



## The Many Facets of Gilsonite

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### Abstract

Gilsonite is a naturally occurring glossy black asphaltic, solid hydrocarbon resin with a low specific gravity. It occurs in its very pure natural state in a mineral called Uintaite. It has been used for many years by various industries worldwide as an additive in carbon black dispersing agents, hard resin printing inks for newspapers and magazines, asphalt modifying agent for road paving, and as an additive in sand molds used by the foundry industry. It is also used in the drilling industry as an additive in cementing and drilling fluids for many years beginning in the mid 1950's. Over the past ten years, new uses have been found aside from its principal use as an additive in drilling fluids to solve borehole instability. It has been used to solve differential sticking, provide lubricity and torque reduction in deviated wells, as a substitute drilling fluid additive for environmentally sensitive areas, as an additive in low invasion coring fluids, and as a fluid loss additive in oil based and synthetic based drilling fluids. This paper will discuss the uses of gilsonite in these areas and will provide case histories to illustrate the effective of the additive in these many different uses. In some cases, savings over \$1,000,000 per well were achieved.

### Introduction

Uintaite was discovered in 1869 by Samuel H. Gilson as he was prospecting in the Uintah Basin of Utah. Commercial quantities are found in vertical veins ranging in depth from 1,500 feet (460 meters) in widths from a few inches to 22 feet (6.7 meters) and across as long as 12 miles (19 kilometers). Since that time, the mineral has been found in Colorado, Sweden, and several other European countries. Uintaite is a naturally occurring asphaltite, glossy black in appearance, solid hydrocarbon resin with a low specific gravity. It occurs in nature in a very pure state, compared to other asphalts, and has softening points ranging from 300° to 450°F (150°-232°C). Samuel Gilson performed experiments on the mineral in 1885 to determine its potential and named the mineral Gilsonite. It has over 150 products uses, but the main use, aside from the drilling industry, is as an asphalt modifying agent for road paving, an additive in

sand molds used by founding industry, a carbon black dispersing agent, and in hard resin printing for newspapers and magazines, preventing smearing.. Since the mid 1950's, it has been used in cement slurry design to combat lost circulation and improve cement slurry properties. About the same time, it was tried and used in water-based drilling fluids to assist in borehole stabilization. It has been well documented that this additive can minimize borehole collapse in formations that contain water sensitive, sloughing shales. Further research and field trials expanded the use of it as a fluid loss agent in oil and synthetic muds, used to seal off low pressure zones, preventing differential sticking, lubricity, and in low invasion coring fluid.

The mineral is a drilling fluid additive which cannot be tested under normal bench-top test procedure. For many years, its effectiveness as an additive has been difficult to evaluate in the laboratory because most tests were performed at ambient temperatures and low pressures. Because it and some other asphalt-type products require temperature and pressure to be effective, the results of these tests were skewed toward additives that control shale problems by a chemical reaction. These simple tests do not compare "apples with apples, but apples with oranges." In the late 1980's, the Downhole Simulation Cell (DSC)<sup>1</sup> was developed by O-G-S Laboratories which could measure the mineral's value as a shale stabilizer under existing downhole conditions. In addition, the Permeability Plugging Apparatus (PPA) which measures fluid loss under downhole conditions of temperature and pressure was developed by Fann Equipment leading to its effectiveness to prevent differential pressure sticking by measuring filtrate and filter cake under existing conditions. With the introduction of this type of equipment, researchers were able to test it in situations other than resolving borehole instability problems. Several research projects sponsored by the Drilling Engineering Association studied and evaluated the performance of uintaite and other asphalt-type products plus many of the chemical additives as a borehole stabilizer. The tests indicated the gilsonite-type products proved to be quite effective. New tests applied to such problems as stuck pipe in depleted

or underpressured sand formations, lubricity application in tight formations, use in low invasion coring fluids to mitigate filtrate damage of the cores, and usage as a replacement of normal additives in an environmental sensitive area showed great potential.

Gilsonite is widely used to prevent or cure loss of cement slurry circulation while cementing oil and gas wells. According to Smith and Grant<sup>2</sup>, reported in 1989, over 200,000 wells have used over one-half billion sacks of the product in cementing operations. It is effective because of its low specific gravity (1.05) and usage as a combination low density-lost circulation slurry. The product has been compared by one major cement service company with more than 500 different type lost circulation material and has proven to be more successful and more cost efficient than any other product tested.

