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Barite Quality and Retort Low Gravity Solids Analysis: Making a Case for Accurate Reporting

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Abstract

Barite quality is important to drilling fluid performance because low grade barite products introduce increased amounts of low gravity solids (LGS) for any application and the increased LGS are not accounted for under current industry practices. This reduces the quantity of drilled LGS that can be entrained before the drilling fluid properties begin to degrade, increases the quantity of dilution required to maintain a stable fluid with acceptable properties, and adds to the overall quantity of waste generated. The economic evaluation of using low grade barite for drilling fluids is not straightforward and the source of this additional contamination is often not recognized in field operations (Scott and Robinson, 2010). After grinding low-grade barite ore to meet American Petroleum Institute (API) specifications, the low-density contaminants (silica, aluminum oxide, soluble carbonate or sulfide) are liberated and exist as separate particles, no longer interlocked with barite in the particles.

Industry practice for solids analysis calculations ignores this issue and underreports the quantity of low gravity solids in drilling fluids which use low grade barite by using the specific gravity (SG) of the low-grade barite in the calculations. The author will present data that illustrates this issue and will propose calculations and methods that allow more accurate reporting of low gravity solids. In addition, industry opinions often hold that retort methods and solids analysis in general are not accurate. This paper will discuss more accurate retort equipment and how current API gravimetric procedures and calculation methods serve to increase the quality of retort data.

Introduction

Barite is the common name for barium sulfate (BaSO4), a high-density mineral used primarily as a weighting additive in drilling fluids. While it is used for other purposes, drilling fluids account for over 85% of the total worldwide barite ore production and consumption (Bleiwas and Miller, 2015). It is well suited as a weighting additive for drilling fluids due to its low solubility, low hardness (Mohs hardness of 3-3.5 which limits abrasion and erosion) and high density, sufficient to formulate drilling fluids to the density required for oil and gas drilling. Due to technical and economic factors, there is no large-scale alternative to barite for drilling fluids (McRae, 2024)

Low Grade Barite

Barite is a principal component of most drilling fluids, and its quality affects drilling fluid cost, performance, dilution requirements, and overall waste volumes. Barite is often sourced from the lowest cost option and minimally processed, such that lower quality products are increasing being used for drilling fluids. It is not uncommon to see fluids providers proposing low grade barite products with SG values of 3.9 for unconventional reservoir land operations (Offenbacher, et al., 2023).

Barite occurs in various locations around the world with the purity of the ore and the contaminating minerals dependent on the source. Mining practices generally produce the higher SG ore first with lower grade material being produced later as the higher SG ore is depleted. Pure barium sulfate has a specific gravity of 4.50. While drilling-grade barites have historically been >4.2, current API 13A specifications include both 4.2 and 4.1 grades.

Quartz is the most common contaminant in low grade ores, followed by carbonate or sulfide minerals. Examples of x-ray diffraction of several 4.1 SG samples are shown in Table 1.

Table 1: X-ray diffraction analysis

Sample	XRD Quartz %	XRD Barite %	Clay & Mica %	Other %	Measured SG	Calculated SG XRD
4.1 SG Barite A	19.0	81.0	0.0	0.0	4.10	4.14
4.1 SG Barite B	12.0	84.0	0.0	4.0	4.13	4.20
4.1 SG Barite C	19.0	76.0	4.0	1.0	4.10	4.05
4.1 SG Barite D	15.0	85.0	0.0	0.0	4.12	4.20
4.1 SG A-D Average	16.3	81.5	1.0	1.3	4.11	4.15
4.2 SG Barite Lab Stock	13.0	84.0	0.0	3.0	4.20	4.20

For drilling fluids applications, barite ore is ground to the API 13A specification such that >97% is less than 200 mesh (74 microns) or finer. This size is below what mineral processors call the “liberation size”, the size at which there are individual high SG barite particles (free of contaminants) and the non-barite contaminants as individual low gravity particles.

As can be seen from the data in Table 2 for a 3.78 SG low grade ore, as the ore is ground finer and finer the percentage of interlocked grains is reduced to near zero at a grind size similar to API barite (MPD, 2004). This means that when added to the

drilling fluid there are discrete high gravity particles (SG ~4.5) and discrete low gravity particles, even though these low gravity particles added with the low grade barite go unreported.

Table 2: Liberation of barite particles after grinding

Grind Size (mesh)	Free Barite %	Free LGS %	Interlocked Grains %
<10 to >14	4.00	10.00	86.00
<14 to >20	7.82	12.29	79.89
<20 to >28	8.05	15.52	76.43
<28 to >35	10.81	38.61	50.58
<35 to >48	16.05	40.30	43.65
<48 to >60	41.93	40.52	17.55
<60 to >100	46.36	45.05	8.59
<100 to >150	53.30	44.22	2.48
<150 to >200	57.20	40.50	2.30
<200	60.00	40.00	<2

The significance of this phenomena is that it does allow for additional processing to produce a higher quality product, although few companies use these additional upgrading processes. Upgrading processes include flotation, magnetic or electrostatic separation, and other more conventional crushing, washing and jigging methods. This is supported by the fact that Magcobar (Magnet Cove Barium Company, Magnet Cove, Arkansas and the M in M-I Swaco beginning in 1939 processed 3.8 SG low grade ore using flotation to produce a drilling fluid grade product with a specific gravity of up to 4.35 (slb 2012, Brobst, 1958) and continued to produce API quality barite from this mine up until 1977. Baroid operated a similar low grade barite mine at the nearby Chamberlain mine with flotation processing at Malvern, Arkansas.

