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Evaluation of Uintaite and Asphaltic Additives in Synthetic Base Fluids

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Abstract

Uintaite is a well-known drilling fluid additive that has been used in the oil and gas industry since the 1950's. Known globally as Gilsonite, the oil and gas drilling industry has adopted it as the standard; however, in recent years products have entered the market misconstrued under the same name. Uintaite is a unique naturally occurring asphalt-like rock found exclusively in northeastern Utah, and has been proven effective as an additive in a wide range of applications. Geologically, Uintaite is part of the asphaltite family along with other natural bitumens such as grahamite and glance pitch.

A preceding study discussed Uintaite performance in synthetic based systems including its ability to comply with the United States Environmental Protection Agency (EPA) standards for discharge. This paper follows the natural progression from that study, comparing Uintaite's performance in synthetic base drilling fluids against other asphaltites and asphaltic products, commonly referred to as 'black powders'. A comprehensive evaluation was performed to understand the effectiveness of each filtration control additive on the base synthetic drilling fluids properties; while at the same time evaluating their potential impact in the original fluid formulation to comply with environmental regulation, providing rigorous technical data to assist the drilling industry in better understanding this key drilling fluids additive. This paper is intended to describe the differences between authentic Uintaite and other asphaltic products.

Introduction

Synthetic base muds (SBM) are one type of invert emulsion drilling fluids described by Park et. al. ⁽¹⁾ as where "the synthetic liquid forms the continuous phase while a brine serves as the dispersed phase". These synthetic-based fluids can be composed of linear alpha olefins, internal olefins, esters, or paraffin that are released into the marine environment as a residue on the cuttings as they are discharged. During

drilling operations, the solids in the mud system and the formation are primarily exposed to the synthetic liquid and not to the aqueous phase, preventing swelling and degradation of borehole walls.

During the SBM's early development stage the scientific and technical community also developed and introduced a range of additives that are compatible and further improve the technical and environmental virtues of SBMs. One such additive is for fluid loss control where there is a relatively small range of alternatives to choose from, including man made and natural materials. The artificial products used in the industry as fluid loss control additives are mainly synthetic polymeric products (Watson, Viste, & Lauritzen, 2012) ⁽⁴⁾, that are not as economical as the natural asphaltic additives. Several types of the latter are commonly known as 'black powders' due to the apparent color and their small particle size.

This study provides a detailed description of different asphaltic products that often tend to be confused with Uintaite. There is a wide range of asphaltic products that, due to their similar appearance and somewhat analogous laboratory performance have been recently experimented with in the industry, with various degrees of success in the field. The purpose of this descriptive analysis is to determine the similarities and differences in their technical and environmental performance, more specifically to provide information detailing their synergy with SBM components and the marine environment.

A summary of technical laboratory performance and environmental compliance for Uintaite, two other asphaltites, and one natural asphalt in a standard SBM formulation designed for deepwater operations is contained in this study. The base fluid utilized to perform the tests was actual field mud from the United States Gulf of Mexico. It must be mentioned that the base fluid tested had already been treated with a non-asphaltic filtration control additive, therefore the initial fluid loss values are relatively low.

Excluding Uintaite, the asphaltic products described here have diverse geographical origins. Like crude oil, they can be found on nearly every continent as a result of natural crude metamorphosis into a solid state where the geological environment dictated genesis. The differences are presented in **Table 1**.

Table 1- Description of Asphaltites and Natural Asphalts

	Natural Asphalt	Uintaite	Glance pitch	Grahamite
Physical Properties				
Specific Gravity @ 77F	1.4-1.45	1.01-1.04	1.10-1.15	1.12-1.50
Streak	black	brown	black	black
Lustre	dull	lustrous	lustrous	dull
Hardness, Moh's scale	1-2	2	2	2-3
Structure	homogeneous	uniform	uniform	fractured
Fracture	semi-conchoidal	conchoidal	conchoidal to hackly	hackly
Flows	190F	306F	260F-430F	intumescens
Softening point	>250F	>300F	270-375F	350-600F
Chemical Characteristics				
Soluble in CS ₂	56-67%	>99%	>95%	45-100%
Inorganic or mineral matter	36.90%	0.30%	5%	variable (up to 50%)
Fixed carbon	10.8-12%	<20%	20-30%	>30%
Ultimate Composition				
Carbon	82.33%	89.28%	80.87%	86.56%
Hydrogen	10.69%	8.66%	10.42%	8.68%
Sulphur	6.56%	<1%	9.52%	1.79%

Source: Richardson, C. (1910), and US Geological Survey bulletin (1944)

Uintaite

Boden and Tripp in their “Gilsonite veins of the Uinta basin, Utah” explain that Uintaite is a *solid hydrocarbon used mainly in drilling fluids for fluid loss control. Discovered in 1869, it is a naturally occurring non-hazardous and non-toxic mineral formed from a complex combination of different hydrocarbons. A unique natural combination rich in nitrogen and beta-carotenes while low in sulfur with a (N+S)/O ratio of 2 and an H/C ratio of 1.5, make Uintaite very special.* ⁽⁵⁾

Uintaite has been generally grouped as a form of native asphalt, although its unusual properties make it markedly different from the bitumen or asphalts which may range from liquid to definite solid form whether native or processed. More specifically, Uintaite is classified mineralogically as an asphaltite. It occurs in vertical veins rather than in beds, pools, or lakes where the bitumen and asphalts are found. (Boden and Tripp, 2012) ⁽⁵⁾

It occurs in a very pure state compared to other asphalts and has softening points ranging from 300F to 450F (150- 232C). Gilmore and Sanclemente (1989) confirm that Uintaite has been used in cementing and oil and 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. ⁽⁶⁾

Uintaite has natural differences with other asphaltic products, since it is insoluble in petroleum naphthas and contains little to no inorganic minerals. It has similar compositions to shale oil due to its origin from the kerogen in oil.

Natural Asphalts and other asphaltites

As defined by Richardson in 1910, asphaltites are naturally occurring, hard, solid bitumens whose chief constituents, asphaltenes, have very large molecules. They are grouped into three classes, namely: Gilsonite, glance pitch, and grahamite. Since all are derived from the petroleum metamorphosis. The native bitumens consist of a mixture of native hydrocarbons and small amounts of their nitrogen, sulphur and, in some cases oxygen derivatives. All asphalts and asphaltites originate in petroleum and are products of metamorphosis, influenced by the petroleum from which they are derived and the environment to which they have been exposed. ⁽²⁾

Richardson (1910), defines Grahamite as *a brittle, solid native bitumen, the result of the metamorphosis of petroleum, generally pure but at times associated with adventitious mineral matter, characterized, when pure, by a peculiar schistose fracture, which has been termed hackly. It does not melt, but merely intumescens, on the application of heat; it is soluble in carbon disulphide and only to a small extent in light naphtha, and yields a high percentage of residual coke upon ignition. It presents a regular rate of metamorphism from petroleum to grahamite, which clearly differentiates it from natural asphalt and gilsonite. Grahamite does not melt; asphalt, gilsonite and glance pitch become liquid on the application of heat. Grahamite is but slightly soluble in naphtha, whereas the other solid bitumens contain a considerable percentage which is soluble, corresponding in amount to the degree to which they have been metamorphosed.*

The grahamites yield a higher percentage of residual coke. In powder, grahamite, like asphalt and glance pitch, is black and it gives a black streak. This differentiates it sharply from uintaite, which yields a light brown powder. It does not melt readily, this alone differentiates it from all other bitumens, putting all the grahamites in a class by themselves. Grahamite is an asphaltite that varies considerably in composition and physical properties, some deposits occurring fairly pure and others are associated with considerable mineral matter, running as high as 50% (Richardson, 1910). ⁽²⁾

Glance Pitch resembles Uintaite in the external appearance, except for the streak, which is a decided brown in the case of uintaite, and black in the case of glance pitch. It also differs in having a higher specific gravity and producing a larger percentage of fixed carbon. It always has a brilliant conchoidal fracture, and a fusing-point between 250 and 350F. Glance pitch appears to be intermediate between the native asphalts and grahamite. It is probably derived from a different character of petroleum than Uintaite, having

reached a parallel stage in its metamorphosis, under approximately the same external conditions (Abraham, 1920) ⁽⁷⁾.

