

**A New View  
of  
Downhole Losses**

# Costliest Problem with SBM's

- Lost Circulation
  - Running casing/liners
  - Cement displacement
  - Drilling

# Some Factors Impacting Losses

- PFFG operating window
- Pipe running speed
- Displacement annular velocities
- LCM selection
- **Deviation**

# Deviation

- Current fluid engineering emphasis
  - Barite sag
  - Cuttings beds/hole cleaning
  - Dynamic sag
- What effect is settling having on the LCM ?
  - What is the settling velocity ?
  - Is the LCM treated fluid homogenous ?

# LCM Products used in DWP

- Calcium Carbonate
  - 50, 150, 300, (600 in 1999)
- Graphite
  - G-Seal
  - SteelSeal
  - LC Lube
    - All supplied by Superior Graphite
- Ground Rubber
  - Pipe Rubber –TSF Rather only

# Settling Velocity

$$v_S = \frac{g (\rho_P - \rho) D_P^2}{18 \mu}$$

particle diameter

fluid viscosity

As the diameter of a particle doubles its settling rate increase by a factor of 4

# Settling Velocity Model

(From the Internet)

**Input:**

<b>Property</b>	<b>Value</b>	<b>Units</b>
<b>Particle size</b>		<b>microns</b>
<b>Particle density</b>		<b>kg m<sup>-3</sup></b>
<b>Fluid density</b>		<b>kg m<sup>-3</sup></b>
<b>Fluid viscosity</b>		<b>Pa s</b>



**Output:**

Meters sec<sup>-1</sup>

Accuracy and plausibility of this model have been discussed and agreed upon with Dr. David Power – M-I rheologist and Dale Jamison Baroid creator of DFG DrillAhead hydraulics program, *to use as a relative comparison of particle settling*. The only dispute was that M-I preferred a viscosity of 5-10 centipoise while Baroid wanted 10-15,000 centipoise. 10,000 centipoise was used for the modeling because it more accurately reflects empirical data.

# Output from the settling model

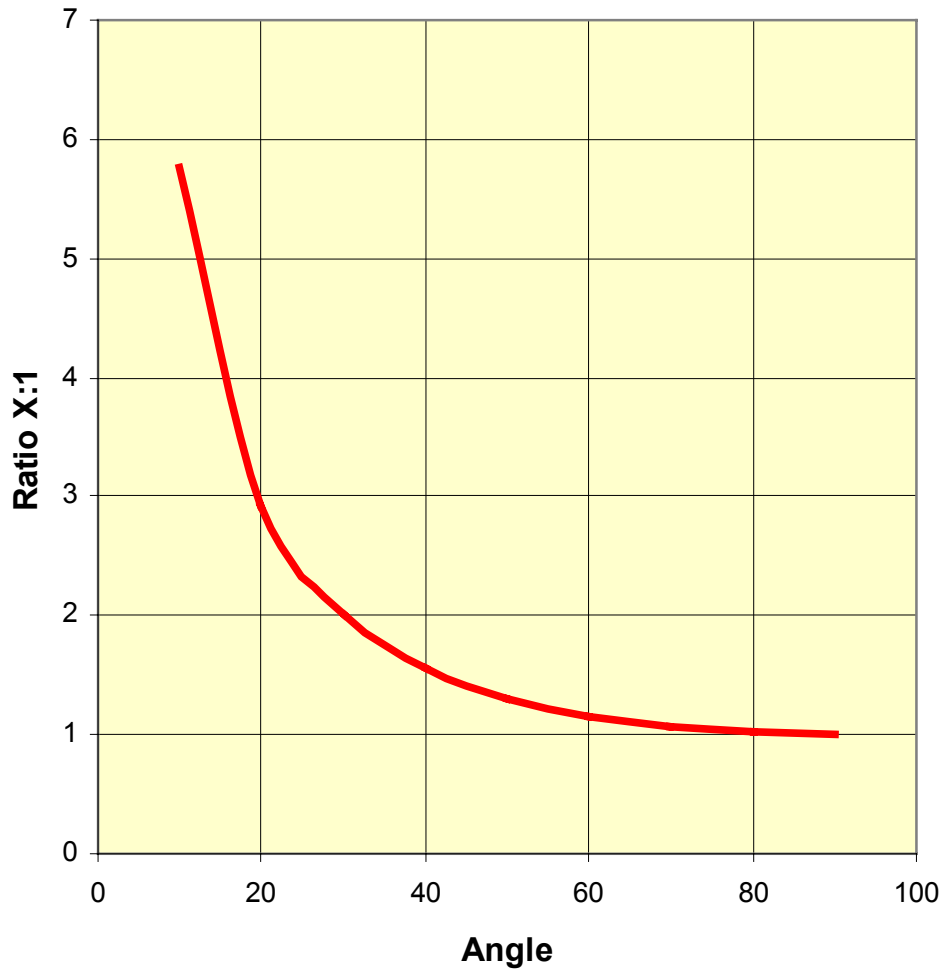
Product			Mud Density ppg	Viscosity Pa s	Settling Velocity m s <sup>-1</sup>
microns	SG	ppg			
<b>Calcium carbonate</b>					
10	2.6	21.7	11.66	10	0.00000001
50	2.6	21.7	11.66	10	0.00000016
100	2.6	21.7	11.66	10	0.00000066
150	2.6	21.7	11.66	10	0.00000148
200	2.6	21.7	11.66	10	0.00000262
250	2.6	21.7	11.66	10	0.0000041
300	2.6	21.7	11.66	10	0.0000059
<b>Graphite</b>					
50	1.7	14.2	11.66	10	0.00000004
100	1.7	14.2	11.66	10	0.00000017
150	1.7	14.2	11.66	10	0.00000037
200	1.7	14.2	11.66	10	0.00000066
250	1.7	14.2	11.66	10	0.00000103
300	1.7	14.2	11.66	10	0.00000149
350	1.7	14.2	11.66	10	0.00000202
400	1.7	14.2	11.66	10	0.00000264
<b>Barite</b>					
10	4.2	35.0	11.66	10	0.00000002
45	4.2	35.0	11.66	10	0.00000031
<b>Pipe Rubber</b>					
50	1.2	9.53	11.66	10	-0.00000003
100	1.2	9.53	11.66	10	-0.00000011
200	1.2	9.53	11.66	10	-0.00000043
300	1.2	9.53	11.66	10	-0.00000097
400	1.2	9.53	11.66	10	-0.00000172