### **Gilsonite Uses and Testing Procedures**

Uintaite and other asphaltic-type materials have been used for many years as a shale stabilizer and to reduce borehole erosion. The causes of borehole instability are numerous. The reasons for the instability can be mechanical, chemical, or physical in nature. The mechanical problems include borehole erosion by high annular velocities, adverse hydraulic stresses due to differences in pore pressures and fluid pressures, and hole collapse from high swab and surge pressures. Chemical alteration problems include hydration, dispersion, and disintegration of shales due to the interaction of clays with mud filtrate. Physical instability problems include rock bursts of shales due to different pressures, slippage along fracture bedding planes of hard brittle shales, and the collapse of fractured shales above deviated holes.

Gilsonite uses a physical process to stabilize shales rather than the chemical process most widely used in the industry. The mineral, when added to a drilling fluid system, would penetrate the micro-fractures or pore spaces of shale as the bit penetrates the formation. By a plastic mechanism, it would extrude into the shale pore space, microfractures, and bedding planes and form a coat or a thin film on the borehole surface. Since uintaite is not soluble in water, the penetration is not deep, resulting in the surface coating of the shale. This coat is believed to change the membrane efficiency of the rock. Sulfonated asphalts penetrate deeper into the fractures because of its higher solubility and do not plate as well as the insoluble products. Cagle and Schwertner<sup>4</sup> reported in 1972 that the mineral was superior to the other asphaltic-type products because of its low solubility in water, fewer impurities in water, and higher softening point.

For many years, it has been difficult to duplicate the

effectiveness of the mineral as a borehole stabilizer in the laboratory compared to the field. There have been unfair comparisons made of uintaite with other asphalt products using the bench top tests. These tests were conducted under ambient temperatures and pressures while it uses temperature and pressure in the borehole to effectively cover the shales. Earlier tests were performed and results published using these bench top tests. These tests showed comparison of uintaite and the sulfonated asphalts using a simple bentonite dispersion test — mixing it with bentonite in one container, and a sulfonated asphalt in another container and comparing the viscosity reductions. Where uintaite uses the physical process to reduce shale instability the sulfonated asphalts react chemically to reduce viscosity — similar to a lignosulfonate. Tests like these obviously do not reflect the true effectiveness of the gilsonite product. It is like comparing apples with oranges, not apples with apples.

In the mid-1980's, the Chevron Drilling Fluids Laboratory at the Drilling Technology Center in Houston began a project to determine methods to measure the effectiveness under downhole conditions. The initial tests used a triaxial tester which operated under normal laboratory temperature conditions but could duplicate shallow downhole pressures. A series of tests using existing laboratory equipment were initiated. A high temperature, high-pressure (HTHP) filter loss cell was modified for use with a thin, 0.5-inch thick Berea sandstone core as the filter medium. Tests were performed at 350°F and 1000 pounds per square inch (psi) pressure. Tests were performed under various conditions to determine the depth of invasion of the drilling fluids used - both gilsonite and sulfonated asphalts. After the tests were run, the cores were cooled and sliced and examined under a high-power microscope. The tests revealed that the uintaite extruded into the void space and deposit a thin film on the surface of the core. The asphalts extruded deeper into the core, leaving no cake and with slight plugging action. Tests were performed under various temperatures using uintaite with various softening points. Information was provided that indicated the mineral was sensitive to temperature, meaning the higher softening point mineral should be used in high temperature wells, low temperature softening points in lower temperatures wells, and a combination of temperatures could work effectively in all situations. While these tests indicated possibilities of how uintaite and the asphalts work, there provided no definitive answers for shale inhibition.

The DSC apparatus could tests large diameter cores at downhole pressures and temperatures. Chevron initiated a test of ten samples to determine how well the mineral and asphalts behaved downhole<sup>4</sup>. The initial test used a Pierre Shale (Cretaceous age) sample which had

a definite shale structure. An initial run was conducted using a KOH lignosulfonate mud as shown in Table 1. Following a 45-hour test, the shale sample was removed and a 60% erosion or washout of the borehole was measured (Figure 1). A second test run was performed using the same mud system with 6 pounds per barrel (ppb) of gilsonite (Table 2). After a 45-hour test, the sample was removed and the borehole indicated no washout (Figure 2). There was a black film of the mineral covering the total borehole wall. Measurements indicated no softening of the shale, no filtration invasion and no exchange of cations. These results indicated the black film might have changed the membrane efficiency of the shale. Seven other tests were run using several different temperature softening points under several different test temperatures. In addition, several samples of asphalt mud systems were run for comparison purposes. The tests indicated for the best shale protection, higher softening point uintaite should be used in deeper, hotter wells, lower temperature softening point material should be used in shallow wells, and a mixture of both could work in any environment.

