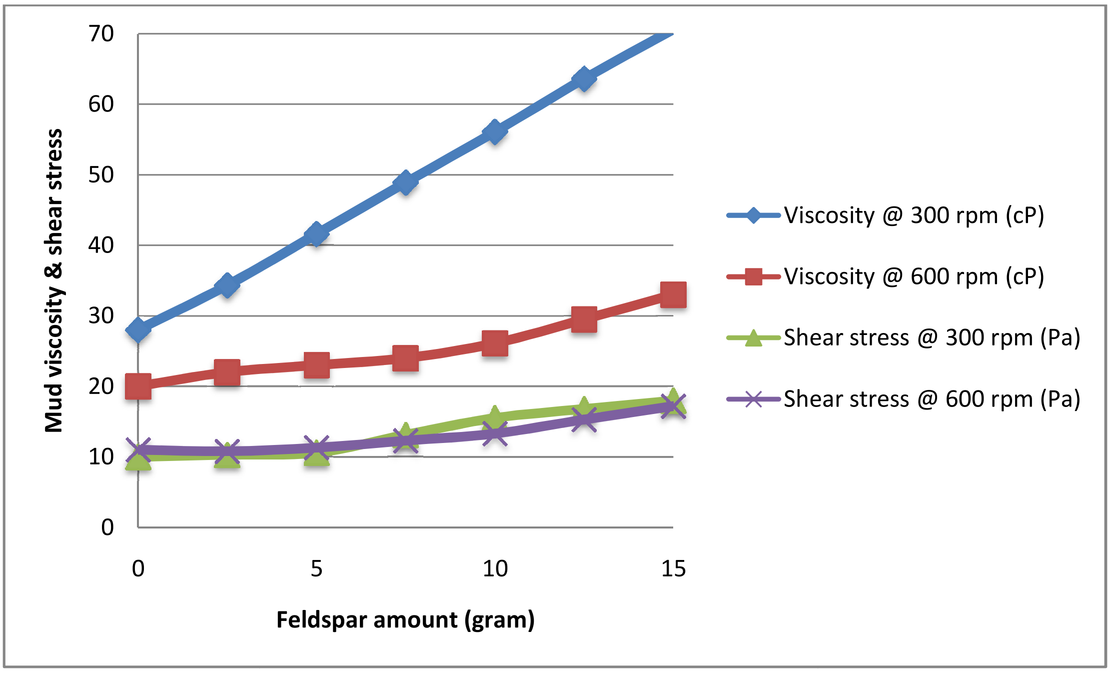


Figure 15: mud viscosity and shear stress versus feldspar amount at 225 ºC (437 ºF) and 800 psi

From the HPHT viscometer result, the viscosity of drilling fluid is increases as the shear rate is increases. This is a not good sign when a fluid behaves in this manner, which drilling fluid is said to be shear thickening. Shear thickening is a undesirable characteristic for drilling fluids. However, this characteristic of mud shows a slight concern about the feldspar addition amount as they may causes the stuck pipe or affect the hole cleaning. The effective viscosity of the fluid will be relatively higher at the lower shear rates in the annulus where the higher effective viscosity of the fluid aids in the hole cleaning. The effective viscosity of the fluid will be relatively lower at the higher shear rates in areas such as the drill pipe and bit nozzles.

As shear rate is increases the shear stress is increases. This philosophy is already explained in the literature review of the project. As the shear rate defined as speed of motion of the fluid with respect to nearby fluid elements and shear stress is defined as resistance to flow. Both shear rate and shear stress shall parallel in inclination or declination.

The *figure 13, 14 and 15* show the inclination of the viscosity and shear stress upon the inclination of feldspar addition volume. The drilling fluid character behavior shows that at any temperature scale (170, 210 and 225 deg C) is the higher shear rate causes the lower viscosity. It is shows that the heat inclusion did not affect the drilling fluid behavior. However the feldspar addition volume is shows to interrupt the formulation. After 7.5 gram addition of feldspar, the exceptional results show the shear stress increases as shear rate is increases. This exceptional behavior is noticeable in every constant temperature. This could interpret as the good characteristic of drilling is acceptable until the feldspar addition of 7.5 gram.