10 Pa s equals 10,000 cps

# Converted to Oilfield Values

Product	Settling - Inches per hour				
microns	1	24	36	48	72
<b>Calcium carbonate</b>					
10	0.0	<b>0.0</b>	0.1	0.1	0.1
50	0.0	<b>0.5</b>	0.8	1.1	1.6
100	0.1	<b>2.2</b>	3.4	4.5	6.7
150	0.2	<b>5.0</b>	7.6	10.1	15.1
200	0.4	<b>8.9</b>	13.4	17.8	26.7
250	0.6	<b>13.9</b>	20.9	27.9	41.8
300	0.8	<b>20.1</b>	30.1	40.1	60.2
<b>Graphite</b>					
50	0.0	<b>0.1</b>	0.2	0.3	0.4
100	0.0	<b>0.6</b>	0.9	1.2	1.7
150	0.1	<b>1.3</b>	1.9	2.5	3.8
200	0.1	<b>2.2</b>	3.4	4.5	6.7
250	0.1	<b>3.5</b>	5.3	7.0	10.5
300	0.2	<b>5.1</b>	7.6	10.1	15.2
350	0.3	<b>6.9</b>	10.3	13.7	20.6
400	0.4	<b>9.0</b>	13.5	18.0	26.9
<b>Barite</b>					
10	0.0	<b>0.1</b>	0.1	0.1	0.2
45	0.0	<b>1.1</b>	1.6	2.1	3.2
<b>Pipe Rubber</b>					
50	<b>0.0</b>	<b>-0.1</b>	<b>-0.2</b>	<b>-0.2</b>	<b>-0.3</b>
100	<b>0.0</b>	<b>-0.4</b>	<b>-0.6</b>	<b>-0.7</b>	<b>-1.1</b>
200	<b>-0.1</b>	<b>-1.5</b>	<b>-2.2</b>	<b>-2.9</b>	<b>-4.4</b>
300	<b>-0.1</b>	<b>-3.3</b>	<b>-4.9</b>	<b>-6.6</b>	<b>-9.9</b>
400	<b>-0.2</b>	<b>-5.9</b>	<b>-8.8</b>	<b>-11.7</b>	<b>-17.6</b>

## Settling Depth Hole Size to Angle

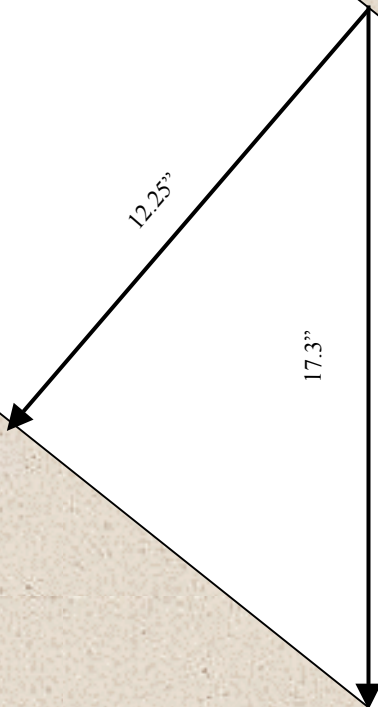


Angle	20	40	60
Hole OD	Settling Depth (in)	Settling Depth (in)	Settling Depth (in)
20	58.5	31.1	23.1
17	49.7	26.4	19.6
14.75	43.1	22.9	17.0
12.25	35.8	19.1	14.1
10	29.2	15.6	11.5
8.5	24.9	13.2	9.8
6.5	19.0	10.1	7.5
6	17.5	9.3	6.9
4.5	13.2	7.0	5.2

11.7 ppg fluid  
10,000 cps viscosity

**Example: 12 ¼" hole**

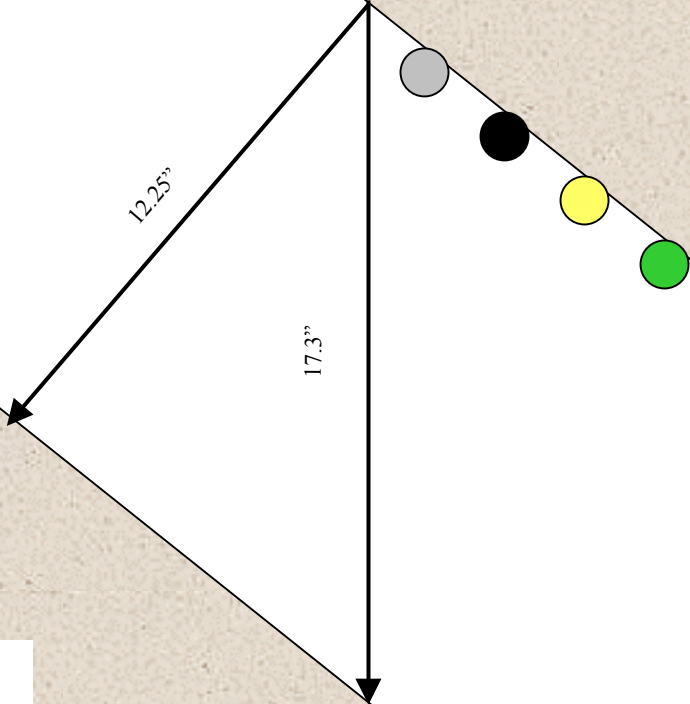
Angle	45
Hole OD	Setting Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4