Asphalts are the most abundant material relevant to this study. Found in several locations globally, they present the most variability in composition and purity. For example, Saint Patrick County, Trinidad has one of the largest deposits in the world in the form a lake (Trinidad Asphalt Lake) while other sources of asphalts are man-made through refinery byproducts. Most native asphalts have high contents of organic matter and water; in order to refine it, it is normally heated to drive off the water and volatile matter. ⁽⁷⁾

Analytical Testing

Three asphaltite samples, Uintaite, sample A, sample B, plus a natural asphalt sample C, were analyzed for their physical properties and distinguishing characteristics as shown in **Table 2**. Softening point was determined using a modified version of ASTM E-28-67. Viscosity was calculated from API Recommended Practice 13B-2 Section 6.3. Fixed carbon was analyzed as a percent measured. Consistent with the bibliography, the Uintaite sample was found to have the lowest amount while samples A, B, and C had approximately 50% more fixed carbon than Uintaite.

One of the main differentiating physical properties is the Specific Gravity (SG); the internal analysis of this sample set was consistent with the theoretical values of the asphaltic products studied, with Uintaite showing the lowest SG of 1.07.

The streak test, a simple geological test for mineral identification, was also performed. A raw sample is rubbed against white porcelain showing the true color of the material, not what it appears like under reflected light in rock form. Uintaite is brown, whereas other asphaltites are black in their streak color, the same results were observed with these samples (Abraham, 1910).

Lastly, the flame test was performed using the procedure for Test 14 as detailed in *Asphalts and Allied Substances* ⁽⁷⁾. Similarly, as with other descriptive tests carried out, the Flame test also corroborated the theoretical references where uintaite, sample A, and C melted, and sample B puffed up.

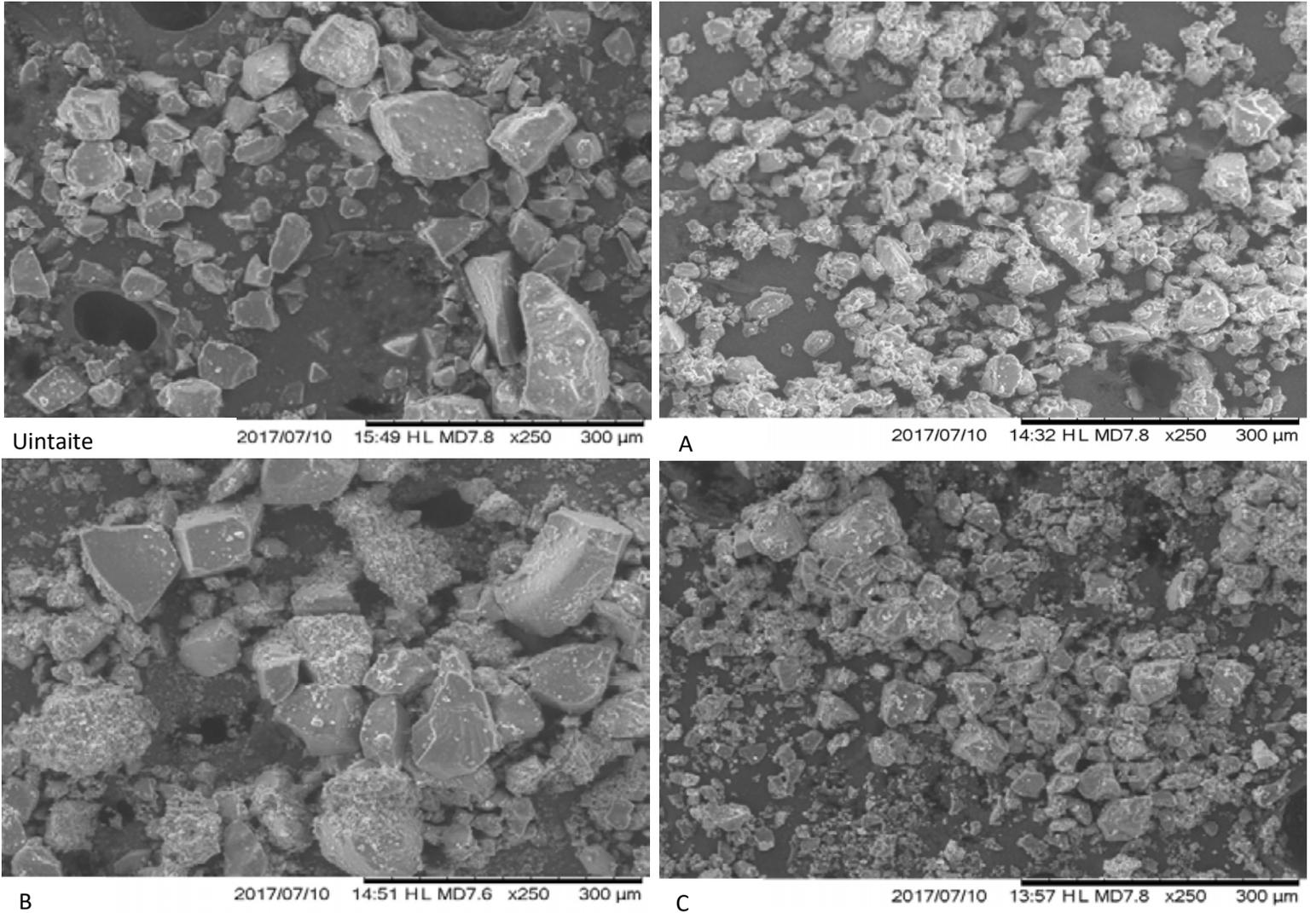
Table 2 – Samples analysis and description

Ore	S Point (°F)	Vis (cps)	FC (%)	SpGr (kg/m ²)	Streak Test	Flame Test
Uintaite	357	16,000	19.0	1.0725	Brown	Viscous melt
A	378	19,300	27.5	1.163	Black	Melts like wax
B	474	Too solid	33.9	1.130	Black	Slightly puffs up
C	424	>165,000	32.1	1.107	Black	Melts like viscous wax

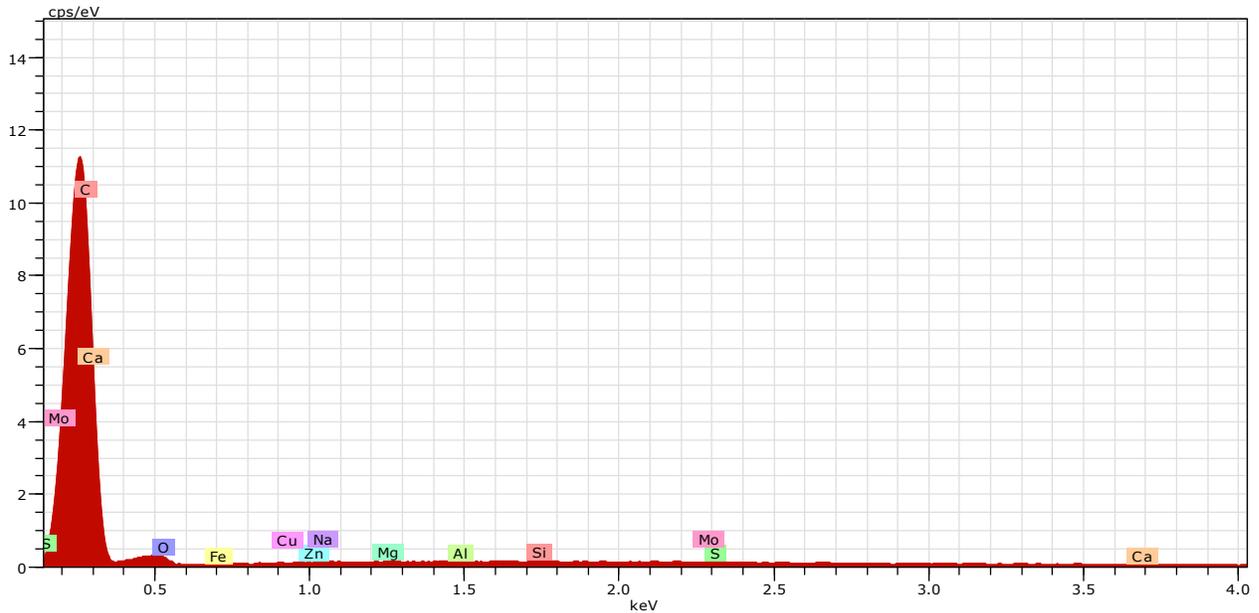
Analytical testing included the use of Scanning Electron Microscopy – Energy Dispersive Spectroscopy (SEM-EDS). The SEM images are presented in **Figure 1** and the EDS results are shown in **Tables 3, 4, 5, and 6**.

