

## CHAPTER 1

### INTRODUCTION

#### 1.1 BACKGROUND

This project aims at studying and comparing Malaysian bentonite which is localized in eastern Sabah with those specific grades of bentonite which are used as drilling fluid additives in deep oil well drilling. Bentonite is highly colloidal and plastic with the unique characteristics of swelling to several times its original volume when placed in water. Bentonite is formed from volcanic ash (igneous origin) deposited in an ancient sea, and modified by geological process into Sodium Bentonite. Bentonites were estimated to have accumulated between 74.5 and 70 million years ago.

Bentonite has been called the clay of a thousand uses. Sodium Bentonite is noted for its affinity for water which gives it tremendous swelling properties. Sodium Bentonite contains exchangeable sodium cations. When dispersed in water it breaks down into small plate-like particles, negatively charged on the surface and positively charged on the edges. This unique ion exchange is responsible for the binding action which takes place. Bentonite exists as plate-like particles and has large surface area. It forms enormous amount of gels when mixed with water even when the amount of bentonite in such gels is relatively small. These characteristics give bentonite an enormous range of potential uses. For instance, this special clay can be used as an animal feed binder, a natural soil sealant or drilling mud, a foundry sand binder, or as a stucco and mortar plasticizer. In this project the main attention is given to its importance in the petroleum oil industry. It is used as one of the drilling fluid constituents in order to drill the targeted zone safely and economically. For bentonite to be of use in the oil industry, it should not have a high level of iron contaminant and inconsistent composition.

## **1.2 PROBLEM STATEMENT**

Malaysia imports bentonite for use in the petroleum oil industry as an additional constituent in the drilling fluid. To fulfill this interest, Malaysia should invest in different countries which export their raw material (bentonite) for drilling applications. To have bentonite is very important in a country with oil and gas fields in production state. Malaysia started producing its own bentonite since its discovery in Sabah. In order to apply it in the oil or gas industry, Malaysia should produce bentonite which fulfills API specifications to make it suitable for use as a drilling mud. However researches indicated that the Sabah bentonite does not meet the standard quality of Wyoming bentonite and therefore suitable beneficiation methods should be selected to upgrade the bentonite to meet the API specifications for use in the petroleum oil industry. Therefore, the most important issue is to produce those bentonite accumulations in Sabah, as per the specifications of the API standards.

## **1.3 OBJECTIVES OF INVESTIGATION**

The objectives of this paper are:

- To study the basic characteristics of Sabah bentonite in order to compare it with that of the standard Wyoming bentonite from USA.
- To check if Sabah bentonite is suitable for use as a drilling mud as per the API specifications.
- To identify the problems associated with the Sabah bentonite when used in drilling. If the quality of the bentonite is not fulfilled, then the drilling engineer will encounter problems. Therefore suitable beneficiation methods should be selected to improve the properties and qualities of the local bentonite as per the standard use of bentonite in the petroleum oil industry.

## **1.4 METHODOLOGY**

The first part of this report includes the general outlook and properties of the so-called clay mineral, bentonite, from various parts of the world. It is then followed by the

general properties of Malaysian bentonite which had been tested by the minerals and geosciences department. In order to compare and contrast the Malaysian bentonite with the bentonite from the other parts of the world, the limits and characteristics of bentonite required for drilling deep wells according to the American Petroleum Institute (API) have to be specified. Comparison made between Malaysian bentonite and the API specification for bentonite showed that, the Sabah bentonite does not meet the criteria. Lastly, methods on how to improve the Malaysian bentonite so that it reaches the accepted grade are proposed. Bentonite is a clay mineral is composed largely of Montmorillonite, which is mainly a hydrous aluminum silicate.

## CHAPTER 2

### HISTORY, CHARACTERISTICS, AND UTILIZATION OF BENTONITE

#### 2.1 HISTORY OF BENTONITE

Early Americans found bentonite vital to their lives. Pioneers found moistened bentonite to be an ideal lubricant for squeaky wagon wheels. The mixture was also used as a sealant for log cabin roofing. The Indians found bentonite useful as soap. Small amounts of Wyoming bentonite were first commercially mined and developed in the Rock River area during the 1880s. Newer, more substantial deposits were discovered in other parts of Wyoming during the 1920s and the first processing plant in Wyoming was built during this period. Since that time, many other processing plants have been built for the same purpose.



Figure 1 Uses of bentonite in relation to history

## 2.2 MINERAL CHARACTERISTICS

Generally, Wyoming bentonite is composed essentially of montmorillonite clay, also known as hydrous silicate of alumina. In more simplistic terms, the structure of bentonite is much like a sandwiched deck of cards. When placed in water, these cards or clay platelets shift apart. Bentonite attracts water to its negative face and magnetically holds the water in place. Because of these unique characteristics, Wyoming bentonite is capable of absorbing 7 to 10 times its own weight in water, and swelling up to 18 times its dry volume.



Figure 2 Wyoming bentonite can absorb up to 7 to 10 times its own weight in water

## 2.3 MINING

Before mining can begin, delineation of the deposit is performed by drilling and sampling. Mining then begins by removing the overburden from the mineral deposit with the use of large earth movers. The overburden is then stockpiled nearby for reclamation after the bentonite has been removed from the bed. When contact with the bed is made, extreme care is taken to avoid contaminating the mineral deposit with the overburden, thus insuring the highest quality raw material. Care must also be taken to conserve as much bentonite as possible when trimming the overburden from the bentonite.



Figure 3 Bentonite seams are commonly visible throughout the Wyoming landscape



Figure 4 Bentonite is mined from shallow beds with front-end loaders.

When all the bentonite has been removed from the bed, reclamation can begin (See plates below).



Figure 5 Plant growth is monitored on reclaimed lands.



Figure 6 Restored, reclaimed land shows little effect of mining operations

The surface of the mine site must be returned to equal or superior condition. The habitat for plant and animal is very important as are all other environmental considerations.

#### **2.4 COLLECTION OF BENTONITE**

In order to utilize the bentonite mineral, the utilization process should pass by a number of activities supposed to be done one after the other. Those activities are mining, processing, packing, and finally, quality control to enable it to be used in the oil industry as per the API specifications.

#### **2.5 PROCESSING**

The bentonite from each bed is stockpiled and thoroughly tested to ensure the attainment of highest quality. The bentonite is then carefully dried and ground to meet all the product specifications. The finished product is stored in silos to await packaging and shipping to customers. In the oil industry, the raw material should be transported to the place where drilling activities are in progress.



Figure 7 Process of drying bentonite in a rotary kiln

Upon arrival at the processing plants, the bentonite is placed into designated stockpiles and carried into the plant with front-end loaders. The bentonite is then dried in a long cylinder called a rotary dryer where approximately 10 to 15% of the moisture is removed. Natural gas or coal is used primarily as fuels for drying. The finished product has moisture content of 7 to 10%. Once delivered from the rotary dryer; the bentonite is processed into either a fine powder or granulated into a small particle or flake.

## 2.6 PACKAGING

This is the last process to be undertaken. Bentonite can be packaged in 50 lb., 100 lb. or up to 4,000 lb. super sacks. After the packaging process takes place, the bentonite is shipped either by truck or rail to the consumer. Another form of packaging is to ship direct in bulk pneumatic trucks or rail cars to the consumer.



Figure 8 Granular bentonite is a major constituent of "scoopable" cat litter

## **2.7 QUALITY CONTROL**

Bentonite is thoroughly tested throughout the mining, processing and shipping stages to ensure the highest quality product is delivered to every customer. Samples of all the products and laboratory results are available to all potential customers.