11.7 ppg fluid  
 10,000 cps viscosity  
 150 micron CaCO<sub>3</sub>  
 250 micron graphite  
 45 micron barite  
 300 micron rubber

**Example: 12 ¼" hole**  
**Settling times of 24, 36, 48 hrs**

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4



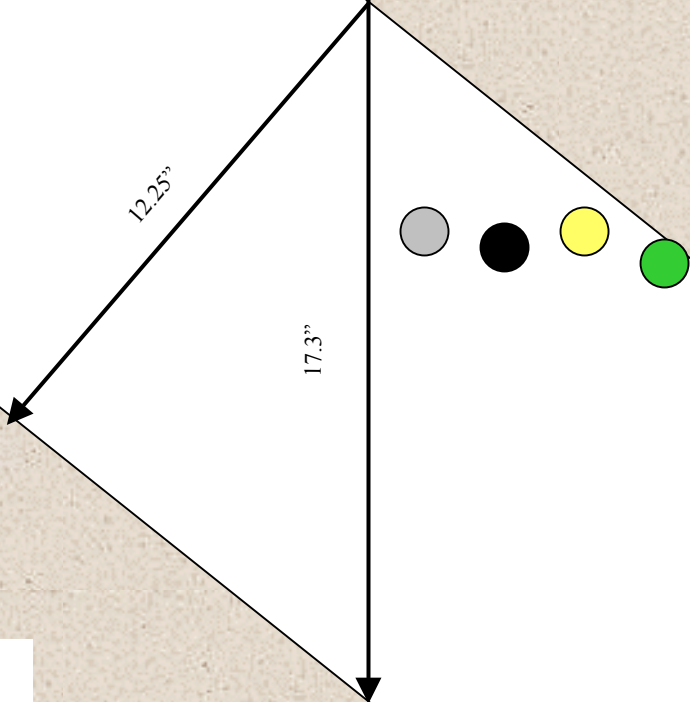
- calcium carbonate
- graphite
- barite
- rubber





11.7 ppg fluid  
 10,000 cps viscosity  
 150 micron CaCO<sub>3</sub>  
 250 micron graphite  
 45 micron barite  
 300 micron rubber

**Example: 12 ¼" hole**  
**Settling times of 24, 36, 48 hrs**

**24 hrs**

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4



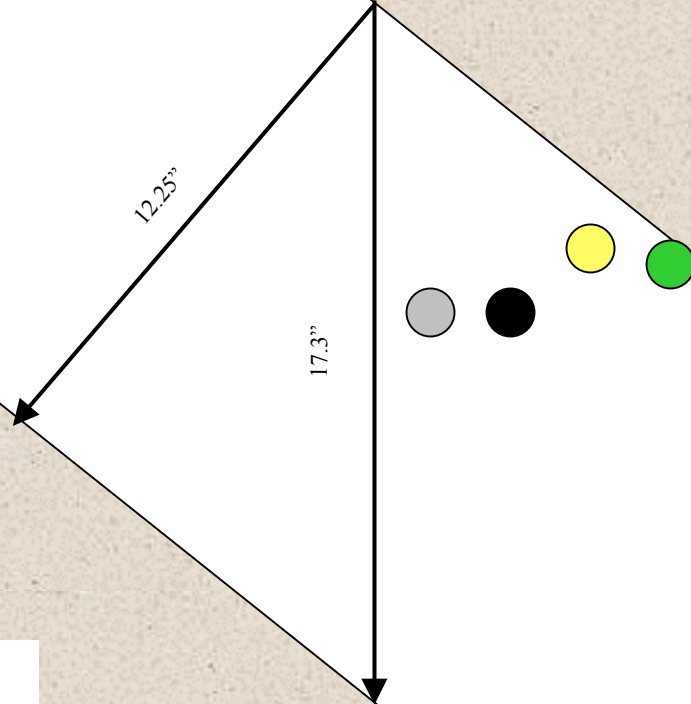
- calcium carbonate 
- graphite 
- barite 
- rubber 

11.7 ppg fluid  
10,000 cps viscosity  
150 micron CaCO<sub>3</sub>  
250 micron graphite  
45 micron barite  
300 micron rubber