Figure 1 was obtained using a Hitachi TM 3030Plus microscope. The images clearly show that the particle size, distribution, and shape are characteristic for each asphaltic material. Uintaite, top left, presents a uniform particle size, distribution, and a characteristic polygonal particle shape. The top right image corresponds to sample A with a noticeable smaller particle size with 90% or more of the particles exhibiting irregular shapes and protrusions. The bottom left image shows sample B with uniform particle size, however, only 50% of the particles presented a polygonal shape with the remaining have less defined edges and irregular forms. Image C, bottom right, exhibits no clear shape pattern with smaller particles dispersed across the surface.

Figure 1-SEM images of Uintaite, asphaltic samples A, B, and C



The below set of graphs and tables were obtained using Bruker Quantax 70 for EDS, where samples are bombarded with a electron beam to determine the spectrometry and elemental analysis. The graphs reproduce the frequency in which each particular atom was impacted by the electrom beam, therefore inferring the abundance of each element.

Figure 2 - EDS reading of Uintaite sample**Table 3 – EDS elements from Uintaite sample**

Element	AN Series	norm. C [wt.%]	Atom. C [at.%]
Carbon	6 K-series	87.62	90.97
Oxygen	8 K-series	11.31	8.82
Zinc	30 K-series	0.45	0.09
Copper	29 K-series	0.41	0.08
Iron	26 K-series	0.22	0.05
Sulfur	16 K-series	0.00	0.00
Calcium	20 K-series	0.00	0.00
Magnesium	12 K-series	0.00	0.00
Sodium	11 K-series	0.00	0.00
Molybdenum	42 L-series	0.00	0.00
Aluminium	13 K-series	0.00	0.00
Silicon	14 K-series	0.00	0.00

In the case of Uintaite, the analysis reiterates the reference literature about this asphaltite. Uintaite has the most active carbon, relative to samples A, B, and C. Spectrum analysis showed it had the least number of elements in its composition. Carbon along with oxygen constituted the main components while only traces of zinc, copper, and iron were detected. It is important to note that sulfur was not detected in Uintaite, which is attributed to its lacustrine geological origin.

Figure 3 - EDS reading of sample A

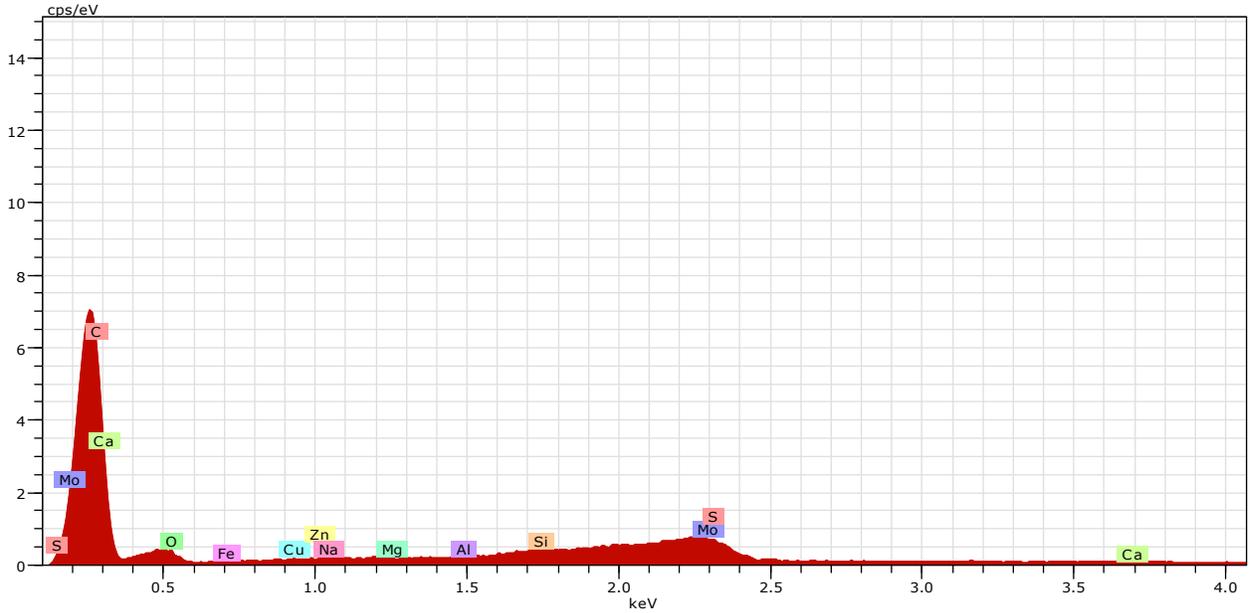


Table 4 – EDS elements from sample A

Element	AN	Series	norm. C [wt.%]	Atom. C [at.%]
Carbon	6	K-series	79.96	86.88
Oxygen	8	K-series	12.49	10.19
Sulfur	16	K-series	4.04	1.64
Silicon	14	K-series	1.78	0.83
Zinc	30	K-series	0.62	0.12
Copper	29	K-series	0.54	0.11
Iron	26	K-series	0.17	0.04
Calcium	20	K-series	0.17	0.05
Sodium	11	K-series	0.15	0.08
Magnesium	12	K-series	0.07	0.04
Aluminium	13	K-series	0.02	0.01
Molybdenum	42	L-series	0.00	0.00

Figure 3 and **Table 4** above correspond to sample A. EDS did not detect as high of carbon content with a lower percentage of atomic contribution from carbon and oxygen. Sulfur was found to be the third most abundant element in this sample, along with nine other elements, indicating different geological genesis and higher impurities content.

Figure 4 - EDS reading of sample B

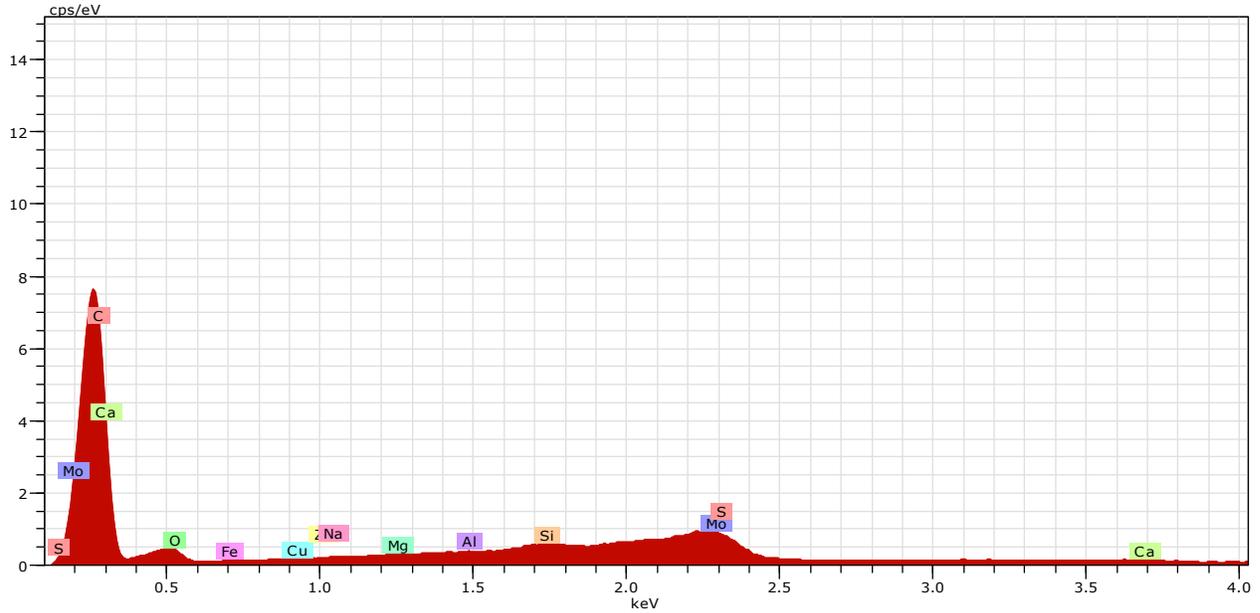


Table 5 – EDS elements from sample B

Element	AN	Series	norm. C [wt.%]	Atom. C [at.%]
Carbon	6	K-series	78.75	86.32
Oxygen	8	K-series	12.20	10.04
Sulfur	16	K-series	3.66	1.50
Silicon	14	K-series	2.32	1.09
Molybdenum	42	L-series	1.00	0.14
Calcium	20	K-series	0.73	0.24
Aluminium	13	K-series	0.64	0.31
Magnesium	12	K-series	0.48	0.26
Sodium	11	K-series	0.14	0.08
Iron	26	K-series	0.08	0.02
Copper	29	K-series	0.00	0.00
Zinc	30	K-series	0.00	0.00