## **CHAPTER 3**

### **PRODUCTS AND USES OF BENTONITE**

#### **3.1 WELL DRILLING**

Drilling mud, or drilling gel, is a major component in the well drilling process. Drilling mud is crucial in the extraction of drill cuttings during the drilling process. Bentonite, when mixed with water, forms a fluid (or slurry) that is pumped through the drill stem, and out through the drill bit. The bentonite extracts the drill cuttings from around the bit, which are then floated to the surface. The drilling mud, or gel, also serves to cool and lubricate the drill bit as well as seal the drill hole against seepage and to prevent wall cave-ins.

#### **3.2 OTHER USES**

##### **3.2.1 Taconite Pelletizing**

Taconite, a low grade iron ore, has been developed as an economic source for iron. During processing, the taconite is ground into a very fine powder. The ground taconite is then mixed with small amounts of bentonite which serves as a binder to the taconite. This mixture is processed into balls or pellets. The process is finished when these pellets are sintered in rotary kilns that give the pellets a hard surface. The taconite pellets are easy to handle at this point and can be loaded into various containers for shipment to steel mills.

### **3.2.2 Metal Casting**

Bentonite serves as an economical bonding material in the molding processes associated with the metal casting industry. Bentonite, when mixed with foundry molding sands, forms a pliable bond with the sand granules. Impressions are formed into the face of the bentonite/sand mixtures. Molten metal is poured into the impressions at temperatures exceeding 2,800 F. The unique bonding characteristics of bentonite ensure the durability of the mold during these high temperatures. Once the process is complete, the bentonite/sand mold can then be broken away from the casting face and reused.

### **3.2.3 Cat Litter**

In recent years, bentonite has become a major component in the manufacturing of cat litter. Because of the unique water absorption, swelling, and odor controlling characteristics of bentonite, it is ideal for use in "clumping" types of cat litters. Clumping cat litter has become widely accepted as an economical alternative to the conventional non-clumping type cat litters. Because bentonite forms clumps when wet, the clumps can easily be removed and disposed of. The remainder of the unused material stays intact and can continue to be used. Clumping cat box litters will last longer with less frequency of changing.

### **3.2.4 Animal/Poultry Feeds**

For many years, bentonite has been used as a binder in the feed pelletizing industry. Small amounts of bentonite can be added to feed products to ensure tougher, more durable pellets. By absorbing excess moisture and oils, bentonite aids in the free movement of pellets, preventing lumping and caking.

Research has been conducted which indicates that bentonite has additional benefits for both animals and poultry. The bentonite used in the feed slows the digestive system and enables the animal or fowl to better utilize the feed nutrients. Other studies have shown bentonite as a useful ingredient in the control of certain toxins which affect animals and fowl.

### **3.2.5 Additional Uses**

Bentonite has also proved helpful in sealing freshwater ponds, irrigation ditches, reservoirs, sewage and industrial water lagoons, and in grouting permeable ground. In addition, it has been used in detergents, fungicides, sprays, cleansers, polishes, ceramic, paper, cosmetics and applications where its unique bonding, suspending or gel like properties are required.

## CHAPTER 4

### OCCURRENCE, ORIGIN, AND PROPERTIES OF STANDARD (WYOMING) BENTONITE

#### 4.1 WYOMING SODIUM BENTONITE

Bentonite is an industrial mineral, rich in a clay mineral called montmorillonite. Bentonites used for hydraulic barriers in North America are produced from the naturally occurring sodium bentonites mined in the state of Wyoming. These bentonites have unique cation chemistry. The cations that balance electrostatic charge in the clay structure are "exchangeable" cations and consist of sodium ( $\text{Na}^+$ ), calcium ( $\text{Ca}^{++}$ ), and Mg ( $^{++}$ ) cations. The largest deposits of commercial sodium bentonite are found in Wyoming, Montana and South Dakota. Over the years, these special bentonites have become famous and commonly referred to as "Wyoming" bentonite. The combination of its relative purity, its unusual geochemistry and structure is why "Wyoming" bentonite is used as a sealant. Purity is defined by the amount of sodium montmorillonite as compared to the other minerals present in the bentonite. A typical "Wyoming" bentonite contains ~90% montmorillonite while bentonites produced in other parts of the world have only 70-80% montmorillonite. The montmorillonite structure contributes to the usefulness of bentonite. Montmorillonite is a layered aluminum and silicate mineral, which is thought to occur as very small, two-dimensional mineral form called a "platelet". The thickness of this basic building block is approximately 1.0 - 1.5 nanometers, or about 50,000 times thinner than a human hair. These montmorillonite platelets have aspect ratios of 500:1 to over 1000:1 (width by height) which in turn creates a very high surface area per unit volume. These platelets physically occur in nanometer-scale stacks or "decks-of-cards".

Bentonite is considered the product of 1000 uses. During the Cretaceous age, volcanoes in the Yellowstone area of Wyoming were subject to long periods of eruptions. Ash falling from these eruptions dropped into seas which covered much of Wyoming, forming sediment as much as 50 feet deep. These sediments were slowly altered into the clay we know today as bentonite. In these deposits are contained 70% of the world's known supply of western or sodium type bentonite.



Figure 9 Blue areas indicate outcroppings of sodium bentonite in Wyoming.

#### 4.2 GENERAL PROPERTIES OF BENTONITE

Bentonite is the name used for a range of clays that can swell and gel when dispersed in water. The name "bentonite" originates from the discovery of this type of clay near Fort Benton, USA, in the 19th Century. This is a natural sodium bentonite, and has been mined extensively for many years in Wyoming and Dakota for oil well drilling applications. It is important to recognize that the properties of bentonites from different sources vary, and to take these variations into account when deciding on the suitability of a particular bentonite for a specific purpose.

### **4.3 MODE OF OCCURRENCE AND ORIGIN**

The mode of origin of bentonites is by the alteration of volcanic ash (Industrial clays, 1989). The parent ash (volcanic glass) of most bentonites was deposited under marine condition, and a few deposits accumulated in alkaline lakes. The most common parent materials range from andesite to rhyolite in composition. Certain bentonites exhibit strong evidence of its origin by hydrothermal alteration of igneous rocks. Beds and lenticular bodies extending between a few hundred meters to more than 300km in length are common modes of occurrence of bentonite rocks. In most cases the basal contacts are relatively sharp, and gradational contacts with overlying beds are predominant. Most associated lithologies are of marine origin, ranging from glauconitic sands in Mississippi to limestone (Israel) to shales (Wyoming) to calcareous fossiliferous sands and marls (England). Non-marine beds are less common, and include fresh water limestones (Brazil, Canada) and carbonaceous shale and coal beds (British Columbia). In Cyprus radiolarian chert is associated with bentonites, and diatomite is found with bentonites in Algeria and Peru. Most economic bentonite deposits are of Cretaceous age or younger, although bentonite can be found in formations ranging in age from Upper Paleozoic to Pleistocene.

### **4.4 PHYSICAL CHARACTERISTICS OF BENTONITE**

There are three main characteristics of bentonite that make it commercially useful. They include thixotropy, swelling, and adsorption. Thixotropy is the property by which bentonite-water slurries under certain temperature, and ionic concentrations become very viscous - gel like, but lose some of the viscosity under shear stress. Swelling to several times their original volume in water can be caused by hydration of the clay lattice, and when the water is removed, the clay lattice assumes its original spacing. The adsorption of exchangeable metallic ions in the clay lattice determines some of the properties of the clay.

#### 4.5 PROPERTIES OF POWDER BENTONITE

Commercial bentonites are hydrated alumino silicates, and comprise predominantly the mineral montmorillonite. The name “montmorillonite” is derived from the discovery of this type of clay near Montmorillon in France. Bentonite occurs as a clay ore containing up to 50% moisture. Commercially viable deposits consist of accessible clay seams, low in accessory minerals, which can be cleanly worked to minimize unwanted inclusions such as sand. The characteristics of the clay vary, and selection is based on factors such as yield and gelling ability.