**Example: 12 ¼" hole**  
**Settling times of 24, 36, 48 hrs**

**36 hrs**

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4



**calcium carbonate** 

**graphite** 

**barite** 

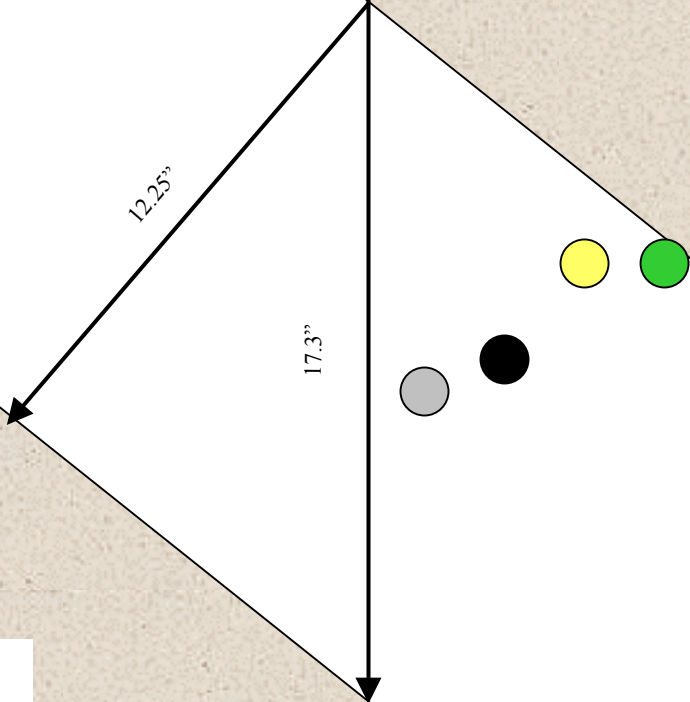
**rubber** 





11.7 ppg fluid  
 10,000 cps viscosity  
 150 micron CaCO<sub>3</sub>  
 250 micron graphite  
 45 micron barite  
 300 micron rubber

**Example: 12 ¼" hole**  
**Settling times of 24, 36, 48 hrs**

**48 hrs**

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4



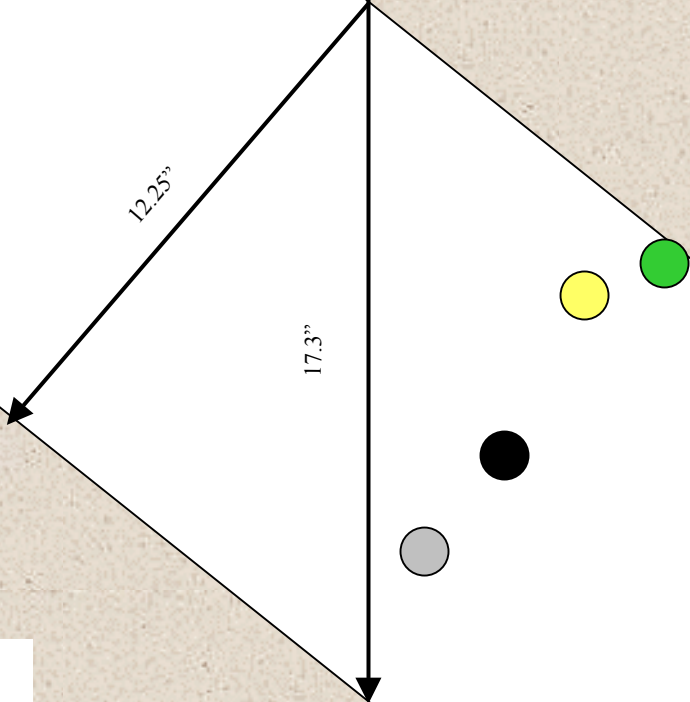
- calcium carbonate 
- graphite 
- barite 
- rubber 





11.7 ppg fluid  
 10,000 cps viscosity  
 150 micron CaCO<sub>3</sub>  
 250 micron graphite  
 45 micron barite  
 300 micron rubber