#### **Development of a Blended Gilsonite**

A group was formed to develop a new product which could be used in all temperature environments, contain a strong surfactant which could provide good wettability and rewettability, and would be easily dispersed in any water-based drilling fluid system. Again, the DSC was used to develop and test the final product. A very strong surfactant was developed along with a blend of different temperature uintaite, and a deflocculant additive was added for better dispersibility in the mud system. Using the blended product, a drilling fluid with the blend was circulated in the cores at various high temperatures and pressures using the DSC. Observation indicated no washout and a thin impervious film was formed on the core, a Pierre Shale sample. A field trial of the new blended mineral was conducted by Chevron in the Gulf of Mexico. The mud system was lignite/polymer and was initially treated with 2 ppb of the product and maintained with 2-5 ppb. The well was successful, reaching the total depth of 8400 feet with no problems. Hole angle averaged 21 degrees. Mud weights ranged from 9.7 to 10.7 pounds per gallon (ppg). No excessive torque or drag was encountered. Caliper logs in the open hole interval showed washout averaging 16% while surrounding wells without the blended material experienced 30-40% washouts. The test indicated that the product could minimize borehole instability, was easily dispersed in the mud system, and could maintain good wettability properties. Additional tests in the Gulf and in other areas of drilling were conducted using various other water-based mud systems and similar results were achieved. Older aged shales such as found in the Rocky Mountains and Canada indicated even lower hole washout.

#### **Shale Stability Uses**

Gilsonite for many years has been used as a shale stabilizer. One of the first reported uses was cited by Cagle and Schwertner of Amoco on wells drilled by Amoco during the late 1960's. The authors discussed the use of the mineral to stabilize water-sensitive shales in the Hackberry Field in Southwestern Louisiana. Amoco was experiencing sloughing shale problems in a long 1500 foot shale which contributed to many sloughing problems, requiring hole cleanup, especially after trips. It was found that the wells could be drilled with fewer shale problems if the mud weight was raised to 12.5 ppg. A pressure differential caused the strengthening of the formation with a hydrostatic overbalance of 3.5-ppg mud opposite a 9.0 ppg equivalent formation. Further studies by Amoco revealed that the sloughing tendencies in the shale was caused by weakening of the shale due to mud filtrate invasion of the shale through the bedding planes and microfractures. Studies of various asphalt materials by Amoco's Tulsa Research Lab indicated that uintaite was superior to the blown asphalt products, and when the correct softening point was used allowed trouble-free drilling on all but a few wells.

It was noted that after drilling wells with the mineral, no heaving shale problems occurred in these wells which used in the 12.5 ppg mud. It was decided to experiment with lower mud weights. Eventually, with the use of it, the mud weights were reduced to 9.5 ppg. As a result, with faster penetration rates, the average cost per foot was reduced by 23% for a savings of \$625,000.

On another well, in Evanston, Wyoming, borehole instability was encountered. The shale sections are normally hard and brittle, normally Cretaceous or older in age. The area is in the thrust fault zone known as the hinge line. In this part of the field, hole instability is frequently encountered. On this well, excessive torque and drag, bridges after trips, and reaming problems continued to increase. An inhibitive, KOH gypsum mud system was being used and some chemical alteration was observed from the cuttings. An on-site analysis suggested that tectonic stress was the probable cause of borehole instability problem. A hole cleaning program was initiated by first viscosifying the mud by increasing the YP from 7 to 15 lbs/ft<sup>2</sup>. Secondly, 5 ppb of the blended material was added to the system. Torque and drag was reduced substantially. Bridging and reaming after trips were no longer encountered. Within two days, hole stabilization was achieved and drilling continued without further instability problems. On other wells drilled in troublesome shale areas, mainly in the older shale rocks, blended gilsonite in concentrations of 5-6 ppb have been used in various mud systems, including

polymer muds and salt treated systems. The problems from the shales were reduced substantially.