There are three common types of bentonite, namely:

- Natural sodium bentonite
- Natural calcium bentonite
- Sodium-activated bentonite

All bentonites have a capacity to exchange cations which is much greater than that of other clays such as china clay, ball clays and attapulgite.

Natural sodium bentonite is characterized by very high swelling ability, high liquid limit and low filter loss. This bentonite was used as the standard by which all other bentonites were measured for many years. The predominant exchangeable cation in natural sodium bentonite is the sodium cation but there may also be significant amounts of other cations present.

Natural calcium bentonite, where calcium is the predominant exchangeable cation, is mined world-wide. It has much lower swelling ability and liquid limit, and much higher filter or fluid loss than natural sodium bentonite.

Sodium-activated bentonite is produced by the addition of soluble sodium carbonate to calcium bentonite. This affects a base exchange on the surfaces of the clay particles, replacing calcium ions with those of sodium. The result is a bentonite exhibiting many of the typical characteristics of a natural sodium bentonite.

Most bentonites used in petroleum oil industry to produce support fluids are sodium-activated. Natural sodium bentonite is rarely used because of its high cost. Natural calcium bentonite is usually not suitable for this purpose.

Processing methods used in the production of sodium-activated bentonite depend

on the deposit and its geographical location. They could include several of the following:

- Selective mining.
- Field lying and rotavation. This is a process used in hot, dry climates where the bentonite is spread out and rotavated with the addition of sodium carbonate.
- Crushing to 50 mm maximum size at the production plant.
- Extrusion: In wet climates, where field lying is not possible, a blend of raw bentonite and sodium carbonate is extruded to promote activation.
- Drying by a rotary Louvre drier to optimum moisture contents in the range 11% to 22 % of dry weight
- Milling to a particle size that promotes good powder flow but does not diminish clay performance. Generally, powders with 95 % of particles less than 150 microns (dry sieve basis) are used.

Natural sodium bentonite and sodium activated bentonite, when dispersed in water under conditions of high shear mixing, break down into minute plate-like particles, negatively charged on their surfaces and positively charged along their edges. Typically, if 3% or more bentonite powder is dispersed in water, a viscous slurry is formed which is thick when allowed to stand but thin when agitated. This phenomenon is known as thixotropy, and results from the orientation of the plate-like particles within the slurry. If the slurry is allowed to stand, the plate –like particles become oriented in a different style. Electrical bonding forces between the particles form an interlocking structure which causes the slurry to gel. When the gel is agitated, the electrical bonds are broken and the slurry becomes fluid with the particles oriented in random fashion as shown in the figure 10 below.

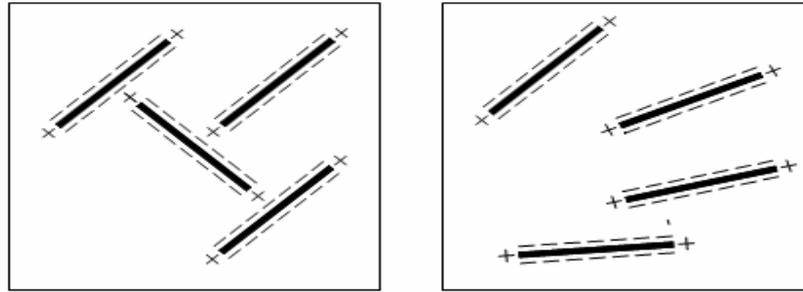


Figure 10 Sodium bentonite dispersed in water and agitated gel

#### 4.6 BENTONITE SLURRY PROPERTIES

Bentonite slurries of the type normally used to support excavations, can vary widely in their physical and chemical properties. They must, however, perform the following functions:

- Support the excavation by exerting hydrostatic pressure on its walls
- Remain in the excavation, and not flow to any great extent into the soil suspend detritus, and prevent sludgy layers building up at the base of the excavation

In addition, they must allow:

- Clean displacement by concrete, with no significant interference with the bond between reinforcement and set concrete
- Cleaning to remove suspended detritus, by passing through screens, and
- Easy pumping.

In general, the first two points or items above require thick, dense slurries, while the other three items need very fluid slurries. There are therefore conflicting requirements which must be resolved before an acceptable specification for slurry properties can be drawn up.

In the following paragraphs, consideration is given to the effect of slurry properties on each function. This will assist in the establishment of limits for most of the slurry properties and in defining slurry which is acceptable for each function and also for the overall excavation process.

The primary aim of any bentonite slurry specification must be to ensure that the slurry is capable of fulfilling functions which are mentioned above, without deleterious effects on the finished pile, wall or other form of construction or drilling activity. In addition, for economic and environmental reasons, the maximum re-use and minimum disposal of used slurry are required. The specification for the slurry properties should be as wide as possible, consistent with achieving satisfactory results. In most cases, for any given function, maximum and minimum values can be chosen which then enable limits to be derived as the basis for the specification.

#### **4.7 SUSPENSION OF SOLIDS**

While excavating under bentonite, fine soil particles will accumulate in the slurry. If this material is to be kept in suspension, for example to prevent the formation of a layer of sediment at the base of a pile bore, the bentonite slurry should have a high viscosity under quiescent conditions. A measure of this can be obtained from the 10 minute gel strength which can be determined when testing the rheological properties of the slurry, or other testing method for gel strength.

#### **4.8 PUMPING**

Pumping bentonite slurry over distances of several hundred meters can become difficult and inefficient if the viscosity of the slurry is too high or the slurry contains a large amount of suspended solids. The slurry should have low viscosity to minimize the energy required for pumping but should have sufficient gel strength to prevent soil particles from settling out in the delivery lines if pumping is interrupted.

#### **4.9 BENTONITE SPECIFICATIONS**

Bentonite powder is normally satisfactory for use in support fluids in petroleum oil industry if it complies with one of the following specifications:

- API Specification 13A, Fifteenth Edition, May 1, 1993, Section 6 (OCMA

grade bentonite)

- The Engineering Equipment and Materials Users Association (EEMUA) Publication No. 163 entitled "Drilling Fluid Materials", last reprinted in 1988.

The API Specification and the EEMUA Specification differ slightly in some respects. The main difference in the specifications is in the requirements for the rheological properties and filtrate loss of the slurry. The rheological properties of the slurry at different rates of shear are determined using a direct reading viscometer. Filtrate loss is determined using a filter press.

Tests to determine the properties of bentonite slurry in accordance with the API Specification are carried out on a 6.4% suspension of bentonite in deionized water, aged for up to 16 hours. This specification requires a minimum viscometer dial reading of 30 at 600 rpm, and a maximum Yield Point/Plastic Viscosity Ratio of 6. Expressed another way, this equates to a minimum dial reading of 30 at 600 rpm, and a maximum dial reading of 0.875 times the 600 rpm reading at 300 rpm. The filtrate volume must not exceed 16 ml in 30 minutes.

The EEMUA Specification expresses the rheological properties in terms of Yield (not to be confused with Yield Point). This specification requires the yield of a bentonite/distilled water slurry, aged for 24 hours and having an apparent viscosity of 15 cp (centipoises), to be not less than 16 m<sup>3</sup>/tonne<sup>3</sup>. An Apparent Viscosity of 15cp equates to a 600 rpm reading of 30, and a Yield of 16 m<sup>3</sup>/tonne<sup>3</sup> equates to a 6.4% bentonite suspension, which is the same as that used in the API Specification. Thus, the requirement of the EEMUA Specification can be re-written as follows:

- A 6.4% suspension of bentonite in distilled water, aged for 24 hours, should have a minimum viscometer dial reading of 30 at 600 rpm.

This is the same as the API Specification except that the API Specification only requires the bentonite suspension to be aged for up to 16 hours. The EEMUA Specification does not specify a maximum Yield Point/Plastic Viscosity Ratio therefore does not require a viscometer dial reading to be taken at 300 rpm. The filtrate volume is measured on a 7.5% suspension, aged for 24 hours, and should not exceed 15 ml in 30 minutes. The maximum moisture content of the bentonite powder is specified as

13% in the API Specification and 15% in the EEMUA Specification. This difference will not affect the performance of the bentonite, therefore the requirement of the API Specification could, if necessary, be relaxed to 15% to accommodate some bentonites in common use.