**Example: 12 ¼" hole**  
**Settling times of 24, 36, 48 hrs**

**72 hrs**

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4



- calcium carbonate 
- graphite 
- barite 
- rubber 

11.7 ppg fluid  
10,000 cps viscosity

Example: 12 ¼" hole  
Settling times of 24, 36, 48 hrs

graphite

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4

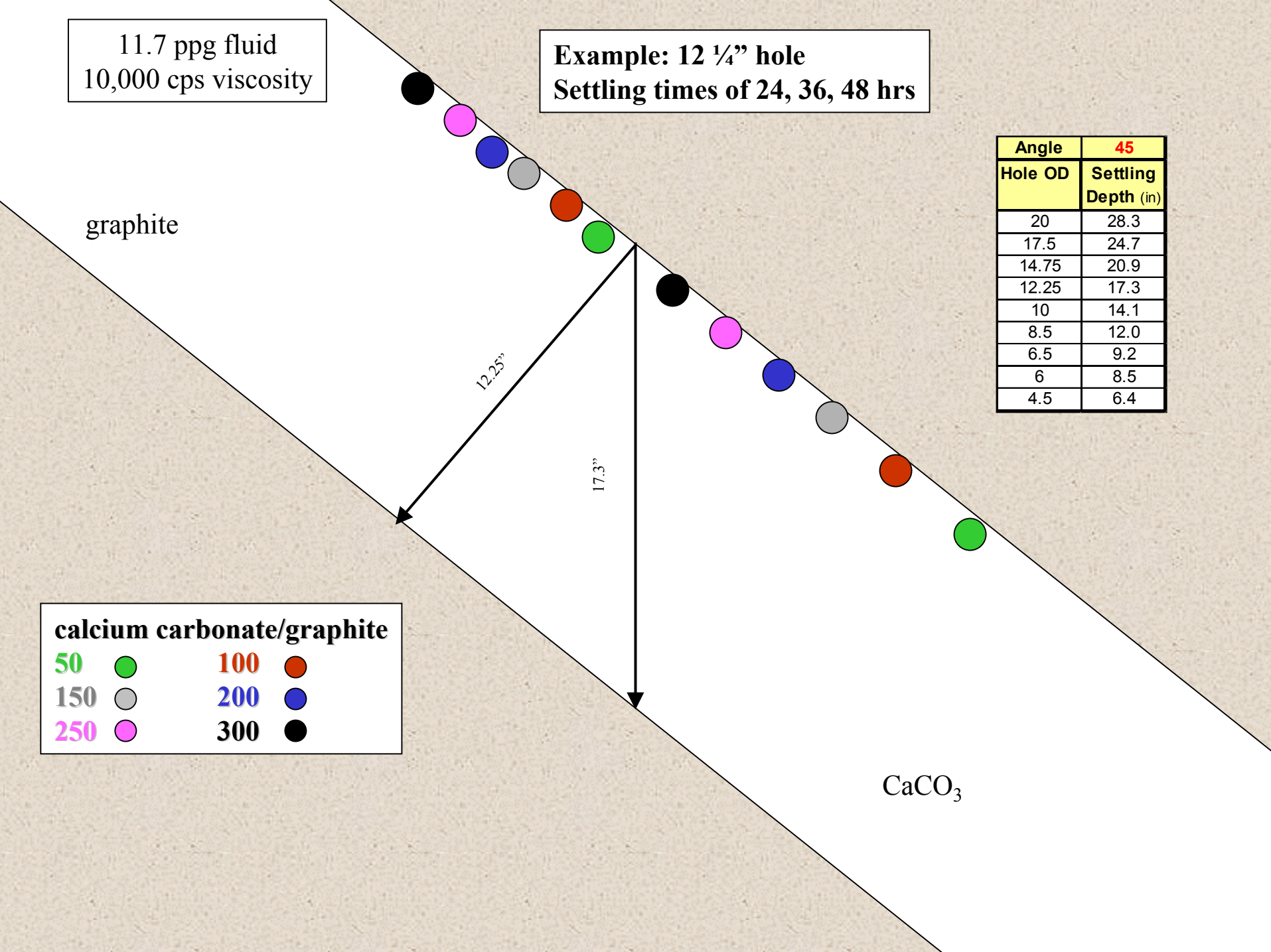
12.25"

17.3"

calcium carbonate/graphite

50 ● 100 ●  
150 ● 200 ●  
250 ● 300 ●

CaCO<sub>3</sub>



11.7 ppg fluid  
10,000 cps viscosity

Example: 12 1/4" hole  
Settling times of 24, 36, 48 hrs

graphite

24 hrs

12.25"

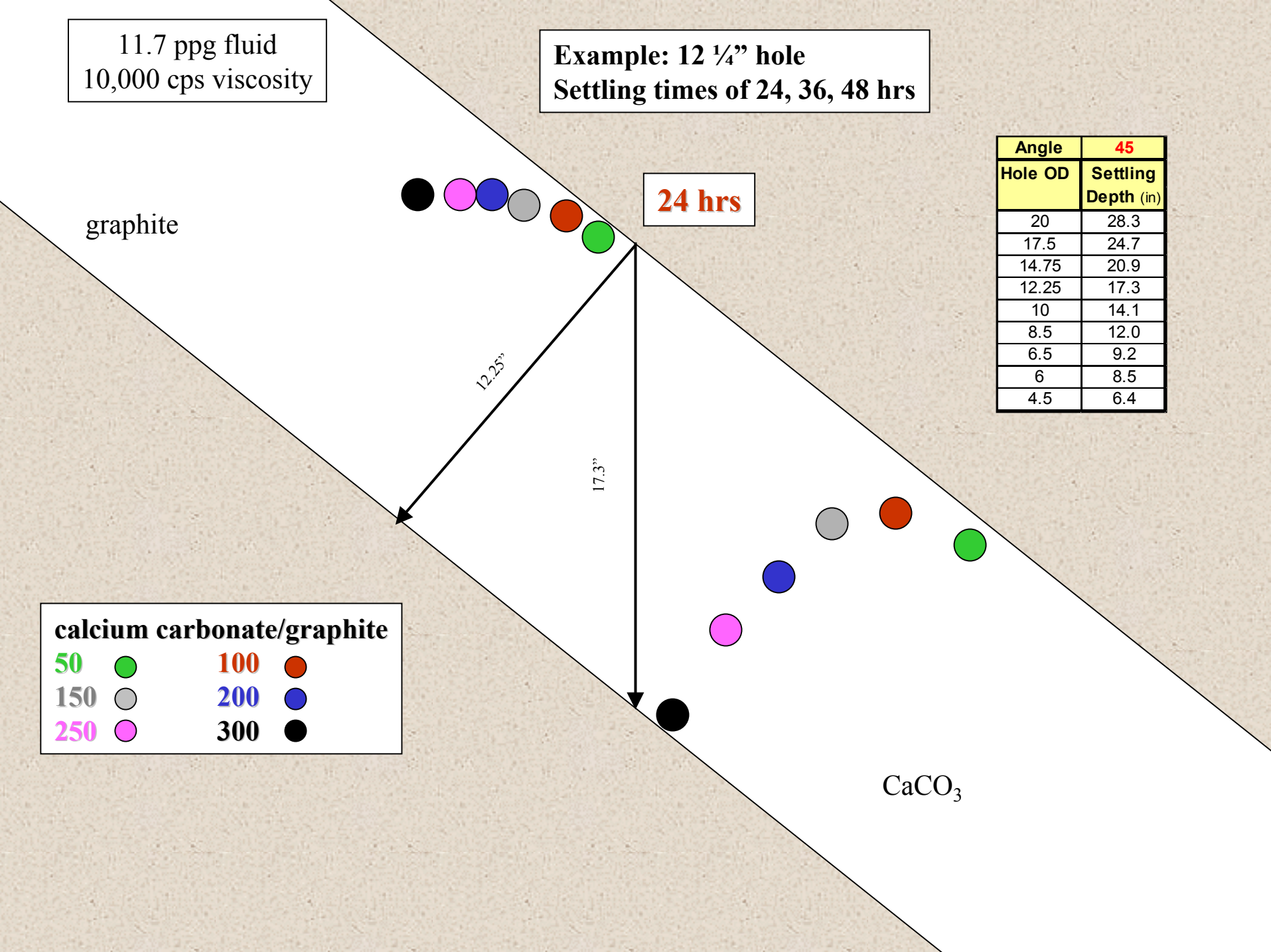
17.3"