### **Drilling Severely Depleted Sands**

A second important use of uintaite has developed over the past ten years. It has been proven to be very instrumental as a treatment to drill severely depleted sands. Drilling in the Gulf of Mexico as in other areas of the world, there have been many occasions where the increase in mud weight to control bottom hole pressures have allowed high differential pressures across exposed, lower pressure or depleted sands. The results in many cases have been differential pressure sticking, which usually occurs with differential pressures in excess of 1500 psi. Recognizing the limitations of current technology and the need for improved simulation of downhole filtration, the Drilling Fluids Section at the Chevron Drilling Technology Center and the Fann Company developed the Permeability Plugging Apparatus (PPA). The apparatus consisted of a modified high temperature filtration cell that was rated for 3000 psi pressure and 500°F temperature. The cell was modified to hold either 0.25 to 1 inch thick Berea sandstone disks or porous ceramic disks. Once developed, tests were performed to see what types of material or combination of material would be seal off the permeability and form a thin filter cake on the surface of the core. The results indicated that the mineral, because of its low solubility, could plug off the porous spaces and form an inter-matrix filter cake. The thin wall cake formed on the surface would effectively minimize differential pressure sticking. A combination of blended uintaite with types of lost circulation material such as cellulose fiber in many cases would provide the desirable treatment to eliminate sticking.

Using this type of technology in the Bay Marchand Block 2 and the South Timberlier fields, depleted sands with differential pressures in excess of 4000 psi were drilled using a pretreatment of 5-6 ppb blended gilsonite and an equal amount of fiber material. In the Bay Marchand wells the objectives were reached without any differential sticking problems. In both the 12 ¼ inch and 8-½ inch hole, casing was run after twelve depleted sands were drilled without problems. In the South Timberlier wells, in the 8-½ inch hole, a combination of gilsonite, cellulose fiber, and glass beads were used to seal off the low pressured sands with excess of 4700 psi differential. Again, no sticking problems were encountered.

In 1992, drilling in the West African Country, Nigeria, Chevron experienced 84 incidents of stuck pipe mainly in sloughing shales and differential pressured sands. A representative of Chevron's Drilling Technology Center was invited to investigate the problem. The wells had water sensitive shales, normally 3000-4000 ft thick,

which required 10.5-11.0 ppg mud weights followed by a lower pressured sandstone formation. Stuck pipe occurred in both sections resulting in high maintenance costs to resolve both problems. Various types of water-based mud systems were tried with little success in both the shales and the sandstone formations. Mud weights in excess of 11.0 ppg were required to hold back the shales. Drilling into the normal pressured sandstone formations below the shales resulted in differential pressure stuck pipe. After investigation, it was recommended that the mud system be treated with 5-6 ppb blended gilsonite prior to encountering the shales and maintaining this amount. Prior to drilling into the sandstone formation, 6 ppb of gilsonite and 6 ppb of cellulose fiber was added to seal off the formation and deposit a thin wall cake. Tests were run daily using the PPA at the company's base camp. Treatments were adjusted to insure a thin filter cake. The combination of uintaite and fiber material effectively sealed off the pore spaces and provided a thin, inter-matrix filter cake. Drilling costs dropped by \$200/foot with the elimination of these two problems.

### **Torque and Drag Reduction - Lubrication**

Tests performed in the DSC using cores of various age and hardness in a gilsonite treated mud system indicate that the blended material can reduce the effects of drilling fluid filtrate invasion. In water based mud systems, filtrate invasion can destabilize the shales and cause many problems such as sloughing shale, borehole enlargement, stuck pipe, and excess bridging during trips. Gilsonite used as a pretreatment suggested at 5.0-6.0 pounds per barrel (ppb) in any water-based mud system can reduce or eliminate these problems. The following three case histories illustrate the use of product not only as a shale stabilizer but also as a lubricant to reduce torque and drag.

In the South Pass area, offshore Louisiana, the blended material was used to reduce torque and drag. Normally, wells in this area are deviated approximately 30° from vertical and are drilled with a conventional lignosulfonate mud. On well A, conventional and bead-type lubricants were used for torque and drag reduction. On well B, 3-4 ppb of the blended material was added at approximately 10,600 feet, measured depth. By comparison, the torque on well B was reduced on an average from 1400 foot-pounds to 900 foot-pounds, a 36% reduction, and drag from 60,000 pounds to 30,000 pounds, (a 50% reduction). Caliper log comparisons from the two wells indicated substantial improvement. Another well was drilled in the Eugene Island area of offshore Louisiana. While this area is not known for borehole instability, hole enlargement, however, is a problem. Prior to the introduction of blended uintaite, hole enlargement averaged about 50% in the 12.25-inch hole. At casing point, 4 ppb of the gilsonite, suspended

in a water-based solution, were added to a conventional water-based solution. Hole enlargement in the 8-½ inch hole was reduced to an average of 15%.