Both Specifications require the residue greater than 75 microns (US standard sieve No. 200), not to exceed 2.5% by weight. The EEMUA Specification has the additional requirement that the amount of bentonite passing through a dry 100 mesh (150 micron) screen shall be at least 98% by weight.

Where applicable, testing procedures should be carried out in accordance with the latest edition of API Publication RP13B "API Recommended Practice - Standard Procedure for Testing Drilling Fluids".

The following four tables figure out the important characteristics of standard Wyoming bentonite.

#### Sources:

Aloula Oil Services, Alhawari- Benghazi- Libya, [www.aloula-oil.com](http://www.aloula-oil.com)

Potential of an Andrassy and Mansuli Bentonite as a Drilling Mud Material ,  
A.Samsuri, SPE, K.P. Leyong, and H. Abdullah, University of Technology, Malaysia

Table 1 Physical and Chemical Characteristics of Standard Bentonite (Wyoming Bentonite), Untreated Beentonite

Appearance	Light brown to grey powder
Bulk Density	Approx. 0.9 g/cm <sup>3</sup>
Density	Approx. 2.5 g/cm <sup>3</sup>
Ion Stability	Incompatible with bi-valent cations
API Yield	92 barrels (minimum)
API Filtrate Loss	13.5 ml (maximum)
Sieve Residue	4.0 % (maximum)
Solubility	Insoluble in oil and water
Liquid Limit	583.12%
Plastic Limit	57.64%
Plasticity Index	524.48%
Moisture Content	4.88%
Moisture Absorption	30.31%
Ignition Loss	8.53%
CEC	79 meq/100g
Specific Surface Area	819.62m <sup>2</sup> /g

Table 2 Chemical Composition (% weight) of Standard (Wyoming) Bentonite, Untreated Bentonite

Fe (Iron)	13.98 (% weight)
Na (Sodium)	4.13 (% weight)
Mg (Magnesium)	5.15 (% weight)
Al (Aluminium)	15.84 (% weight)
Si (Silicon)	57.58 (% weight)
K (Potassium)	0.51 (% weight)
Ca (Calcium)	1.88 (% weight)
Mn (Manganese)	0.94 (% weight)

Table 3 Suspension Properties of Standard(Wyoming) Bentonite, Untreated Bentonite

Viscometer Dial Reading at 600 rpm	30 (minimum)
YP/PV Ratio	3 (maximum)
Fluid Loss	15 cm <sup>3</sup>

Table 4 Mineral Composition of Standard (Wyoming) bentonite , Untreated Bentonite

Montmorillonite	**** (maximum)
Quartz	* (maximum)
Kaolinite	* (maximum)
Illite	* (maximum)
Feldspar	tr.

Note that

\*\*\*\* = Dominant | \*\*\* = Major, \*\* = Minor, \* Appriciable, tr = Trace

## **CHAPTER 5**

### **OCCURRENCE, ORIGIN, AND PROPERTIES OF SABAH BENTONITE**

#### **5.1 OCCURRENCE**

Sabah, which is in the island of Borneu forms part of eastern Malaysia and has considerable quantities of calcium montmorillonite clay (Ang Numkiat, 1988). Investigation for bentonite was carried out at Andrassy and Mansuli in the eastern part of Sabah. Generally, smectite is the essential component of bentonite in which the economic importance of the Sabah bentonite is based. This smectite clay mineral is composed of montmorillonite and contains calcium and magnesium as the main and most important exchangeable cations. Smectite minerals are unstable and with increasing age, depth of burial and diagenesis, alter to mixed-layer, illite smectite clays, sometimes referred to as metabentonites in which their valuable properties will be largely destroyed. The bentonite deposits are found in formations ranging in age from Paleozoic to Pleistocene which is possibly recent (Allagu Balaguru, 1991). Formations of the deposits however are found to be in the Upper Cretaceous and Tertiary (in Epoch of Miocene). Most of the Sabah bentonite occurs in beds or lenticular bodies aligned along a definite stratigraphic zone. Bedded deposits ordinarily have a characteristic sharp contact with the underlying rocks and a gradational one with the overlying strata. The Sabah bentonite is not just pure bentonite by nature, but it is composed of a number of impurities. For example, the dominant gangue mineral is ferrous iron with small amounts of kaolinite, quartz, illite, muscovite, and hematite. Iron is present as magnetite and as amorphous oxides and hydroxides. In order to make the local Malaysian bentonite to be economical and put into valuable applications, the impurities mentioned above should be eradicated and the resultant raw material should meet the specifications

of the API standards (according to Sonny Irwan and Ariffin Samsur). The Location of potential areas of bentonite in Sabah is shown in figure 11 below.

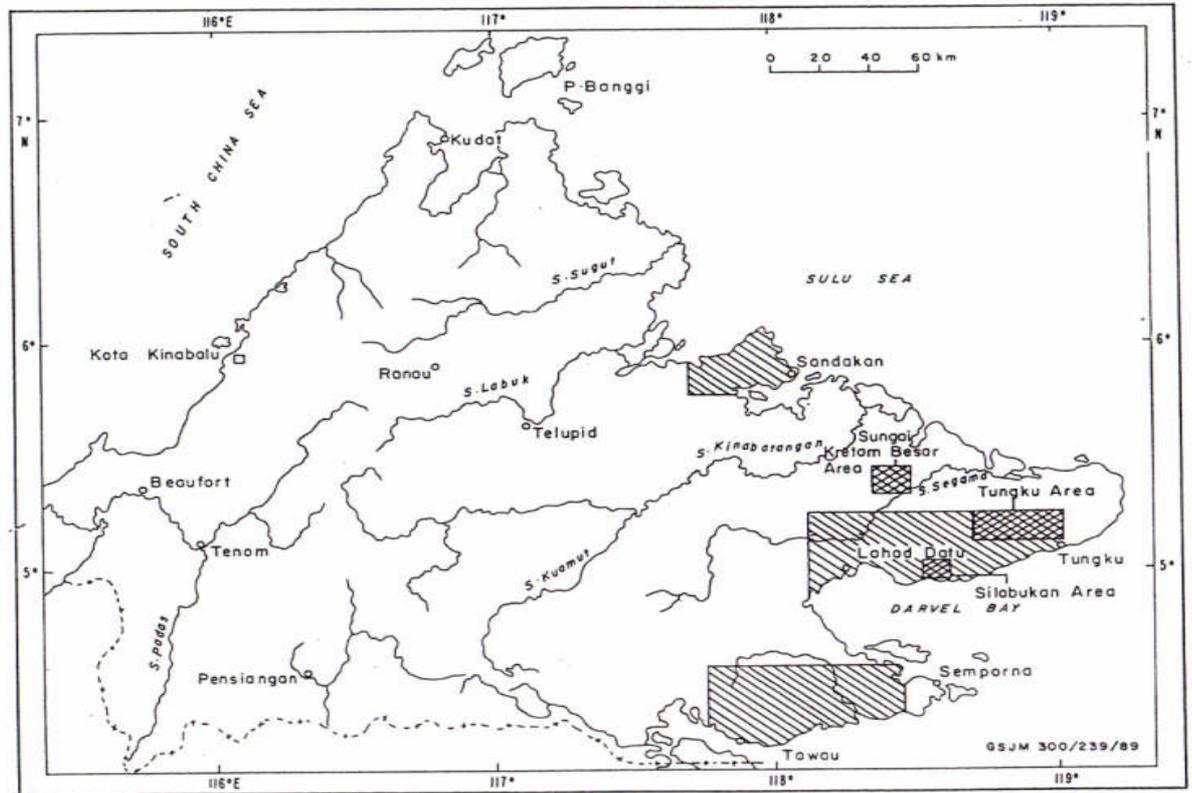


Figure 11 Marked Locations are Potential Bentonite Deposits in Sabah

## 5.2 ORIGIN

The bentonite is formed from the alteration of igneous materials. Bentonites are known to form generally from:

- Alteration of volcanic ash or tuff, essentially in situ.
- Hydrothermal or deuteritic alteration of igneous rocks, and
- Miscellaneous and uncertain mode of origin (Grim, 1978).