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4

calcium carbonate/graphite

50 ● 100 ●  
150 ● 200 ●  
250 ● 300 ●

CaCO<sub>3</sub>



11.7 ppg fluid  
10,000 cps viscosity

Example: 12 ¼" hole  
Settling times of 24, 36, 48 hrs

graphite

36 hrs

12.25"

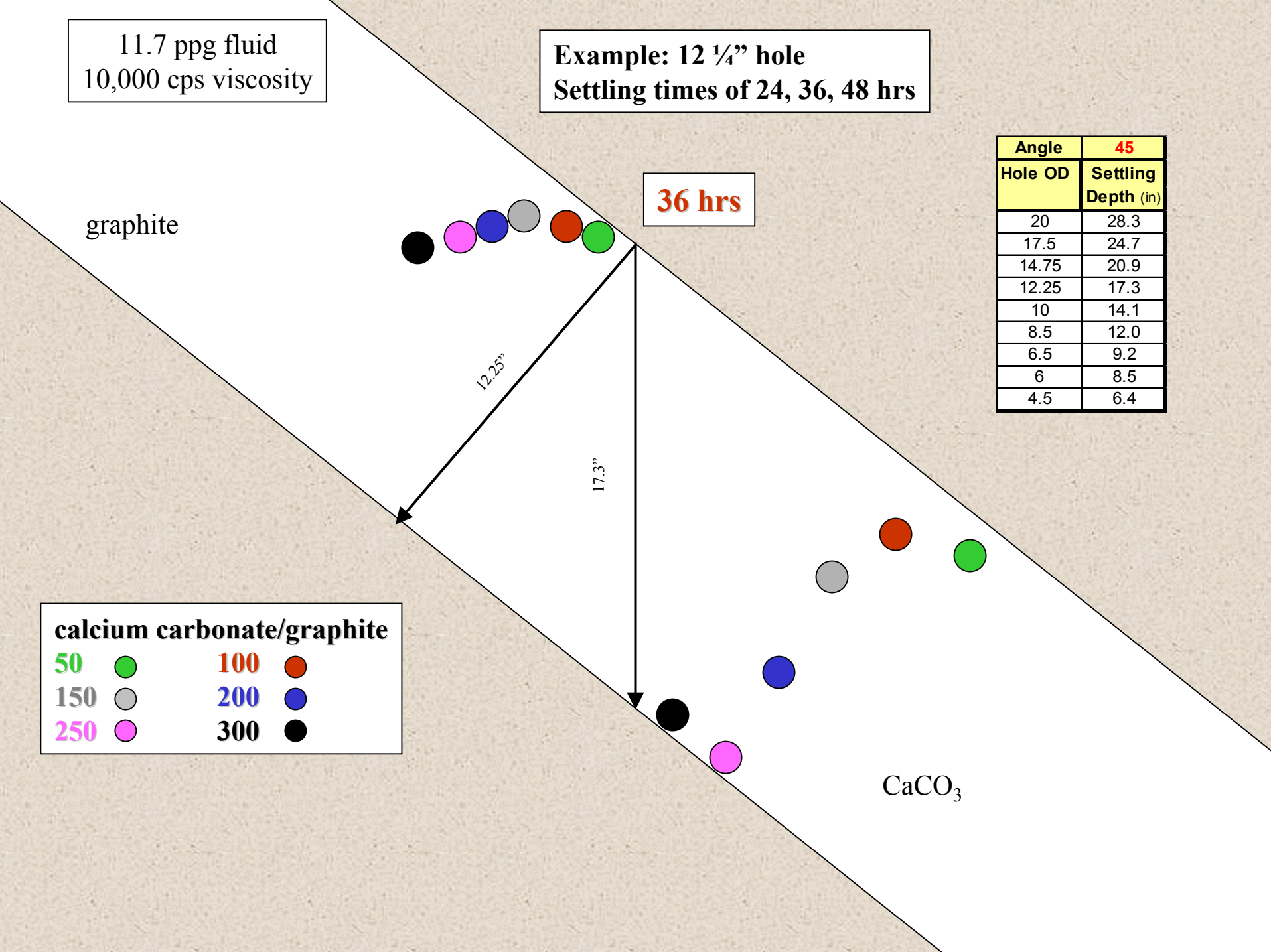
17.3"

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4

calcium carbonate/graphite

50 ● 100 ●  
150 ● 200 ●  
250 ● 300 ●

CaCO<sub>3</sub>



11.7 ppg fluid  
10,000 cps viscosity

Example: 12 1/4" hole  
Settling times of 24, 36, 48 hrs

graphite

48 hrs

12.25"