The graph and table above show the results obtained for sample B. Like sample A, the carbon activity is lower than Uintaite's, although in this case the presence of sulfur is more prevalent, along with other elements such as molybdenum and silicon.

Figure 5 - EDS reading of sample C

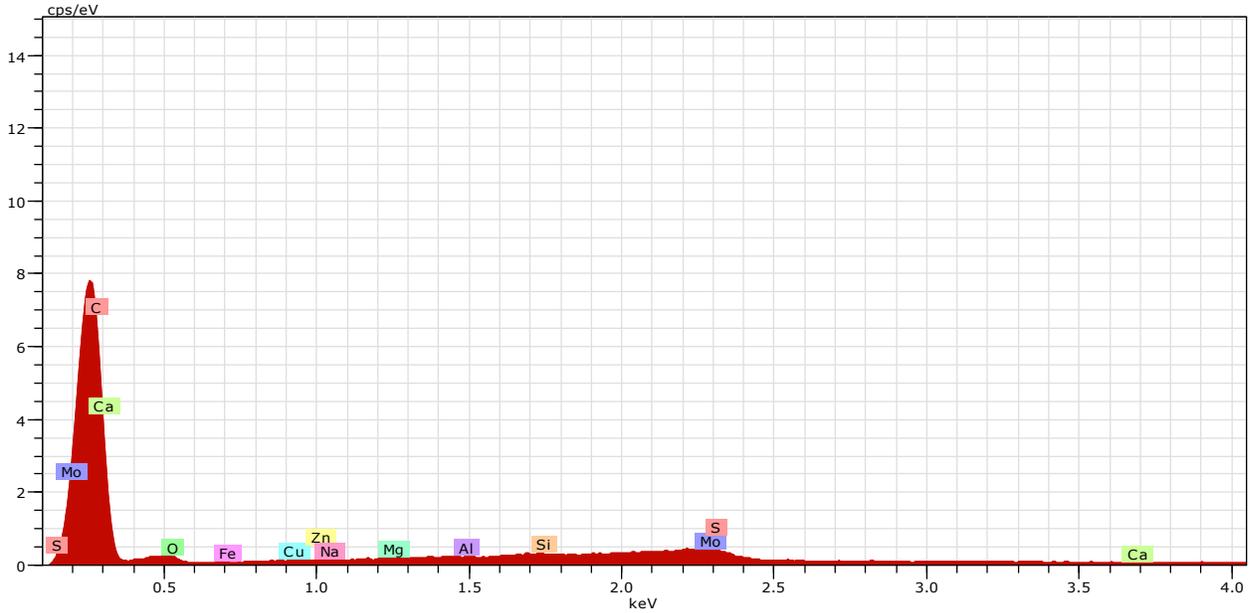


Table 6 – EDS elements from sample C

Element	AN	Series	norm. C [wt.%]	Atom. C [at.%]
Carbon	6	K-series	85.89	90.76
Oxygen	8	K-series	9.52	7.55
Sulfur	16	K-series	2.26	0.89
Silicon	14	K-series	1.07	0.48
Zinc	30	K-series	0.53	0.10
Copper	29	K-series	0.44	0.09
Aluminium	13	K-series	0.14	0.07
Iron	26	K-series	0.12	0.03
Magnesium	12	K-series	0.05	0.02
Molybdenum	42	L-series	0.00	0.00
Sodium	11	K-series	0.00	0.00
Calcium	20	K-series	0.00	0.00

Figure 5 and Table 6 above correspond to sample C. Carbon activity is comparatively lower than Uintaite’s and with relatively high sulfur content as well. Silicon indicates the presence of mother rock in which natural asphalts are normally impregnated to before morphing into a solid state.

Fluids Performance

Uintaite’s performance in all types of drilling fluids formulations is well proven and recognized. However, synthetic and special base fluids are an area where this additive is not widely utilized due to the industry paradigm regarding black powders, fueled by the lack of technical information. Although Uintaite’s malleability is well known for stabilizing sloughing shales through pore space penetration, micro fractures and bedding planes (Boden & Tripp, 2012) ⁽⁵⁾, other non-asphaltic fluid loss control additives have been predominantly utilized in special applications like ultra high temperature, deep-water, and sensitive environmental areas.

Uintaite improves drilling fluid properties due to its unique characteristic as a low-density material that bonds with clays and other solids to improve wellbore stability, thus preventing differential sticking and formation damage. As a result, Uintaite has been universally employed in wellbore strengthening; its “smear effect” on non-permeable formations and bonding characteristics make it highly effective at controlling lost circulation and strengthening the overall wellbore. (Boden & Tripp, 2012) ⁽⁵⁾

Extensive laboratory testing was performed to determine behavior in synthetic base fluids. The tests were completed utilizing actual field mud. The tests were aimed to demonstrate these asphaltites’ behavior in a SBM and their effectiveness to improve key drilling fluid properties such as rheology, fluid loss and emulsion stability. Keeping in mind that environmental compliance is paramount for any discrete drilling fluid additive as well as the SBM, a complete set of environmental testing was carried out in parallel, for all four samples.

To perform the tests, the mud samples were hot rolled at 250F for a period of 16 hours to three weeks, and a complete set of drilling fluids properties tests were carried out including electrical stability, rheological profile, and HPHT fluid loss. The table below summarizes the battery of tests performed:

Table 7-Tests performed

PRODUCT (ppb)	T-1	T-2	T-3	T-4	T-5
SBM - blank	1 equivalent barrel				
UINTAITE		6			
A			6		
B				6	
C					6

All samples were prepared and tested in accordance with API RP 13B-2: Recommended Practice for Field Testing of Oil-based Drilling Fluids. The field SBM was obtained from Gulf of Mexico wells with a density of 13 PPG.

Sample Mixing/Aging

Laboratory mixers controlled with Variacs were used to mix the mud components into 350mL (1-barrel equivalent) samples for testing at 250F. Maintaining a constant vortex, 6 grams of asphaltites were thoroughly mixed for at least ten minutes. Each 350mL sample was loaded into an Aging Cell, pressurized with 50 psi of nitrogen for aging, and placed in the roller oven to condition at temperature for desired time. After the mud sample was cooled and re-mixed, it was tested for rheology, fluid loss and electrical stability. The same samples were used throughout this study and after each analysis were mixed at ambient temperature before hot rolling again. The HPHT fluid loss results as well as the rest of the relevant drilling fluids properties are shown in **tables 8, 9, 10, 11, and 12.**

Table 8 – Mud tests before hot rolling

RESULTS	BLK	UINTAITE	A	B	C
Plastic Viscosity (cP)	34.5	18.6	42	26.3	27.4
Yield Point (lbs/100ft ²)	21.8	23.3	28.6	48.6	56.4
Electrical Stability (V)	491	501	533	536	540
Gels 10" (lbs/100ft ²)	17	16.8	15.7	15.8	84.9
Gels 10' (lbs/100ft ²)	33.6	35.8	32.1	32.4	73.7