These well histories confirm the results of the DSC testing of the blended mineral conducted by Chevron. First, the product, used in sufficient concentrations, provides borehole stability, reduces hole enlargement significantly, and reduces torque and drag. Secondly, it should be used as a pretreatment to seal off filtrate invasion as the virgin shale is drilled. The additive plugs microfractures, bedding planes, and pore spaces and deposits a thin film on the borehole wall which mitigates borehole erosion. It has been proposed that this film deposits an impermeable membrane which does not allow either filtrate invasion or cation exchange. In tests run on the Downhole Simulation Cell, neither filtrate invasion nor cation exchange was observed if treated prior to drilling the shale section. However, it can be used successfully even after borehole instability has occurred and will seal off the microfractures and pore spaces of the shale as shown in the above well histories.

#### **Development of a Low Invasion Core Fluid for High Permeability Sandstones**

Mud-filtrate invasion during coring operations has been a major factor affecting the validity of in-situ saturations in reservoir rock. Laboratory studies have documented the possible effects of the drilling mud filtrate invasion on the rock wettability. Considerable effort has been devoted to the measurements of relative permeability by the laboratories of major oil companies or commercial laboratories. Accurate data is quite important in the projection of future reservoirs. Many different attempts have been made to preserve the in-situ wettability by use of special coring fluids and preservation techniques at the drilling site. Considerable improvement in data reliability could be achieved if the coring mud-filtrate invasion is eliminated during coring operations.

Mud filtrate invasion of the core occurs by three mechanisms. First, filtrate invasion occurs ahead of the bit. A filtrate bank builds up at low coring rates. The invasion is relative to the core filtrate invasion velocity and the core bit velocity. Second, filtrate invasion occurs at the core bit. Filtrate is generated at high rates because of the bit cutting action. Third, static filtration will occur on the core after the core enters the core barrel. Filtrate cake permeability controls filtrate invasion in the inner barrel for all types of sandstones, especially for high permeability sandstones. During the mid 1990's, a consortium of oil and service companies sponsored a program to try to resolve the problem. A series of experiments were performed at the Terra-Tec laboratory at Salt Lake City to resolve this problem. In the past, specially designed PDC coring bits were found to

provide high coring rates<sup>5</sup>. These bits and low fluid loss oil muds were found to provide cores with significant intervals with uninvaded centers. The objective of these experiments was to find if low invasion coring fluids could be designed using water-based drilling fluids.

The results of the series of experiments indicated that a newly-designed polycrystalline-diamond compact (PDC) coring bit with a specially designed water-based mud with bridging solids could consistently minimize filtrate invasion and provide cores with uninvaded centers. One of the mud systems which provided the best results was a bland mud system using the uintaite. It was found that this type of system would generate a very low spurt loss of filtrate ahead of the bit which was eliminated by the core bit velocity. The insolubility of the uintaite sealed off the pore spaces more effectively than the more soluble asphalts and minimized filtrate invasion.

Chevron conducted several laboratory tests using this specially designed mud system in high porosity sandstone prior to several field tests. The bland mud system consisted of bentonite, CMC or PAC for fluid loss, slight amounts of caustic soda to maintain pH at 8.0 or less, and gilsonite in concentrations of 6-10 ppb depending upon the anticipated porosity of the sand interval. This combination proved to be successful in the lab as the insoluble mineral was very effective in plugging the sandstone pores at the core surface. Several successful coring operations were conducted on wells in Western Offshore Australia using this system. Invasion of the sandstone was held to a minimum with no more than 0.25-inch invasion of the core. At first, the geologists and petroleum engineers were disturbed when they found the entire core coated with a black film. However, they learned that the film was the uintaite mineral plugging the surface pore space and penetration of filtrate into the core was not deep. The system sealed off filtrate invasion. As a result, the native wettability of the cores was obtained and reliable data was obtained by the operator. The mineral was found to be the determining additive to accomplish this objective<sup>6</sup>.