After grinding to API grind size, these unreported LGS are of a size (97% <74 microns) that make removal by solids control equipment difficult and uneconomical. Any separation method used in an effort to remove these fine LGS will also discard barite and an associated quantity of mud.

The quantity of low gravity solids contained in low grade barite is simple to calculate from a mass and volume balance. The volume percent LGS contained in low gravity barite increases about 5% for every 0.1 change in SG. Table 3 shows the quantity of low gravity solids in barite grades between 4.2 and 3.9.

Table 3: Volume % and Weight % LGS in Barite

SG Barite	4.2	4.1	4	3.9
Volume % LGS	15.8%	21.1%	26.3%	31.6%
Weight % LGS	9.8%	13.4%	17.1%	21.1%

Low Gravity Solids

The term low gravity solids (LGS) is used as a surrogate for drilled solids. However, reported LGS values usually include added mud products as well as drilled solids, yet exclude the non-barite contaminants in the low grade barite. Low grade barite contaminants include quartz, carbonate minerals (calcite and siderite), sulfide and sulfate minerals (pyrite/pyrrhotite, gypsum, anhydrite, and celestite), hematite and other trace minerals.

LGS concentrations are the primary metric used to monitor having an adequate dilution rate to maintain acceptable fluid properties and stability. While it is outside the scope of this paper, it is not only the concentration of LGS, but also the type and size of solids that affect properties and stability. For instance, there is a strong correlation between both thermal stability and the tolerance to contamination with the concentration of solids below 2 microns being above 20%.

High concentrations of LGS adversely affect not only fluid properties and stability, but also rate of penetration, drilling fluids costs, annular pressure losses/equivalent circulating density, surge/swab pressures, gel strengths and pressure required to break circulation, fluid loss and filter cake thickness, torque and drag, tendency for stuck pipe, potential for lost circulation, and potential for poor mud displacement during cementing (Robinson, 2006; Guo et al., 2014; Judzis et al., 2007; Black et al., 2008).

The target concentration of LGS is usually specified in mud programs and on mud reports as an indication of an acceptable level of incorporated drill solids for having acceptable fluid properties and stability. It is the primary value used to adjust dilution rates. While the target LGS value depends on many factors, commonly specified values are 5-10% for water based systems and occasionally up to 15% for nonaqueous based fluids. These values are not adjusted based on the SG of barite being used and the associated increase in unreported LGS for low grade barite. The industry practice for calculating LGS is to use the density of the barite grade instead of the density of pure barite such that the added LGS from the barite grade is not reported. A more accurate calculation for the true concentration of both barite and low gravity solids would be to use the density of pure barite, 4.5.

For example, a 14 lb/gal mud built with 3.9 SG low grade barite starts with an additional unreported 4% LGS as compared to using a 4.2 SG barite and 7.4% below the true LGS content.

Figure 1 and Table 4 show the actual volume percent of LGS that comes from various grades of barite for a mud with a liquid phase with an SG 1.0 and no drilled solids. Having the increased concentration of LGS reduces the quantity of drilled LGS that can be entrained before the drilling fluid properties begin to degrade, increases the quantity of dilution required to maintain a stable fluid with acceptable properties, and adds to the overall quantity of waste generated.