17.3"

calcium carbonate/graphite

50 ● 100 ●  
150 ● 200 ●  
250 ● 300 ●

CaCO<sub>3</sub>

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4

11.7 ppg fluid  
10,000 cps viscosity

Example: 12 1/4" hole  
Settling times of 24, 36, 48 hrs

graphite

72 hrs

Angle	45
Hole OD	Settling Depth (in)
20	28.3
17.5	24.7
14.75	20.9
12.25	17.3
10	14.1
8.5	12.0
6.5	9.2
6	8.5
4.5	6.4

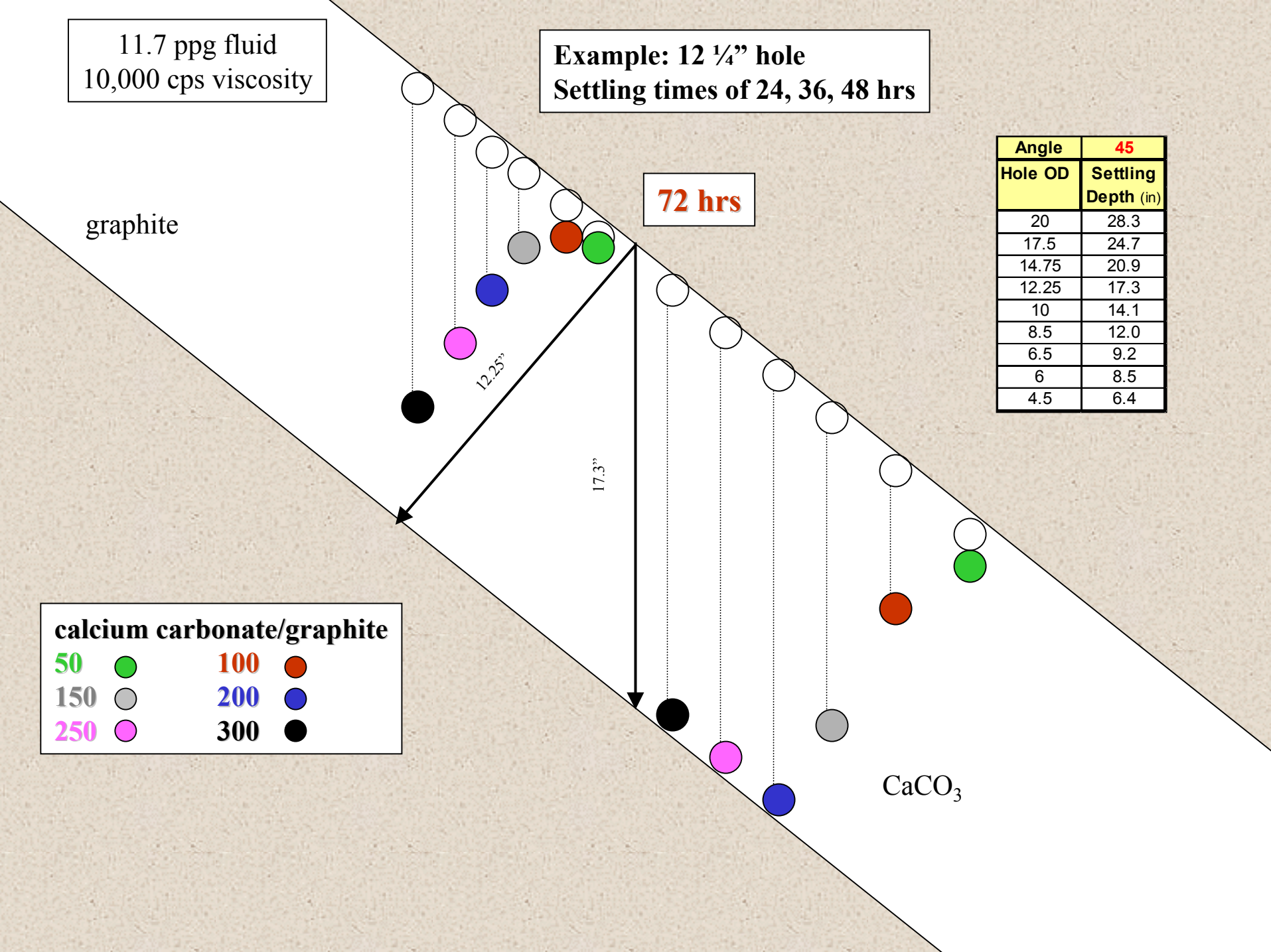
12.25"

17.3"