4.7 Drilling Fluid Rheology Result and Discussion

In order to improve the result liability, the author decided to obtain the non-heat presence viscometer. The yield point, gel strength and plastic viscosity of the drilling fluid are tested using a normal viscometer. There are both result of after hot rolling and before hot rolling in the temperature of 170 deg C. The result is obtained as below:

Additives volume (gram) Viscometer rheology test	0	2.5	5.0	7.5	10.0	12.5	15.0
600 rpm	49	54	56	59	62	67	71
300 rpm	29	33	34	33	38	42	44
Gel Strength (10 sec)	5	5	6	6	6	7	8.5
Gel Stength (10 min)	11	12	12	13	13	13	14
Plastic Viscosity	20`	21	22	23	24	25	27
Yield Point	9	10	12	13	14	15	17

Table 15: mud rheology result before hot rolling

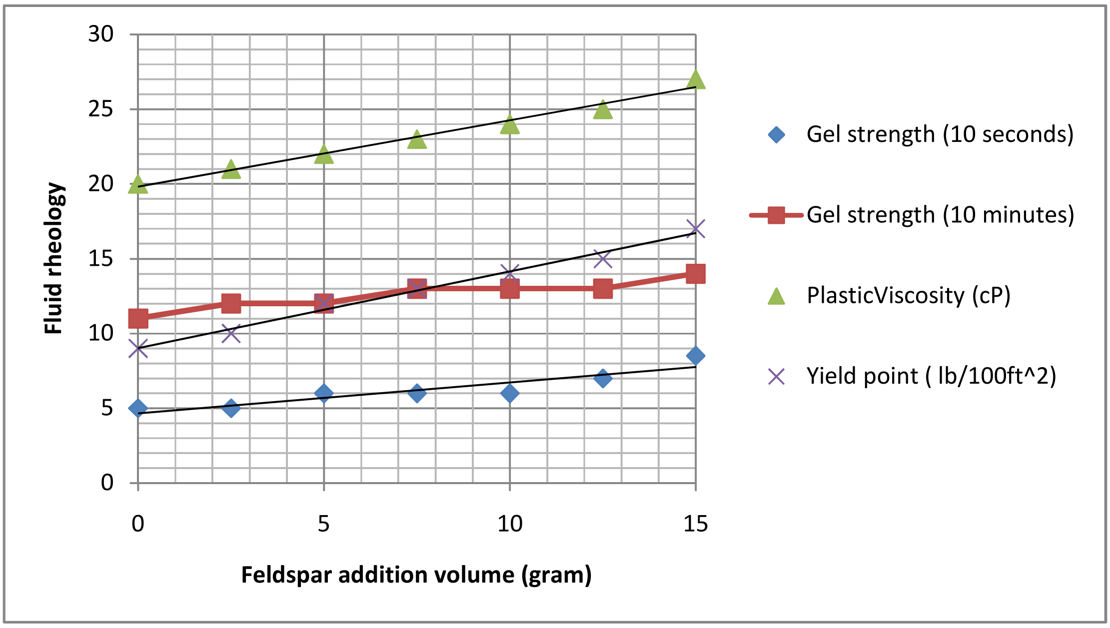


Figure 16: mud rheology result versus feldspar addition volume before hot rolling

Additives volume (gram) / Viscometer rheology test	0	2.5	5.0	7.5	10.0	12.5	15
600 rpm	75	80	84	89	93	96	98
300 rpm	41	47	50	54	55	57	58
Gel Strength (10 sec)	5	5	6	6	6	6	7
Gel Strength (10min)	10	10	12	12	12	12	14
Plastic Viscosity	32	33	34	35	38	39	40
Yield Point	9	14	16	16	17	17.5	18