Table 9- Mud tests after 16 hours hot rolling

RESULTS	BLK	UINTAITE	A	B	C
Plastic Viscosity (cP)	31.4	39.3	35.5	31.7	33.7
Yield Point (lbs/100ft ²)	10.8	12.8	15.3	18.5	13.3
HTHP Filtration (mL)	5.6	1.8	2.4	3	4.9
Electrical Stability (V)	232	220	252	337	268
Gels 10" (lbs/100ft ²)	15.2	10.5	13.7	16.6	44.4
Gels 10' (lbs/100ft ²)	27.3	29	28.4	29.8	27.6

Table 10 – Mud test after 1-week hot rolling

RESULTS	BLK	UINTAITE	A	B	C
Plastic Viscosity (cP)	31.9	37.7	37.5	30.6	36.4
Yield Point (lbs/100ft ²)	10.5	14.3	11.9	20.9	14.3
HTHP Filtration (mL)	2.3	1	0.9	1.2	3.3
Electrical Stability (V)	225	270	343	290	192
Gels 10" (lbs/100ft ²)	15	18.6	12.7	17.4	31.3
Gels 10' (lbs/100ft ²)	30.5	28.4	28.9	38.4	42.2

Table 11- Mud test after 2-weeks hot rolling

RESULTS	BLK	UINTAITE	A	B	C
Plastic Viscosity (cP)	26.1	39.3	34.9	34.4	35.8
Yield Point (lbs/100ft ²)	23.3	10.9	14.2	14	11.6
HTHP Filtration (mL)	2.4	1.2	1.8	2.2	2.3
Electrical Stability (V)	300	327	359	337	243
Gels 10" (lbs/100ft ²)	32.5	11.4	13.3	23	41.9
Gels 10' (lbs/100ft ²)	47.3	29	26.2	63.8	27.1

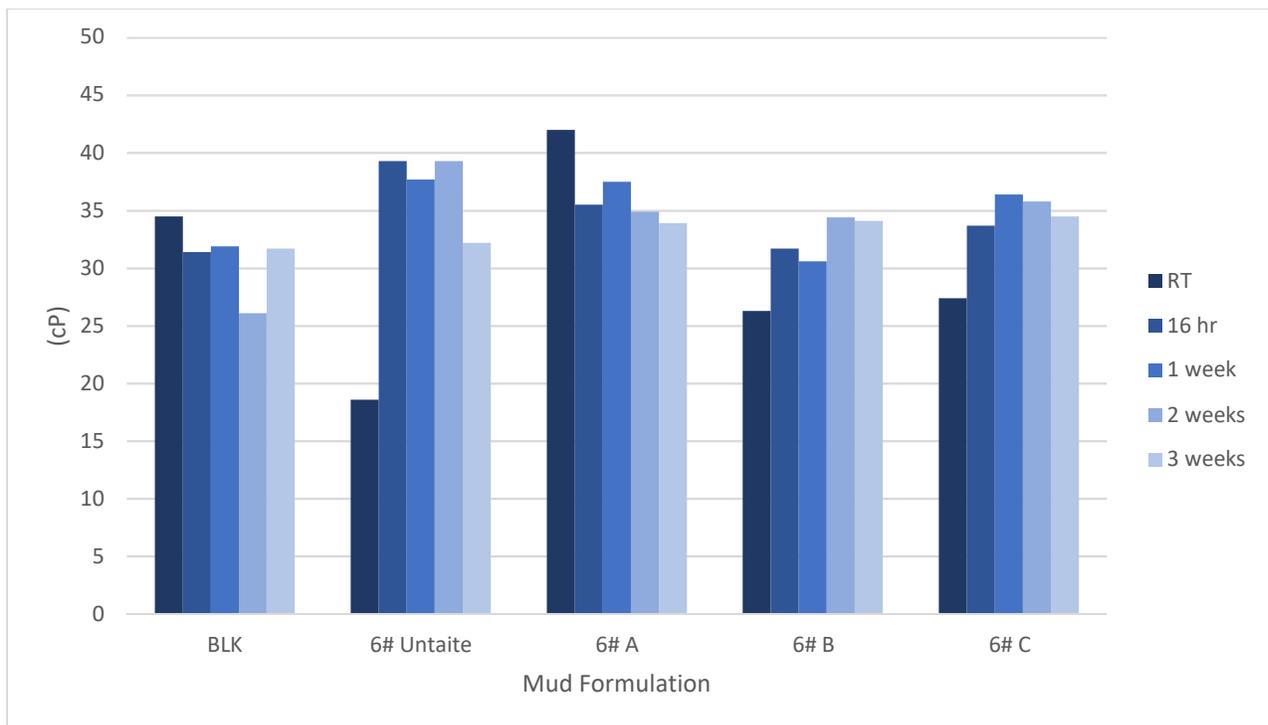
Table 12- Mud test after 3-weeks hot rolling

RESULTS	BLK	UINTAITE	A	B	C
Plastic Viscosity (cP)	31.7	32.2	33.9	34.1	34.5
Yield Point (lbs/100ft ²)	13.2	15.4	17.9	15.4	16.9
Electrical Stability (V)	327	312	353	401	241
Gels 10" (lbs/100ft ²)	22.7	12	14	56	16
Gels 10' (lbs/100ft ²)	27.7	28.4	26.5	29.9	89.1

Rheology

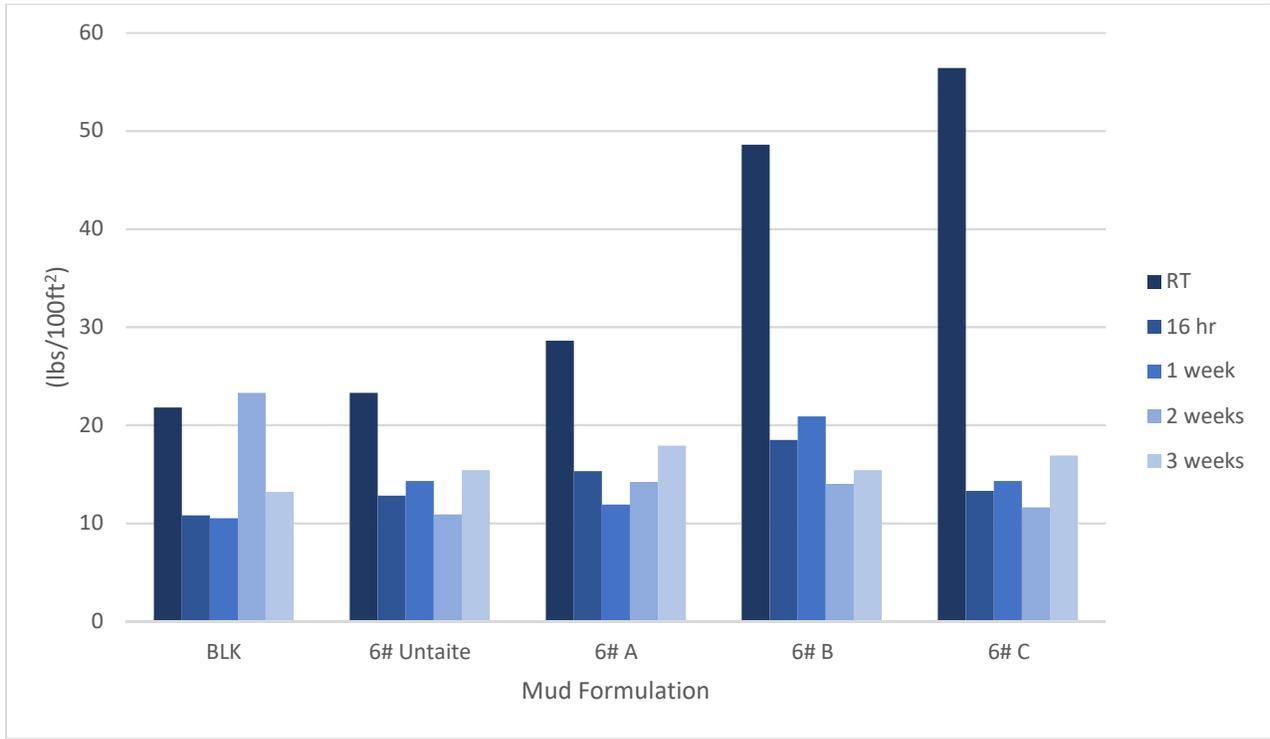
Rheology readings were done using Viscometers Model 900 for 600 RPM and 300 RPM at 150F in accordance with API RP 13B-2 Section 6.3. The plastic viscosity, yield point, 10-second gel strength, and 10-minute gel strength were also calculated.