Most of the world's bentonitic deposits are derived from alteration of volcanic ash and hence, the source of the Sabah bentonite is no of exception but the composition of the igneous rock is different and that is why the Sabah bentonite is different from the other useful bentonite sources (e.g., Wyoming bentonite) and needs upgrading. Alteration of

ash or tuff in situ is by far the most common mode of origin of bentonites. Most of the Sabah bentonites are in the formations of Upper Cretaceous and Tertiary (particularly Miocene) to Recent, and this fact is an important exploration criterion. Most of the bentonites are formed from the alteration of igneous material. The Sabah bentonites are formed from sedimentary processes and hydrothermal activities. These bentonites can be called sedimentary and hydrothermal bentonites. Sedimentary bentonite means that the bentonite is formed from subaqueous alteration of fine grained volcanic ash. Hydrothermal bentonites are those formed or resulting from in situ hydrothermal alteration of acid volcanic rocks (Grim and Guven, 1978).

### **5.3 SEDIMENTARY BENTONITE**

As mentioned above, the main generating process is the alteration volcanic ash deposits in the sedimentary environment. This material may have been subsequently reworked and concentrated by sedimentary processes. It is worthy to mention that this kind of deposit may be found in association with a wide range of lithologies. Based on this, most of the local bentonites of Sabah in this category have been formed from ash mainly of rhyolitic to trachytic in composition.

But in reality, sedimentary bentonites are not usually associated with volcanic rocks and hence the ultimate source of the volcanic ash may be several hundred kilometers away and no longer exposed. For this reason, Moorlock and Highley (1991) recognized the five most important genetic stages in the formation of the local bentonite, which are:

- Eruption of ash and its airborne transport,
- Water sorting and concentration of volcanic ash in shallow-marine environments to give thick accumulation,
- Conversion of the volcanic ash to smectite,
- Protection of the formed bentonite beds from subsequent erosion, and finally
- There should not be subsequent thermal alteration of the smectite to other clay mineral phases.

#### **5.4 HYDROTHERMAL BENTONITE**

This is the most important source of bentonite formed by the insitu hydrothermal alteration of volcanic rocks, normally of acidic composition. This kind of deposits may become irregular in shape and controlled by faults and joint systems and they may also be highly variable in quality due to the partial alteration of the parent rock. Often they may be in association with recent volcanism, which also should be regarded as an important exploration criterion. It is worthy to mention that the degree of alteration is variable with the main impurities being quartz, feldspar, unaltered volcanic glass and kaolinite (Yusari HJ. Basiran, Alexander S.W. Yan, 1994).

#### **5.5 MINERAL COMPOSITION**

Generally, the untreated local bentonite samples are seen to have montmorillonite as their major component but still less than standard bentonite. In addition, these bentonite samples also contain kaolinite and illite. However, the Andrassy bentonite also contains of feldspar in a very small quantity, which is different from the standard bentonite. There is only trace feldspar in standard bentonite. In some other nearby places, the situation is even worse because the predominant mineral is quartz instead of montmorillonite. The montmorillonite just appears as a minor mineral with the presence of kaolinite, illite and feldspar in small quantities. After wet treatment, the mineral composition of the local bentonite remains unchanged. The treatment process will only affect the chemical component in the structure of the bentonite unit layers or surfaces and not changing the mineral content of the entire sample. As for the bentonite samples after electrolysis treatment, the results are almost the same as that from the wet treatment. However the montmorillonite content of samples in some areas is less than the untreated and wet treated. This may be due to the inhomogeneous property of the samples during the preparation stage.

## **5.6 PROPERTIES OF SABAH BENTONITE**

In order to use a bentonite in industrial applications, the raw material should conform to the approved standards. As such, it is practical to study and determine the physical and chemical properties of the local bentonite so that they could be into application. The following are the important physical and chemical properties to be considered.

## **5.7 PHYSICAL PROPERTIES**

These properties are moisture absorption, moisture content, ignition loss, and the atterberg limits, which include liquid limit, plastic limit, and plasticity index. These physical properties signify the reaction of this important clay mineral when used as an additive drilling fluid.

### **5.7.1 Atterberg Limits**

Commonly, the range of liquid limit for montmorillonite is around 100 % to 800 %. None of the local Sabah bentonite tested is within these values except for a few samples (see table). For the untreated samples, the liquid limit values are below the range of montmorillonite. In fact, the liquid limit of bentonite mainly depends on the moisture of the bentonite itself or the water absorption ability. For some samples which are rich in quartz mineral, the liquid limit is very low. The plastic limit varies from some sample to sample, with some higher than others. It is known that the plastic limit of a bentonite has direct relationship with its plasticity. Some samples have very high plastic limit values because of their better water absorption and swelling compared to the others. Those samples which have the very low plastic limit values generally have high quartz contents. In general, some bentonite samples show good agreement in the liquid limit and plastic limit after wet treatment. It is noted that in some samples, there is an improvement in the liquid limit, with increment of more than 100 % of the original values. In addition, these bentonite samples also show improvement in the plastic limits. This again proved that the mineral content of bentonite plays an important part in

influencing the plasticity of a sample, especially, montmorillonite. Bentonite samples that contain sodium montmorillonite will have better plasticity properties than the calcium based bentonites. When electrolysis is performed for some samples, the Atterberg Limits and the Plasticity Index (PI) decrease dramatically. But when the samples are treated, the situation is reversed whereby the plasticity index increases. But these PI values for the local bentonite failed to meet that of standard bentonite, which is **590.53**. This indicates that the local bentonites are not the sodium montmorillonite (sodium bentonite) type, as Standard Bentonite.

### **5.7.2 Moisture Content (MC), Moisture Adsorption (MA), and Ignition Loss (IL)**

Moisture content (MC) is the percentage of water loss when clay from normal atmospheric room temperature (around 20°C) is dried at 105°C.

Moisture Adsorption (MA) is defined as the percentage of water loss when clay from a saturated atmospheric temperature (around 20°C) is dried in an oven of 105°C. The moisture adsorption value can be used to predict the mineralogy of clay.

Ignition Loss (IL) is the percentage of weight loss when dried clay (at 105°C) is fired to 1000°C in furnace. A bentonite that has a MA value near or greater than 23 % indicates that it contains mostly montmorillonite. On the other hand, if the MA is less than 3%, then it implies that the clay consists mainly of kaolinite. Among the untreated bentonite samples, some have a MA value very near to 23 %. A sample with a MA value that lies between 3 % and 23 % would contain a mixture of kaolinite and montmorillonite, and some impurities. Some samples have a very low content of montmorillonite with a MA value less than 10 %. For ignition loss, there is not much difference among the bentonite samples. This signifies that the amount of unwanted impurities (fired at 1000°C in furnace) for all the bentonite samples are almost identical.

## 5.8 CHEMICAL PROPERTIES

When discussing about the chemical properties of bentonite, it is important to deal with the cation exchange capacity (CEC), and the specific surface area of the same element. It is worthy to mention what it means by the terms “cation exchange capacity”, and “specific surface area”. The performance of the drilling additives in the petroleum oil industry depends on the physical and chemical properties of the important elements which composes the drilling fluid.