Table 16: mud rheology result after hot rolling

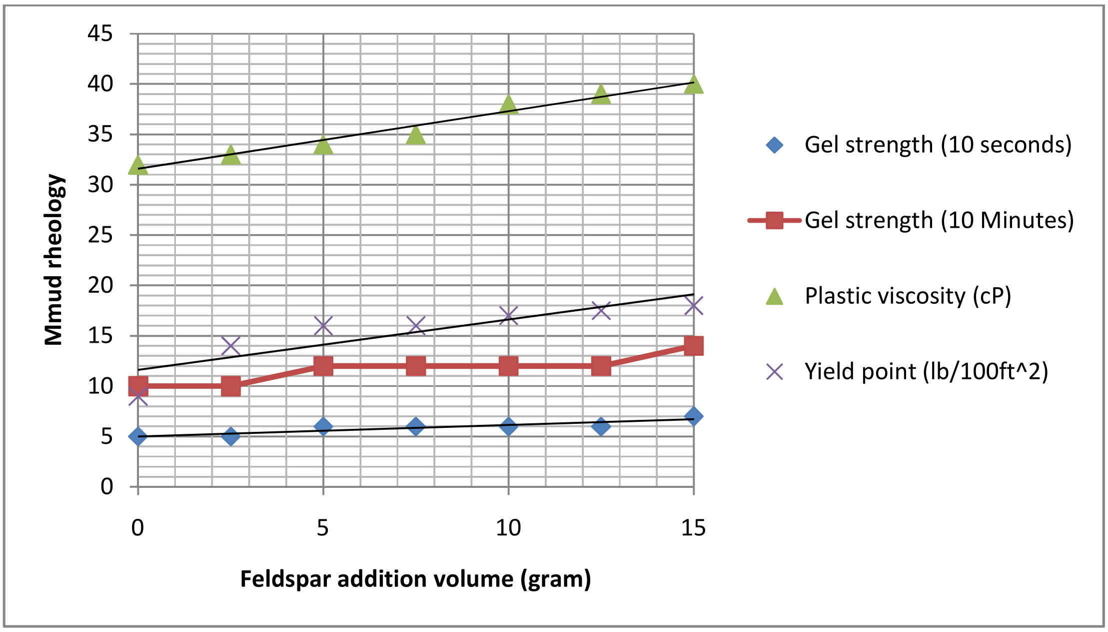


Figure 17: mud rheology versus feldspar addition volume after hot rolling

From the result of mud rheology test, it is shows the different reading of viscometer upon after and before hot rolling process which are taken 16 hours process in 170 deg C. The higher mud rheology volume is noticed of the after hot rolling mud. This is because the additives and their base are mixed better with the applications of heat and rolling process. The degradation of mud after hot rolling is affecting the result of viscometer. The reading of viscometer is differed between both after and before hot rolling. However it's not affect the graph trend which both looks very similar with each other.

The increasing amount of plastic viscosity with the increasing volume of feldspar addition is interpreted from *figure 16 &17*. This behavior is significant because the addition of loss circulation material (feldspar) is changing the ration of particle size over the same volume of solid. However in drilling operations, the plastic viscosity should be consider in the lowest volume in order to lower the pumping rate in circulation process.

The *figure 16 &17* show that the yield point value is increases with the increases of the feldspar concentration in the drilling fluid formulation. The increase of feldspar causes the increment of solid in the drilling fluid. From the *figure 16 & 17***,** gel strength (10 minutes and 10 seconds) of the mud in increases as the amount of feldspar is increases while testing in mud static condition. The volume of gel strength in 10 minutes is higher than in 10 second is because of the taking time for mud particles to stabilize and coordinate themselves in a better arrangement. The figure also indicates that there are no significant changes of gel strength versus the feldspar addition amount. The feldspar has a low ability on increasing the gel strength of the drilling fluid.

CHAPTER 5: CONCLUSION

5.1 CONCLUSION

This project is significant to develop new potential additives which obtained from a local source (Cameron Highlands, Malaysia). The fine rock properties which can withstand a wide range of temperature exposure are considered to be an important characteristic to be developed as a drilling fluid additive. In the future drilling activities will become more complicated and deeper. There are more challenges will be faced especially in handling high temperature and high pressure well.

The cost reduction and reservoir management is an important parameter to be considered in drilling activities. This project is a milestone to develop a new natural and free source of drilling fluid additives. The environment issue to deal with, the non-pollute additives should be considered as a new method of drilling optimization.

The discovery of the new potential additives will be proven through the laboratory work. The suitability of quartzo-feldsphatic rock as type of additives in optimizing the drilling fluid properties in high temperature condition is determined as a good loss circulation material additive. The excellent result in filtration process is considered the core finding in this project. Furthermore, the feldspar is fairly acceptable in increasing the viscosity, shear stress, gel strength and yield point.

5.3 RECOMMENDATION AND FUTURE WOK

The project should consider using the different type of drilling fluid base. The other type oil base should be considered such as Sarapar 147 and Saraline 200. These two types of drilling fluid based are mainly used in the industry. The wider range of different drilling fluid based will obtain a wider range of result and the feldspar usage could be commercialized ideally.

The deeper well will cause the higher temperature of the reservoir which commonly comes with higher pressure. In the drilling operations, the depth of well could be controlled using the density of drilling fluid in order to avoid kick or worst cases is a blow out. The wider range of drilling fluid density should be considered in order to obtain more ideal mud formulations. This project is using constant mud density, which is 10ppg only. The further work for different mud density is suggested.

The project temperature limit is only at 225 deg C which considered as Tier II which is called ultra HPHT. However, the Tier III well is still unreachable in this project due to limitation of the equipments. The limitation of the equipment is also causes the result obtained could only reach at 800psi. The further study in this project should consider higher temperature and pressure.

5.3 PROJECT RELEVANCY UPON OBJECTIVES

The main three objectives are met after conducting the laboratory work. The results show a positive sign of feldspar to become a drilling fluid additive in various ways. The addition of feldspar increases the yield point, plastic viscosity and gel strength which is determined as a fairly good viscosifier of the drilling fluid. It is also decrease the volume of drilling fluid filtered through a HPTH filter press with the act as a good loss circulation material. This is recognized that feldspar is a LCM additive in high temperature drilling fluid.