After aging, rheology trends were similar amongst all samples and stabilized over the course of the three-week study given that this mud system is designed to have stable rheological properties.

Figure 6 – Plastic Viscosity at 150F

The range of plastic viscosity (PV) values was 18.6 to 39.3 cP from initial mixing to three weeks at 250F. The slightly higher values can be attributed to the addition of the solid asphaltite materials. It is important to note that no additional treatment was performed in the SBM.

Figure 7 – Yield Point at 150F



The yield point (YP) values were initially high overall but decreased after aging 16 hours at temperature. The YP ranged from 21.8 to 83.3 lbs/100ft² after room temperature mixing. After aging there was a slight yield point increase over time with values spreading from 10.5 to 25.4 lbs/100ft². Mud with no additives, the control, typically gave PV and YP values at the low end of these data sets.

Figure 8 - 10-second Gel Strength at 250°F

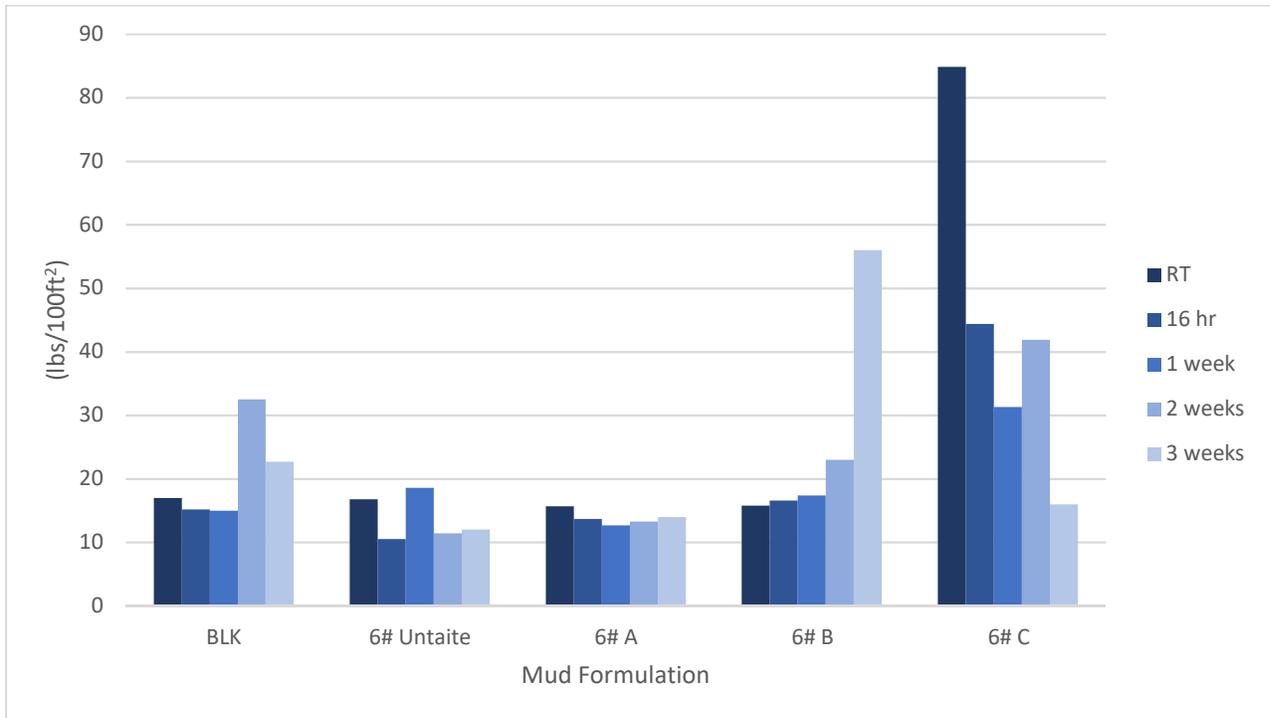
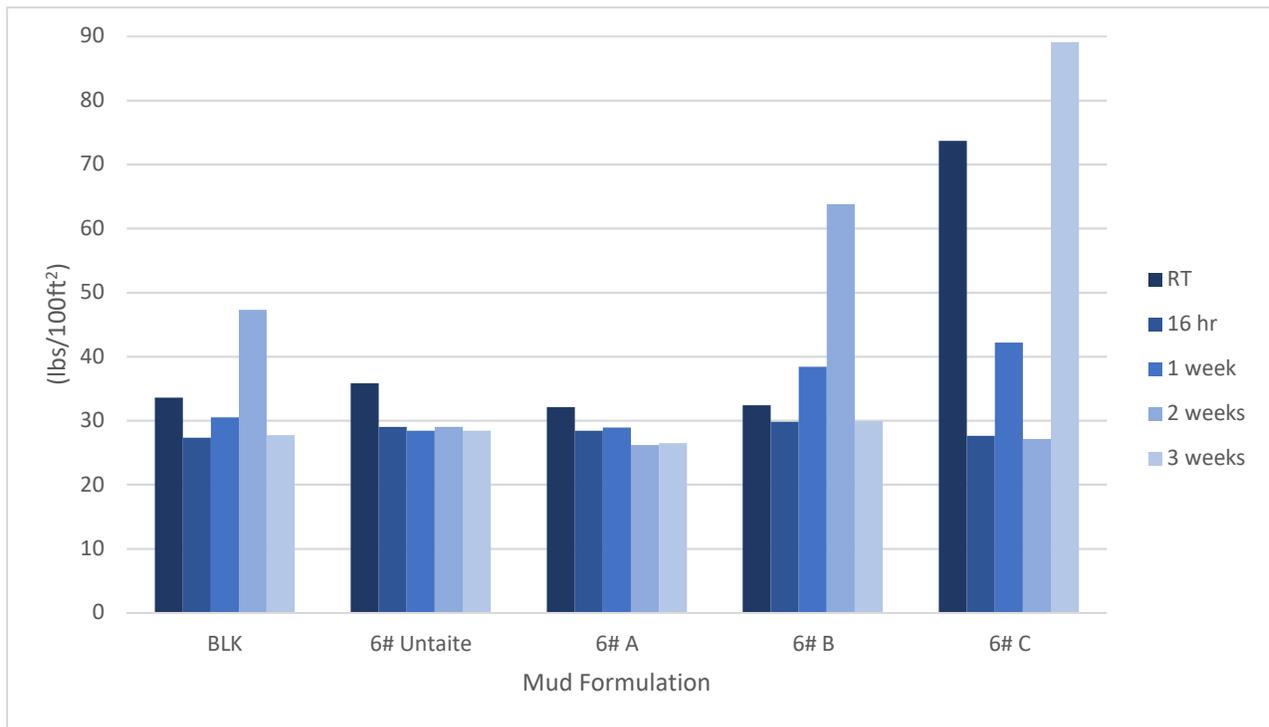