### 5.8.1 Cation Exchange Capacity

Cation exchange capacity, or CEC, refers to the quantity of negative charges existing on the surfaces of clay and organic matter (See Figure 12). The negative charges attract positively charged ions, or cations, hence the name 'cation exchange capacity'. Many essential plant nutrients exist in the soil as cations and are accumulated by the grass plant in this form. Examples are potassium ( $K^+$ ), calcium ( $Ca^{2+}$ ), magnesium ( $Mg^{2+}$ ), and ammonium ( $NH_4^+$ ). Sodium ( $Na^+$ ) which may cause severe problems in coastal soils irrigated with poor quality irrigation water also occurs as a cation. Hydrogen ( $H^+$ ) and aluminum ( $Al^{3+}$ ) are the other predominant cations occupying the CEC in soils. The superscript (+) indicates how many positive charges the cation carries.

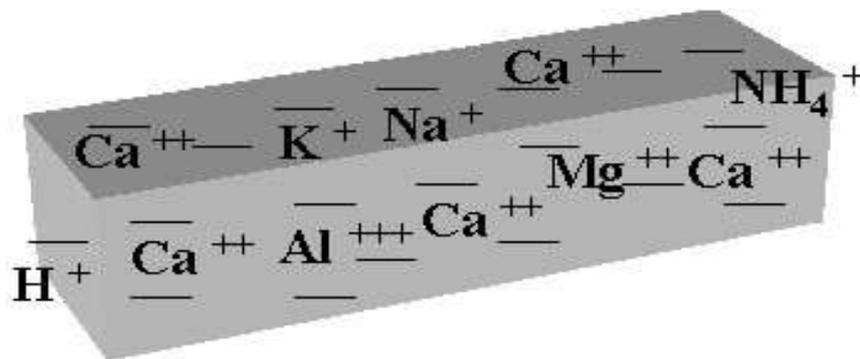


Figure 12 Schematic of a clay particle with negative charges on the surface attracting various cations

### **5.8.1.1 Factors Determining CEC**

The primary factor determining CEC is the clay and organic matter content of the soil. Higher quantities of clay and organic matter beget higher CEC. Different types of clays have different CECs. The amounts of negative and positive charges are both expressed in milliequivalents (meq). One milliequivalent of negative charge on a clay particle is neutralized by one milliequivalent of cation. A milliequivalent takes into account both the weight and the charge of the cation.

### **5.8.1.2 How can CEC be modified**

In coarse native sands of the Sandhills, Coastal Plain, and Coastal regions, as well as sand-based golf greens and sports fields the CEC arises almost entirely from organic matter. To provide more nutrient holding capacity it is desirable to preserve and increase CEC when possible. Reducing organic matter by core aeration and replacement with topdressing sand will obviously decrease CEC. Generally aeration decisions are based on reducing compaction and increasing water and air movement through the root zone. Reducing organic matter in this way greatly decreases CEC. Calcined clay, diatomaceous earth, and zeolite/clinoptilolite are sometimes added to sand-based fields to increase the CEC. The CEC of these materials are variable but typical values are in the range of 25 meq/100 g for calcined clay, 50 meq/100g for diatomaceous earth, and 100 meq/100g for zeolite/clinoptilolite. Whether or not these amendments provide more advantages than peat or organic matter is still a question that needs to be answered. Soil pH is a less obvious factor affecting CEC. Soils contain two sources of negative charge, permanent and variable. Permanent charge is located within the structure of the clay particles. Variable charge is located on the edges of clay and organic matter particles.

### 5.8.1.3 How CEC is measured and why is this important

The direct measurement of CEC is costly. Therefore soil-testing laboratories estimate, rather than measure CEC. Estimates are made by determining the extractable cations ( $K^+$ ,  $Ca^{2+}$ ,  $Mg^{2+}$ , and  $Na^+$ ) and estimating  $H^+$  and  $Al^{+3}$  from soil and buffer pH measurements. Estimates will be erroneously high in two commonly occurring situations. Firstly, CEC will be overestimated if a soil is sampled shortly after a heavy fertilizer or gypsum application. This error arises because the cations that are in the soil solution are misrepresented as exchangeable. Secondly, extraction of high pH soils containing calcium carbonate (limestone) with an acid extracting agent will also provide inflated CEC estimates. The acid extractant dissolves a portion of the limestone and considers the  $Ca^{2+}$  removed as exchangeable. Under these circumstances CEC estimates are inaccurate and best ignored. Generally cation exchange capacity (CEC) is the amount of negative charge in soil that is available to bind positively charged ions (cations). Cation exchange capacity is estimated and reported by most soil testing laboratories. Estimates are reasonably accurate unless the soil has been heavily fertilized or amended just prior to sampling or an acid extractant was used on a soil containing precipitated calcium carbonate. Base saturation, the quantity of CEC occupied by one or more of the basic cations, is useful for managing detrimental levels of soil  $Na^+$  and  $Mg^{2+}$  availability.

Cation Exchange Capacity values of some of the untreated local bentonite are much higher than some of the other bentonite samples. However, it is still not as good as the standard bentonite due to the high content of calcium montmorillonite. But it is possible to improve the quality of the local Sabah bentonite. The improvement indicates that the calcium ions on the local bentonite unit layers had been replaced by sodium ions. For some samples, no change of CEC value was indicated and this is because of its high content of quartz mineral. CEC values of local bentonite were compared with standard bentonite (**79 meq/100 grams**); they failed to reach the standard minimum requirement. Therefore further investigations need to be carried out to improve the local bentonite so that it can come within the standard API specification for use in the petroleum oil

industry.

### 5.8.2 Specific Surface

Based on the mineral content, it is indicated that some Malaysian bentonite samples exhibit higher specific surface area than others. It is believed that some of the untreated sample contains more sodium montmorillonite than the others. It is known that sodium montmorillonite has larger face or planar surface of negatively charged compared to calcium montmorillonite. This surface will attract more methylene blue cationic dye (with a formula  $C_{16}H_{18}N_3S$ ) than the calcium montmorillonite and resulting in higher specific surface. For some of the local samples, only minor amounts of montmorillonite are detected and the specific surface is absolutely lower than other samples. As expected, the local bentonite shows better improvement in their specific surface area after wet treatment, which helps to increase in its magnitude. Electrolysis treatment also yields similar results in which the specific surface area increases significantly for the given samples. This increment is appropriate when correlated with mineralogy composition, physical and chemical properties. However, the specific surface area of the treated bentonite samples is still not as good as the standard bentonite, which has a specific surface around **819.62 m<sup>2</sup>/g**.

## 5.9 CHEMICAL COMPOSITION

The standard bentonite which most of the time is referred to as Wyoming bentonite does not satisfy the theoretical formula of silicon (Si); so are the untreated local bentonite samples, which have a lower amount of silicon than suggested by Grim (1962). The aluminum (Al) content of standard bentonite is **15.84 %**, which is much lower than the theoretical formula and can be concluded that the aluminum had been substituted by ferrous (Fe) in octahedral sheet (as high as 13.98 %). Some local samples also have a similar situation, with Al content of 16.36 % and Fe content of 13.39 %. For some bentonite samples, the amount of Al content ranges from 24.18 % to 29.64 %, which are higher than standard one. For the local untreated Sabah bentonite, the calcium is the main exchangeable cation instead of sodium. Some samples only have a small

magnitude of calcium content, while the others have higher contents of Ca, ranging from 1.71 % to 4.95 %. After wet treatment, the Si content of the treated local bentonite remained the same, which is lower than the theoretical formula due to the substitutions within the lattice in the tetrahedral and octahedral coordinations. This also happened to the Al content of some treated local and standard bentonite, which has an Al content of 18.83 % and 15.84 %, respectively. It is believed that the Si and Al contents of these bentonite samples have been substituted by Fe. This kind of phenomenon is generally known as "isomorphous substitution". In addition, it is also indicated that after wet treatment the Na component has increased. In addition, the sodium content of the local bentonite has also increased after electrolysis treatment process. This increment of sodium means that there is an ion exchange within the bentonite interlayer. In addition, the amount of exchangeable cation calcium ( $\text{Ca}^{+2}$ ) and sodium ( $\text{Na}^{+}$ ) in the standard bentonite is considered reasonable since the amount of sodium is higher than calcium.