#### **The Use of Gilsonite in Cementing Operations**

Gilsonite is widely and effectively used to prevent or cure loss of slurry circulation while cementing oil and gas wells. The low specific gravity of 1.05 and sealing characteristics of gilsonite provides qualities that make it effective against loss of the slurry to permeable zones, natural and induced fractures, and caverns. Since it was first introduced to the industry in 1957, more than 500 million sacks of the material have been used in cementing operations. As stated by Smith and Grant, the properties of gilsonite provide the following benefits in lost circulation applications:

- Provides low slurry density without addition of large water volumes. Compressive strengths are higher due to addition of solid particles rather than water.
- Compatible with other additives since the solid hydrocarbon is chemically inert.
- Protects against premature slurry dehydration since the material is impermeable and nonporous.
- Resists the effects of corrosive waters as well as acidic and alkaline solutions.
- Is strong enough to withstand moderate squeeze pressures, but soft enough to permit pressure deformation, thus providing an effective seal. This gives the material an advantage over ground coal, which does not compress and does not have pressure deformation characteristics.
- Effective to bottomhole temperatures of 350°F.
- Resistant to dissolution by crude oils.
- Scours uncirculated drilling mud and filter cake from borehole walls during slurry placement.

In the early testing, comparing its lost circulation benefits to other materials used, it was determined that it was twice as effective as expanded perlite. Additional tests were run and cautioned that gilsonite slurries:

- Can bridge inside tubing when a heavy slurry is pumped without proceeding it with a cushion of water
- Are not effected by speed of displacement. Tendency to bridge was the same at all velocities down the tubing
- May bridge off if cementing plugs are used under certain conditions-that is when its particles separate from the cementing system due to dilution or thinning with water.

Solubility tests indicate that raw uintaite is soluble to a certain extent in various oils, but more soluble in kerosene and certain solvents. However, the set cement protects the mineral particles as they dissolved only when in direct contact with the hydrocarbons.

Six cases were cited in the paper which illustrated the before and after effects of the use of the material in cementing operations. Successful squeeze jobs, prevention of cement fallback, and full or almost full fillup during a cement operation were obtained. These cases cited success in squeeze jobs after 15 unsuccessful attempts, successful cementing in a shallow well with severe lost circulation, reestablishment of lost circulation in wells used for a waterflooding program, squeezing off corrosive damage in oil casing, and successfully cementing in severely pressured depleted wells.

The authors provided three conclusions regarding the use of the mineral in cementing operations:

- The slurries provide effective and economical prevention and cure for loss of cement circulation.
- Gilsonite may be used in any type of cementing system, with the optimum range being between 10 to 25 lb/sack.
- The slurries have been reported to bridge in the casing when using bottom cementing plugs. While situations may vary from well to well, this should be considered by the user when high material concentrations are being planned.

### Conclusions

Gilsonite has many uses in both the oil industry and in other industries. Tests performed under downhole drilling conditions indicate its effectiveness. The mineral and asphalts should be tested in the laboratory with equipment which simulates downhole conditions. It has proven to be successful in both water-based muds and oil or synthetic based muds in solving many drilling problems. It has been used for many years to solve downhole drilling problems such as shale instability, hole washout, differential pressure sticking, filtrate invasion in sandstone and shale formations. Early tests performed in the 1970's and 1980's indicate that a blended product can more effectively solve these problems than other products such as asphalts. For best performance, especially in deep wells, a blend of high and low temperature softening point material should be used.

The prodcut has been used successfully in many cementing operations where low-density slurries are needed to minimize lost circulaion possibilities as the cement slurries are low density without additional water and have high compressive strengths.

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**Fig. 1- Pierre shale drilled with KOH lignosulfonate mud after 45 hours exposure at 180°F.**



**Fig. 2- Pierre shale drilled with KOH lignosulfonate mud and gilsonite G-A at 180°F and 45 hours exposure.**



**Table 1- COMPOSITION OF KOH LIGNOSULFONATE MUD**

Fresh Water, bbl	0.87
Caustic potash (KOH), lbm	2.6
Liognosulfonate, lbm	2.6
Lignite, lbm	5.0
Bentonite, lbm	22.0
Barite, lbm	191.0
Ground Pierre shale, lbm	40.0

**TABLE 2- COMPOSITION OF GILSONITE MUD**

Fresh Water, bbl	0.87
Caustic potash (KOH), lbm	2.6
Liognosulfonate, lbm	2.6
Gilsonite	5.0
Bentonite, lbm	22.0
Barite, lbm	191.0
Ground Pierre shale, lbm	40.0