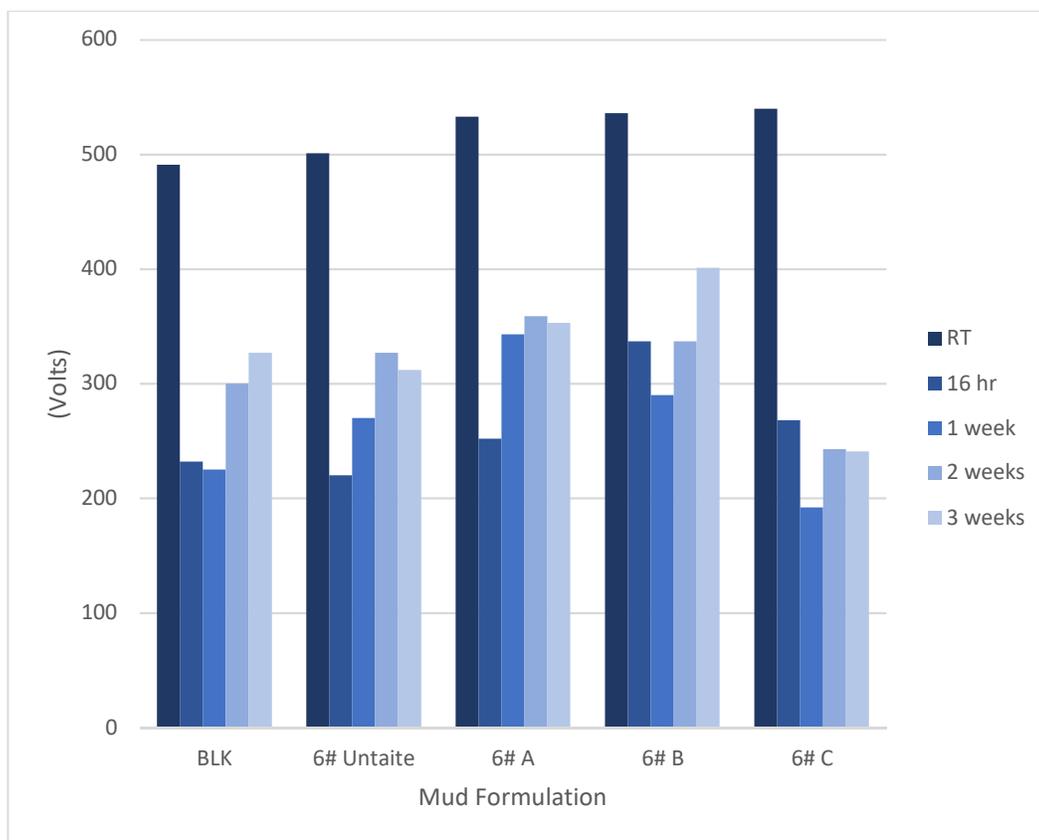
Figure 9 - 10-minute Gel Strength at 250°F

The gel strength was where differentiation occurred between the samples, which was most evident in the ten-minute results. The Blank, base SBM, had relatively constant 10” and 10’ values from pre-aging up to one week at 250F but then spiked after two weeks which could be an indication of the fluid beginning to destabilize. SBM B steadily increased in gel strength over time while SBM C was more erratic, therefore both asphaltite additives worsened the SBM performance. In contrast, SBM Untaite and SBM A saw an improvement through their stabilized 10” and 10’ gel strengths which could help extend the life of the mud.

Electrical Stability

The strength of the emulsion was determined at 150F following API RP 13B-2 Section 10 with the Electrical Stability Meter. The electrical stability (ES) measurements can be correlated to the rheological data above. All samples were 491 to 540 V pre-aging and then followed the trend of PV and YP. SBM Untaite, SBM A, and SBM B showed similar or increased stability over the blank SBM while an ES decline in SBM C was evident due to the emulsion breakdown by three weeks.

Figure 10 - Electrical Stability at 150F



HPHT Filtration

Fluid loss was measured through high-pressure high-temperature (HPHT) fluid loss at 250F. The equipment and method used was a 4-Unit HPHT Filter Press with 175mL threaded HPHT Cells in conformance with API RP 13B-2 Section 7.2. The delta pressure was maintained at 500psi throughout testing and the filtration media used was 2.5” Specially Hardened Filter Paper for Filter Presses. Time was observed with a stopwatch and initial spurt and 30-minute fluid loss volumes were collected and measured in graduated cylinders.

Fluid loss was analyzed after 250F aging for 16 hours, 1 week, and 2 weeks. Testing after three weeks was not done as there would be a negligible amount to record due to the previous filtrates not being remixed into each sample, which also explains the decrease in fluid loss with each increase in aging time. The Blank mud had the highest initial filtration of 5.6 mL which was to be expected as it did not contain any of the asphaltic products; the treated samples had a range of filtration reduction from 13% to 67% after 16-hour aging. Interestingly after 1-week SBM C had a 43% increase relative to the Blank while SBM Untaite, SBM A, and SBM C still improved fluid loss. The results after 2-weeks showed SBM B and SBM C with filtrate amounts more similar to the Blank and minimal reduction of only 4% to 8%, whereas SBM Untaite and SBM A still significantly decreased fluid loss 25% to 50%. SBM Untaite consecutively had the least amount of filtration and the greatest reduction of fluid loss overall. It should also be noted that water separation in the filtrate was observed with the Blank SBM and SBM C, which indicates emulsion breakdown, as seen in **tables 11 and 12**.

Figure 11 - HPHT Fluid Loss at 500psi - 250F

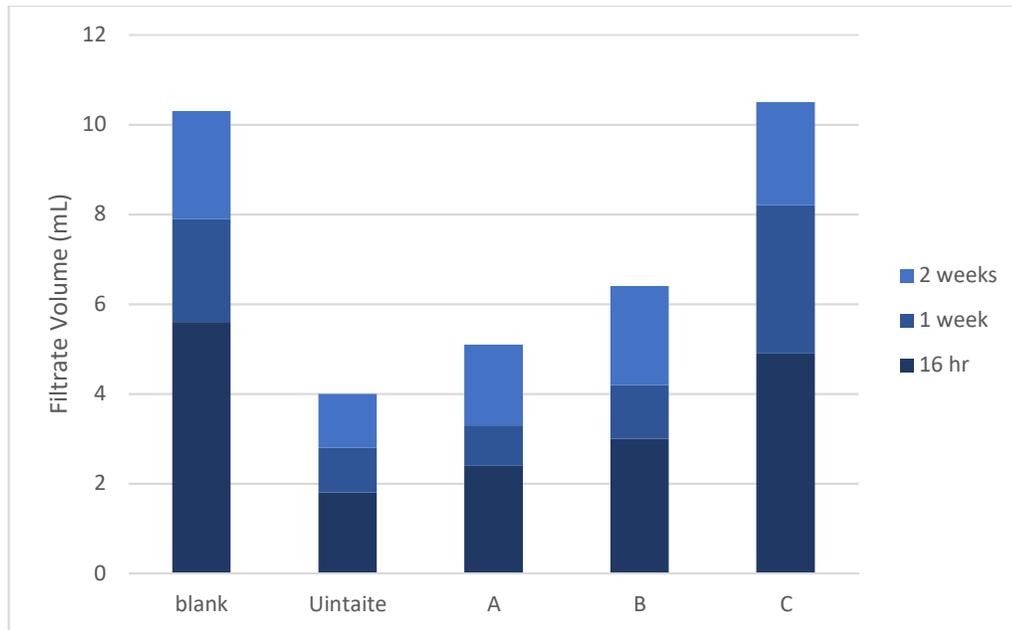
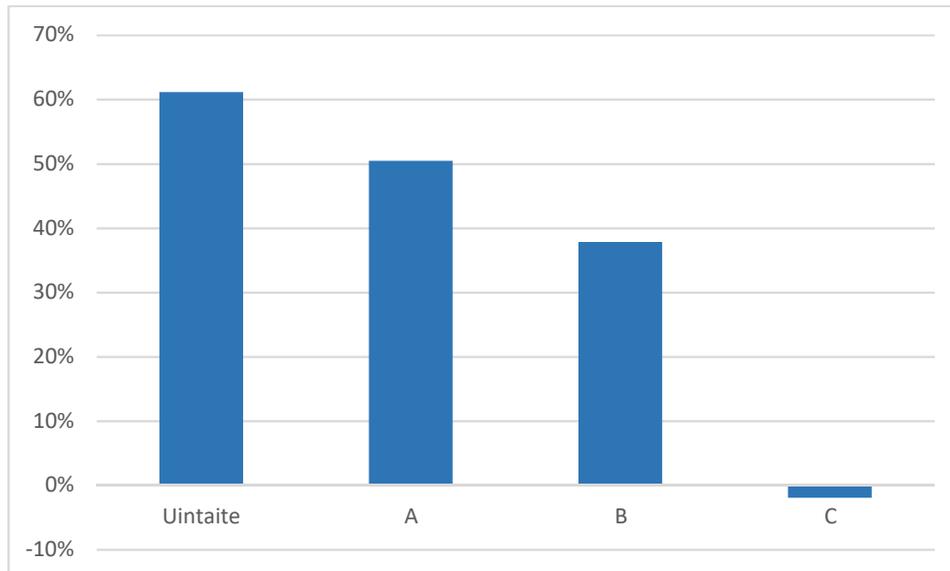


Figure 12 - Cumulative HPHT Fluid Loss % Improvement Versus Untreated Sample



In summary, through testing these four additives in synthetic based mud it was determined that Uintaite provided suitable results improving performance of the blank SBM the greatest. SBM A performed the second best in all tests, however consistently 15-25% below Uintaite's performance. SBM B and SBM C both notoriously underperformed, particularly SBM C in HPHT fluid loss tests.