## **5.10 PERFORMANCE OF BENTONITE AS A DRILLING MATERIAL**

After being treated with sodium carbonate, the Sabah bentonite was also tested for their rheological properties. However, because the treated bentonite samples did not satisfy the standard requirements, polymer extender was then added to the bentonite suspension. The polymer extender which was used for this study is partially hydrolyzed poly-acryl-amide (PHPA) and carboxyl methyl cellulose high viscosity (CMC HV).

## **5.11 VISCOMETER 600 RPM DIAL READING**

Generally, experiments showed that except for moisture content, the suspension properties of almost all untreated local bentonites failed to meet the requirements set by API and OCMA. It can be seen that the untreated local bentonite sample failed to meet the viscometer 600 rpm dial reading as specified in the API and OCMA specifications. After wet treatment, with the addition of 3% of PHPA by weight some samples met the API and OCMA specifications. For the bentonite samples that

underwent the electrolysis treatment, the specific requirement could only be achieved if 4% of CMC were added. Although the yield point to plastic viscosity ratio for untreated bentonite fulfilled the requirements, the viscosity for untreated local bentonite was very low. From physical observation, there was almost no gelling effects for the drilling mud prepared using untreated local bentonite. This is because the local bentonites are composed of calcium montmorillonite and quartz. Generally, calcium montmorillonite has lower swelling and absorbency capacities than the sodium variety and quartz is a non-swelling mineral. After treatment (wet and electrolysis treatments), the situation remained the same. Almost all bentonite samples fulfill the requirement of YP/PV ratio except for some local bentonite clay minerals which have been treated by electrolysis.

#### **5.12 FLUID LOSS CONTROL**

The ability for fluid loss control of local bentonites is very poor and failed to meet the standard requirements. This is because calcium montmorillonite, which is the main component of the untreated local bentonite samples, has poor wall sealing property. After wet treatment, with a small amount of polymer added, some samples have better fluid loss control capability. The addition of 0.5 % of PHPA is enough to reduce the fluid loss. In general, if the CMC is used, a higher amount of the polymer is required in order to meet the specifications. After electrolysis, a similar situation was obtained. So, it can be concluded that the PHPA has a better ability to reduce the fluid loss when used as polymer extender for bentonite clay mineral. Studies on properties of untreated Sabah bentonite were carried out by A. Samsuri, A.Samsuri, SPE, K.P. Leyong, and H. Abdullah (SPE 80494) and the results are shown in tables below.

Table 5 Physical and Chemical Characteristics of Sabah bentonite (Untreated Bentonite)

Liquid Limit	122.84% (maximum), 68.32% (minimum)
Plastic Limit	42.36% (maximum), 29.79% (minimum)
Plasticity Index	80.48% (maximum), 36.11% (minimum)
Moisture Absorption	21.53% (maximum), 9.51% (minimum)
Moisture Content	9.49 % (maximum), 7.39% (minimum)
Ignition Loss	11.31% (maximum), 9.31% (minimum)
CEC	54 meq/100g (maximum), 24 meq/100g (minimum)
Specific Surface Area	434.28 m <sup>2</sup> /g (maximum), 151.69 m <sup>2</sup> (minimum)

Table 6 Suspension Properties of Sabah bentonite (Untreated Bentonite)

Viscometer Dial Reading at 600 rpm	1 (minimum), 5 (maximum)
YP/PV Ratio	0.5 (maximum), 0.5 (minimum)
Fluid Loss	114 cm <sup>3</sup> (maximum), 52cm <sup>2</sup> (minimum)

Table 7 Chemical Composition (% weight) of Sabah Bentonite (Untreated Bentonite)

Fe (Iron)	13.39 (maximum), 3.66 (minimum)
Na (Sodium)	1.62 (maximum), 0.39 (minimum)
Mg (Magnesium)	2.6 (maximum), 1.51 (minimum)
Al (Aluminium)	29.64 (maximum), 16.36 (minimum)
Si (Silicon)	60.72 (maximum), 57.91 (minimum)
K (Potassium)	4.02 (maximum), 0.82 (minimum)
Ca (Calcium)	4.95 (maximum), 0.70 (minimum)
Mn (Manganese)	1.26 (maximum), 0.68 (minimum)

Table 8 Mineral Composition of Sabah Bentonite (Untreated Bentonite)

Montmorillonite	*** (maximum), * (minimum)
Quartz	*** (maximum), * (minimum)
Kaolinite	* (maximum), tr (minimum)
Illite	** (maximum), * (minimum)
Feldspar	* (maximum), * (minimum)
Note that:	
**** = Dominant	*** = major, ** = Minor, * Appriciable, tr = Trace

### 5.13 COMPARISON OF MALAYSIAN BENTONITE WITH THE STANDARD (WYOMING BENTONITE)

Investigations conducted so far indicated that Malaysian bentonite does not meet the API specifications. The bentonite needs some degree of upgrading in order to be used for various industrial applications.

A.Samsuri, K.P. Leyong, and H. Abdullah, compared the Sabah bentonite, with that of the standard (Wyoming) bentonite and the results are shown in the tables below.

Table 9 Comparison of Physical and Chemical Characteristics between Standard Bentonite (Wyoming) and Sabah Beentonite

	Standard Bentonite (Untreated)	Sabah Bentonite (Untreated)
Appearance	Light brown to grey powder	Not Done
Bulk Density	Approx. 0.9 g/cm <sup>3</sup>	Not Done
Density	Approx. 2.5 g/cm <sup>3</sup>	Not Done
Ion Stability	Incompatible with bi-valent cations	Not Done
API Yield	92 barrels (minimum)	Not Done
API Filtrate Loss	13.5 ml (maximum)	Not Done
Sieve Residue	4.0 % (maximum)	Not Done
Solubility	Insoluble in oil and water	Not Done
Liquid Limit	583.12%	122.84% (maximum), 68.32% (minimum)
Plastic Limit	57.64%	42.36% (maximum), 29.79% (minimum)
Plasticity Index	524.48%	80.48% (maximum), 36.11% (minimum)
Moisture Content	4.88%	9.49 % (maximum), 7.39% (minimum)
Moisture Absorption	30.31%	21.53% (maximum), 9.51% (minimum)
Ignition Loss	8.53%	11.31% (maximum), 9.31% (minimum)
CEC	79 meq/100g	54 meq/100g (maximum), 24 meq/100g (minimum)
Specific Surface Area	819.62m <sup>2</sup> /g	434.28 m <sup>2</sup> /g (maximum), 151.69 m <sup>2</sup> (minimum)

Table 10 Comparison of Chemical Composition (% weight) between Standard (Wyoming) Bentonite and Sabah Bentonite

	Standard Bentonite (Untreated)	Sabah Bentonite (Untreated)
Fe (Iron)	13.98 (% weight)	13.39 (maximum), 3.66 (minimum)
Na (Sodium)	4.13 (% weight)	1.62 (maximum), 0.39 (minimum)
Mg (Magnesium)	5.15 (% weight)	2.6 (maximum), 1.51 (minimum)
Al (Aluminium)	15.84 (% weight)	29.64 (maximum), 16.36 (minimum)
Si (Silicon)	57.58 (% weight)	60.72 (maximum), 57.91 (minimum)
K (Potassium)	0.51 (% weight)	4.02 (maximum), 0.82 (minimum)
Ca (Calcium)	1.88 (% weight)	4.95 (maximum), 0.70 (minimum)
Mn (Manganese)	0.94 (% weight)	1.26 (maximum), 0.68 (minimum)