calcium carbonate/graphite

50 ● 100 ●  
150 ● 200 ●  
250 ● 300 ●

CaCO<sub>3</sub>



Well	Year	Interval	Bit	TD MW	FIT	Angle	Csg/Liner	Losses			Products			
								D.Hole	RIH	Cmt	graphite	CaCO3	rubber	
TA-7	2001	3,950 - 5,100	17x20	9.8	-	0	16L		266			35	1405	
		8,500	14 3/4 x 17 1/2	11	11.5	0	13 5/8		208	919		85	388	
		15,700	12 1/4	13.2	13.7	49	9 5/8L	1400	120	0		160	535	3-ppb
Drilled to 15,700 and lost 80 bbls with 13.2-ppg. Hole tight, temp. stuck, losing 2-bph. Treat system with 3-ppb Pipe Rubber Losses and reduce mud weight to 13.1-ppg. Losses stop. Run and cement 9 5/8 csg without any losses. Total sacks of Rubber were not recorded by mud company.														
TA-8	2002	3,000-5,209	17 x 20	9.8	10.6	0	16L		17	109		80	300	155
		10,264	14 3/4 x 17 1/2	11.3	11.5	59	13 5/8		587	1048				40
		Spotted 40sx of rubber on bottom prior to running casing												
		18,597	12 1/4	12.4	13.4	44	9 5/8L		0	-		80	450	65
		19,470	8 1/2 x 9 7/8	14.7	15.5	2-10	7 5/8L		-	-		0	78	10
TB-9	1999	3,655 - 5,054	17 x 20	11.2	-	0	16L					0	2144	0
		8,236	14 3/4 x 17 1/2	12.8	13.5	74	13 5/8					193	819	265
		15,594	12 1/4	13.3	14.3	70	9 5/8L			998		210	454	168
		19,073	8 1/2	13.9	14.7	68						117	370	
Drilled to 19,073 without losses. Well control problems. Could not get liner down. POOH w/Liner set cmt. plug. Pipe Rubber was used but not reported while drilling this interval due to pressure on Baroid to not use it as per UTG. 87 sx were put on boat as Liner pulled														
		18,728	8 1/2	13.6	14.7	69	7L					120	712	75
Re-drill encounters 70% losses using CaCO3/graphite mix @13.9 ppg. Reduce mud weight to 13.5ppg, still losing mud. Doug Chester orders Rubber to be returned to rig and 75 sx added. Losses stop and well drilled to TD. 7" Liner run to bottom. Cemented with no returns. Usage not on mud recap - DIMS only.														

# Effects of Deviation

- Snow plowing on low side of hole
- Insufficient particles on high side of well
- Higher oil content on high side provides better fracturing fluid
- More particles on low side increase difficulty of running wire line to bottom

# Solutions

- Evaluate yield stress reduction effect on surge pressures/ECD vs. LCM particle settling
- Monitor time out of hole and adjust accordingly
- Ensure high side of well is protected
- Educate personnel on settling tendencies of LCM and associated problems

# **Additional Work**

- Conduct PPT's with time delays and using different combinations of products
- Design packer fluids with finer barite to reduce long term settling
- Continue reviewing well histories to identify trends in deviated wells along with LCM concentrations
- Determine how the settling is impacting completion clean-up

# Settling Velocity of LCM in Deviated Wells

## Results based on:

11.66 ppg	
10,000 cps vis	
Graphite	2.175 S.G.
Calcium Carbonate	2.75 S.G.

75% of Grapite is between 175 and 420 microns

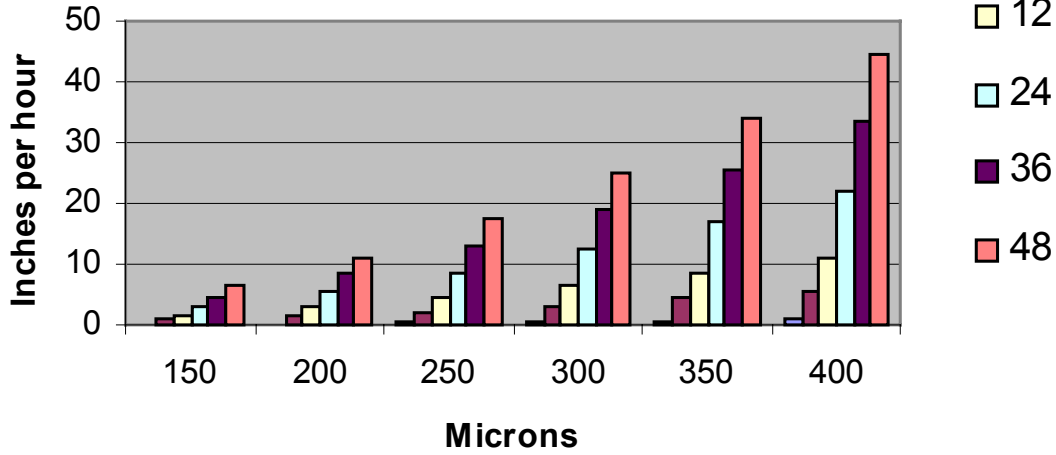
Graphite		Settling in inches per hour							
microns	meters sec <sup>-1</sup>	1	6	12	24	36	48	56	72
150	0.00000092	0.13	0.78	1.56	3.13	4.69	6.26	7.30	9.39
200	0.00000164	0.23	1.39	2.79	5.58	8.37	11.16	13.02	16.74
250	0.00000255	0.36	2.17	4.34	8.67	13.01	17.35	20.24	26.02
300	0.00000368	0.52	3.13	6.26	12.52	18.78	25.04	29.21	37.55
350	0.00000501	0.71	4.26	8.52	17.04	25.56	34.08	39.76	51.13
400	0.00000654	0.93	5.56	11.12	22.25	33.37	44.49	51.91	66.74

CaCO <sub>3</sub>		Settling in inches per hour							
microns	meters sec <sup>-1</sup>	1	6	12	24	36	48	56	72
50	0.00000018	0.03	0.15	0.31	0.61	0.92	1.22	1.43	1.84
100	0.00000074	0.10	0.63	1.26	2.52	3.78	5.03	5.87	7.55
150	0.00000166	0.24	1.41	2.82	5.65	8.47	11.29	13.18	16.94
200	0.00000294	0.42	2.50	5.00	10.00	15.00	20.00	23.33	30.00
250	0.0000046	0.65	3.91	7.82	15.65	23.47	31.29	36.51	46.94
300	0.00000662	0.94	5.63	11.26	22.52	33.78	45.04	52.54	67.56

This data has not been included in the slide show. Slide show used 1.7 SG for graphite and 2.6 SG for CaCO<sub>3</sub>

**Graphite**  
Settling Velocity from 1 to 48 hours



**Calcium Carbonate**  
Settling Velocity from 1 to 48 hours