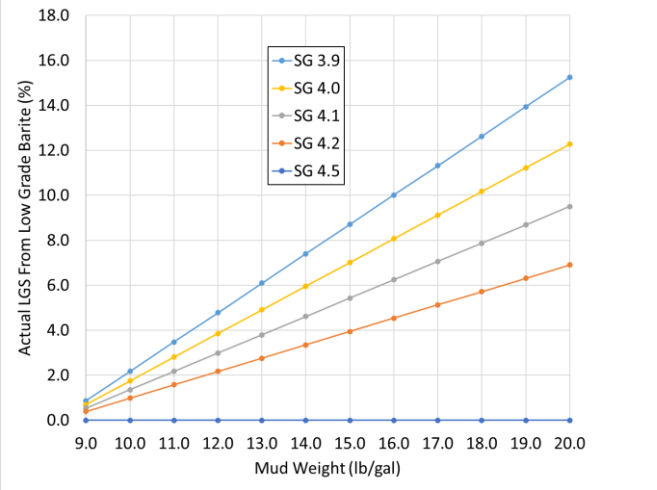

Figure 1 – Actual LGS From Low Grade Barite vs MW

Table 4 - Actual LGS From Low Grade Barite vs MW

Mud Wt	Volume % LGS				
lb/gal	SG 4.5	SG 4.2	SG 4.1	SG 4.0	SG 3.9
9.0	0.0	0.4	0.5	0.7	0.9
10.0	0.0	1.0	1.4	1.8	2.2
11.0	0.0	1.6	2.2	2.8	3.5
12.0	0.0	2.2	3.0	3.9	4.8
13.0	0.0	2.8	3.8	4.9	6.1
14.0	0.0	3.4	4.6	6.0	7.4
15.0	0.0	3.9	5.4	7.0	8.7
16.0	0.0	4.5	6.2	8.1	10.0
17.0	0.0	5.1	7.1	9.1	11.3
18.0	0.0	5.7	7.9	10.2	12.6
19.0	0.0	6.3	8.7	11.2	13.9
20.0	0.0	6.9	9.5	12.3	15.2

Low Gravity Solids Calculations

Solids analysis are based on a mass balance as shown in Equation 1 in conjunction with a volume balance shown in Equation 2. Substitution yields Equation 3 for the volume percent low gravity solids.

$$V_{MUD} \times \rho_{MUD} = V_{HGS}\,\rho_{HGS} + V_{LGS} \times \rho_{LGS} + V_{AQ} \times \rho_{AQ} + V_{NAF} \times \rho_{NAF} \quad (1)$$

$$V_{MUD} = V_{HGS} + V_{LGS} + V_{AQ} + V_{NAF} = 100\% \quad (2)$$

$$V_{LGS} = \frac{[(100-V_{AQ}-V_{NAF})\times\rho_{HGS}+V_{AQ}\times\rho_{AQ}+V_{NAF}\times V_{NAF}-100\times\rho_{MUD}]}{\rho_{HGS}-\rho_{LGS}} \quad (3)$$

Industry practices are and API standards indicate (by example) to use the SG for whatever grade of barite is being used in these calculations. As has been stated multiple times, this underreports the true LGS in the mud and causes reported LGS between wells using different grades of barite to not be directly comparable and to be misleading.

Making a case for accurate reporting of LGS

The use of the LGS content as the criteria for adjusting dilution and gauging fluid health is universal in the drilling industry with the acceptable limits being listed in all drilling fluids programs. While the drilled-solids tolerance depends on the fluid type, it makes no sense to ignore the LGS added from low grade barite. While it may not be a major issue for very low density fluids, clearly the differences for medium to high density fluids should be considered. For medium density fluids the starting LGS content can be 2-9% higher than for a 4.2 SG barite and should be considered for the specified LGS in the mud program.

Using a SG of 4.5 is an engineering sound change and would allow the industry to accurately report the LGS content regardless of the grade of barite being used. Liberation and flotation examples support the fact that for API grind sizes, the particles are either near pure barite with an SG of about 4.5 or particles of low gravity contaminants similar in density to most drilled solids.

Retort Accuracy

Retorts are used for drilling fluid reporting and for solids analysis. A common industry opinion is that field retort methods and solids analysis are not accurate. These inaccuracies come mainly when smaller 10 mL and 20 mL retorts are being used and from "missing mass" or reading errors (Morgenthaler, et al, 2016). Volumetric methods are the most widely used method in the field and in laboratory evaluations and use the observed volume of condensed water and NAF to determine retort solids content and no quality check is made for the potential missing mass.

API Subcommittee 13 studied this issue and adopted a 50 mL retort gravimetric method based on lost mass in the 5th Edition of RP 13B-2 in 2014 for oil-based muds. This method uses the mass of dry solids after retorting, density of the water, oil, and drilling fluid, plus the observed volume of condensed water collected in the more precise JP tube. This gravimetric procedure requires a mass balance of ±3% to limit inaccuracies from lost mass. Interlab testing from 5 laboratories showed that when using this method that the standard deviation for the volume of oil was 0.22 percent and standard deviation for the solids volume was 0.28 percent as compared to 1.04 and 6% respectively for a volumetric procedure. A similar gravimetric method is expected to be adopted for water based fluids.

Conclusions

The current industry practice of calculating low gravity solids using the specific gravity of the barite grade being used underreports the true volume of low gravity solids.

The normal barite grind size for drilling fluids is below the size at which individual particles exist as either pure barite or lower gravity contaminants.

The use of lower grades of barite introduces additional low gravity solids which are ground to a size that make them difficult or uneconomical to remove.

Changing solids analysis equations to use the specific gravity of barite as 4.5 would allow the true low gravity solids content of the fluid to be reported more accurately.

Nomenclature

Variables:

ρ_{AQ} = density aqueous phase
ρ_{HGS} = density high gravity solids
ρ_{LGS} = density low gravity solids
ρ_{MUD} = density drilling mud
ρ_{NAF} = density nonaqueous fluid
V_{AQ} = volume fraction aqueous phase
V_{HGS} = volume fraction high gravity solids
V_{LGS} = volume fraction low gravity solids
V_{MUD} = volume fraction drilling muds (100%)
V_{NAF} = volume fraction nonaqueous fluid

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