Table 11 Comparison of Suspension Properties between Standard(Wyoming) Bentonite and Sabah Bentonite

	Standard Bentonite (Untreated)	Sabah Bentonite (Untreated)
Viscometer Dial Reading at 600 rpm	30 (minimum)	1 (minimum), 5 (maximum)
YP/PV Ratio	3 (maximum)	0.5 (maximum), 0.5 (minimum)
Fluid Loss	15 cm <sup>3</sup>	114 cm <sup>3</sup> (maximum), 52cm <sup>2</sup> (minimum)

Table 12 Comparison of Mineral Composition between Standard (Wyoming) Bentonite and Sabah Bentonite

	Standard Bentonite (Untreated)	Sabah Bentonite (Untreated)
Montmorillonite	**** (maximum)	*** (maximum), * (minimum)
Quartz	* (maximum)	*** (maximum), * (minimum)
Kaolinite	* (maximum)	* (maximum), tr (minimum)
Illite	* (maximum)	** (maximum), * (minimum)
Feldspar	tr.	* (maximum), * (minimum)

Note that:

\*\*\*\* = Dominant    \*\*\* = major, \*\* = Minor, \* Appriciable, tr = Trace

## CHAPTER 6

### **NEW METHODS FOR IMPROVING LOCAL BENTONITE PERFORMANCE FOR DRILLING FLUIDS APPLICATION**

Drilling fluid is a vital element of the drilling process. Any drilling fluid must have common properties that facilitate safe and satisfactory completion of the well. The main component of water-based mud is clay (mostly bentonite). As a result of the large consumption and the high importation cost of this material, it would be helpful to have a local substitute. The use of these local clays in the drilling activities can save a huge amount of hard currency that otherwise would be spent on importing it from abroad. Several attempts have been carried out to investigate methods in improving the local bentonite. This work focuses on the possibility of utilizing local bentonite clay minerals as a basic material for drilling fluids used to drill oil and gas wells. Any drilling fluid must have common properties which facilitate safe and satisfactory completion of the well such as, bottom hole cleaning and removal of cuttings to the surface, controlling high pressure zones, cooling and lubricating down-hole drilling equipment, forming bore-hole wall supporting filter cake, supporting the drill string and casing weight. This allows the interpretation of electric logs. These functions are controlled by the rheological and filtration properties of mud. The local bentonite has to meet the API specifications. Therefore, the properties of the local mud can be improved by the addition of some low cost materials to enhance its viscosity and filtration loss (such as Carboxyl Methyl Cellulose (CMC), and bentonite extenders). The shearing speed can also be used as an enhancement method to improve the dispersion rate of the clay suspension and hence, increase its viscosity and decrease its filtration loss. The bentonite extender can either be a salt or a polymer; it enhances viscosity buildup by slightly flocculating the bentonite suspension. Sodium carbonate is an example of a salt that can be added as an extender.

## **6.1 ADDITION OF LOW COST MATERIALS**

### **6.1.1 Adding of Sodium Carboxymethyl Cellulose (CMC)**

The CMC is a long chain molecule which is used to reduce filtration loss and increase mud viscosity at a temperature of less than 250°F and for salts concentration less than 50,000 ppm. Therefore the addition of CMC to a mud prepared from a low grade local bentonite can cause an increase in its viscosity.

### **6.1.2 Adding of Drispac (Polyanionic cellulose polymer)**

Drispac is a long chain polymer of high molecular weight. A small amount of this additive can both improve viscosity and reduce water loss even at high salt concentration and high down-hole temperature. The addition of Drispac to the mud prepared from the local bentonite can cause a huge reduction in filtration loss.

### **6.1.3 Adding of NaOH**

The effect of adding NaOH must take into consideration not only the effect of sodium ions, but also the effect of hydroxyl ions. The addition of sodium into the mud system, cause the viscosity to increase, possibly as a result of Base Exchange. This is more obvious in Ca-based clays, as some sodium ions would replace the calcium ions, and thus improves clay dispersion and results in higher viscosity. As the addition of NaOH to the mud would increase the pH, its concentration should be limited to a certain value that would keep the pH around 9. The effect of adding NaOH even in small concentration will result in a pH higher than 11, which is unacceptable level of pH. Thus, the use of NaOH to enhance local clay performance is not recommended.

#### **6.1.4 Adding of bentonite extender**

The extender can be either a salt or a polymer, and it enhances viscosity buildup by slightly flocculating the bentonite suspension. Sodium carbonate is an example of a salt that can be added as an extender. Soaking raw bentonite with a solution of sodium salt can result in higher sodium bentonite content by ion exchange capacity. More effective extenders than the inorganic salts are the high molecular weight linear polymers.

##### **6.1.4.1 Adding Sodium Carbonate salt (Soda Ash)**

One of the factors affecting the tendency of ion exchange in clay is the relative concentration of sodium cations. By adding  $\text{Na}_2\text{CO}_3$ , an enhancement of properties is expected as some of the Na-cations could occupy some surface locations, and increasing the swelling tendency of clay. The addition of  $\text{Na}_2\text{CO}_3$  will increase the pH of the mud a bit higher, but to an acceptable value.

#### **6.2 USING APPROPRIATE SHEARING SPEED**

##### **6.2.1 Increasing shearing or mixing speed**

Increasing shearing speed to a higher magnitude can cause a great improvement in viscosity and filtration loss of the local bentonite mud. This method of improving local clay mud properties is an effective method, but it has some economical and equipments limitations. Economical limitations are due to the high energy needed to reach high shearing speed. Equipment limitations are related and determined by the mixing equipments at the rig site. Thus, this method of improving mud properties can be used if these limitations are satisfied at the rig site.

### **6.3 BLENDING**

The other method of improving the local bentonite is to mix imported standard bentonite with low quality local bentonite. The process of mixing these two different types of bentonites is known as blending. In order to improve the quality of the local bentonite, laboratory experiments should be conducted to know the proportions in order to come up with an acceptable grade of bentonite.

## CHAPTER 7

### CONCLUSION AND RECOMMENDATION

#### 7.1 CONCLUSION

Bentonite has been called the clay of a thousand uses and one of these important uses is as a valued additional constituent in the drilling fluids. This and the other applications of bentonite are the reasons for the exploration and production of bentonite in Sabah. However, based on the mineralogy, chemical and physical properties, the non-sodium based Sabah bentonite does not meet the basic and critical characteristics of the standard (Wyoming) bentonite unless some means of improvement are carried out. Generally, sodium bentonite is noted for its affinity for water which gives it tremendous swelling properties and contains exchangeable sodium cations as well. Sabah bentonite is different from sodium bentonite in the characteristics as it is highly dominated by non-sodium based bentonite constituents. In addition to those characteristics, Sabah bentonite failed to meet the API 13A specifications. This is because Sabah bentonite has got the limitation in montmorillonite clay mineral. But different methods of improvement techniques such as, wet and electrolysis treatments were carried out and Sabah bentonite has proved to be usable as a drilling mud material in the petroleum oil industry. In this project, additional techniques like addition of low cost materials, and appropriate shearing speed for improving the local bentonite are proposed. The properties of the local mud can be improved economically by adding some low cost materials to the prepared mud to enhance its viscosity and filtration loss (such as such as Carboxyl Methyl Cellulose (CMC), and bentonite extenders). Also shearing speed can be used as an enhancement method to improve the dispersion rate of the clay suspension, and hence increase viscosity and decrease filtration loss. But the usage of shearing speed should be limited to a practical and economical speed.

## 7.2 RECOMMENDATION

It is recommended that the proposed improvement techniques, like addition of low cost materials, appropriate shearing speed for the local bentonite and blending, should be researched carefully in a laboratory before applying them in the industry. Only then, can be decided whether the treated bentonite is good enough to be used as a drilling mud in the petroleum oil industry.

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