Environmental Analysis

While these asphaltic products’ overall performance in SBM formulations is key to determine its value as an additive in these types of fluids, environmental compliance is the aspect that qualifies the product for its use in SBM and especially offshore deep-water environments. Therefore, in parallel to the traditional drilling fluid properties testing, a complete and exhaustive set of environmental tests were carried out to determine the potential effects, if any, in synthetic based mud. The tests were performed in a certified third-party laboratory, following EPA guideline EPA-821-B-00-013 ⁽⁸⁾.

All environmental tests were carried out utilizing field SBM used in the deep-water United States Gulf of Mexico with 6ppb asphaltic additives concentrations as well as without any additives (witness). These include: Static Sheen, 96-hour LC50 Aquatic Bioassay, Gas Chromatography Mass Spectrometry (GC/MS), and Sediment Toxicity (SedTox).

Table 13 - EPA Discharge Requirements for SBM and actual test results

EPA Test	Requirement to Pass	SBM	SBM Uintaite	SBM A	SBM B	SBM C
Static Sheen	No Change	No Change	No Change	Change	Change	Change
LC-50 Aquatic Bioassay	LC50 > 30,000 ppm SPP	571,300	>600,000	>600,000	247,200	259,200
GC/MS	Crude Oil < 1.0%	0.107	0.100	0.098	0.092	0.104
Sed - Tox	STR < 1.0	0.9	0.8	3.3	0.9	1.6

Static Sheen Test

This test is intended to indicate presence of free oil when drilling fluid, drilled cuttings, deck drainage, well treatment fluids, completion and workover fluids, produced water or sand, or excess cement slurry are discharged into offshore waters. Two types of sheen tests are mandated by EPA under NPDES permits and analyzed under EPA Method 1617. The visual sheen test consists of an observation made when surface and atmospheric conditions permit watching the ocean water for a sheen around the point where the discharge entered the water. When the conditions do not permit visual observations, a static sheen test is mandated by NPDES permits and the protocol published by USA. This test uses sea water in a shallow pan not more than 30 cm deep with 1000 cm² surface area. Either 15 cm³ of fresh mud or 15 grams fresh cuttings are injected below the surface of the water. An observer watches for up to 1.0 hour for a silvery, metallic, colored or iridescent sheen. If sheen covers 50% or more of the area it does not pass, and the mud or cuttings cannot be discharged. ⁽⁸⁾

In the Static Sheen test there was no change in the witness SBM or SBM containing Uintaite. Notably, in the SBM with asphaltites A, B, and C there was a change which resulted in a fail for all samples tested except Uintaite.

96-hour LC50 Aquatic Bioassay

In EPA Method 1619 aquatic toxicity is measured by fish bioassay. A waste can be tested for this criterion by placement in a test water tank and introducing one of three acceptable fish species: fathead minnows, rainbow trout or golden shiners. Aquatic toxicity waste is hazardous by aquatic toxicity if a 96-hour LC₅₀ is less than 500 mg/liter. EPA specifies the use of the 96-hour test duration for point-of-

discharge monitoring to allow operators to continue drilling operations while the sediment toxicity test is being conducted on the discharge drilling fluid.

96-hour $LC_{50} < 500$ mg/L = acute aquatic toxicity.

Compliance target is an $LC_{50} \geq 30,000$ ppm SPP.

SPP = Suspended Particulate Phase of 1 part mud to 9 parts seawater mixture.

As seen in **Table 13**, all samples passed the Static 96-hour LC_{50} Toxicity Test. The SBM had a baseline LC_{50} of 571,300 ppm SPP while both Uintaite and SBM A were greater than 600,000 ppm SPP. SBM B and SBM C were both lower with LC_{50} of 247,200 and 259,200 ppm SPP, respectively, but still well above the minimum requirement.

Gas chromatography mass spectrometry (GC/MS)

GC/MS is an analytical method in environmental testing that combines the features of gas chromatography and mass spectrometry to identify oil contaminants within a non-aqueous drilling fluid sample through separating oil components in the gas chromatograph and detection by the mass spectrometer. Qualitative analysis is first done to detect the presence of any crude oil and then quantitative assessment to determine concentration using the total ion chromatograph and extracted ion profile scans in accordance with EPA Method 1655.

From the GC/MS method it was determined that there was only a trace amount of crude oil contamination in each sample tested, therefore all samples passed well below the 1.0% limit. The results were comparable and all in the 0.1% range for the base SBM and SBM with asphaltite, showing that these asphaltic additives had no effect on oil contamination.

Sediment Toxicity (SedTox) Test

This test is used to measure the effect of the SBM coated cuttings on the sea floor. It uses *Leptocheirus plumulosus*, a common shrimp species in aquatic environments, as the test organism. The test consists of exposing the Leptos to a mixture of SBM and a formulated (man-made) sediment. The sediment is mixed with a base fluid following EPA Method 1646 and the SedTox determined using EPA Method 1644. LC_{50} value for the reference drilling fluid divided by the LC_{50} value for the submitted SBM sample equals the STR (SedTox Ratio).

The compliance limit for an STR is ≤ 1.0 .

Static 96-hour Sediment Toxicity was also performed and had distinctive results. The witness SBM, SBM Uintaite, and SBM B were under the STR limit of 1.0. Witness SBM and SBM B both had a STR of 0.9, while SBM Uintaite had a 0.8 STR. Both the SBM A and SBM C increased the Sed-Tox and consequently failed with ratios greater than 1.0. SBM A was a STR of 3.3 and SBM C was 1.6.

Environmental testing of the asphaltic additives was completed to further differentiate performance in synthetic based mud. Through this set of analysis, it was determined that not all the additives tested would be approved for use in areas with strict environmental regulations such as deepwater. Being that the Blank is a field sample currently being used, it successfully passed the tests. Uintaite also met the standard for each EPA requirement including Static Sheen, Aquatic Toxicity, GC/MS Oil Contamination, and Sediment Toxicity. SBM A failed on both the Static Sheen and SedTox. SBM B did not perform in the Static Sheen test. SBM C was similar to SBM A in that it also was unsuccessful in the Static Sheen and Sediment Toxicity.

Conclusions

From this investigation the following can be concluded:

- Using physical and chemical characterization, Uintaite and other asphalt-like materials can be identified and differentiated from each other.
- Due to its unique origin, Uintaite presents unvarying physical and chemical properties along with the highest purity, whereas other asphaltic products have higher variability in their properties.
- Uintaite presents a synergistic behavior when used in SBM, in addition to improving the overall mud properties, the HPHT fluid loss was improved by up to 60%. Other asphaltites do not seem to positively influence the overall SBM properties, and while HPHT fluid loss improvement was observed, it was not as marked as with Uintaite.
- Sample C did not improve HPHT fluid loss and produced a destabilization in the SBM formulation.
- Only Uintaite passed all required EPA environmental tests for deep-water discharge. The three other asphaltic products, or ‘black powders’ failed.
- Technical performance and environmental compliance make Uintaite a proven economical, environmentally acceptable solution for fluid loss control in SBM formulations.

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Nomenclature

EPA = Environmental Protection Agency in the United States

PV = Plastic Viscosity

YP = Yield Point

SBM = Synthetic Base Mud

HPHT = High Pressure, High Temperature

HT = High Temperature

LC-50 = Lethal Concentration required to kill 50% of the population

RPE = Reverse Phase Extraction

GCMS = Gas Chromatography Mass Spectrometry

NPDES = National Pollutant Discharge Elimination System

SedTox = Sediment Toxicity

STR = SedTox Ratio

SPP = Suspended Particulate Phase