Wellbore Strengthening

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Pictures Removed

- **Pictures have been removed that were used to make transitions or specific points during the presentation.**
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How did we arrive at wellbore strengthening concepts?

In the beginning

- **DEA 13 - Investigation of Lost Circulation with Oil-based Muds (1985-1988)**

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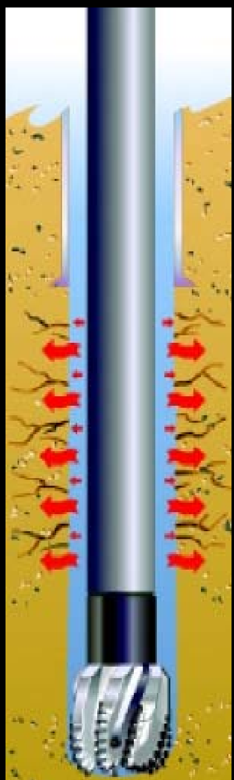
- Fundamental Question **- Is the fracture initiation pressure different for water and oil base fluids?**

DEA 13 - Investigation of Lost Circulation with Oil-based Muds (1985-1988)



Large Sample -
30- in cube

High Cost -
$25-30 K/test

Wellbore Pressure Containment - DEA 13

Fractures can be

- **initiated**
- **stopped**
- **reopened**

DEA 13 - Investigation of Lost Circulation with Oil-based Muds (1985-1988)

- Fundamental Question **- Is the fracture initiation pressure different for water and oil base fluids?**
  - Answer **- No, but the propagation pressure (extension) is lower for oil base fluids.**
- Result **– More difficult to stop lost circulation with oil base fluid.**
  - **Fracture tip screen-out (prevent pressure transmission to the fracture tip) is the assumed mechanism.**
- Strategy **– Prevention is better than remediation**

Wellbore strengthening concepts were “discovered” in the 1990’s

- **1980’s DEA 13 – fundamental lost circulation experimental study**
- **1990 Theory of Lost Circulation Pressure**
  - **SPE 20409; Morita et.al.**
- **1992 A New Approach to Preventing Lost Circulation While Drilling**
  - **SPE 24599; Fuh et.al.**

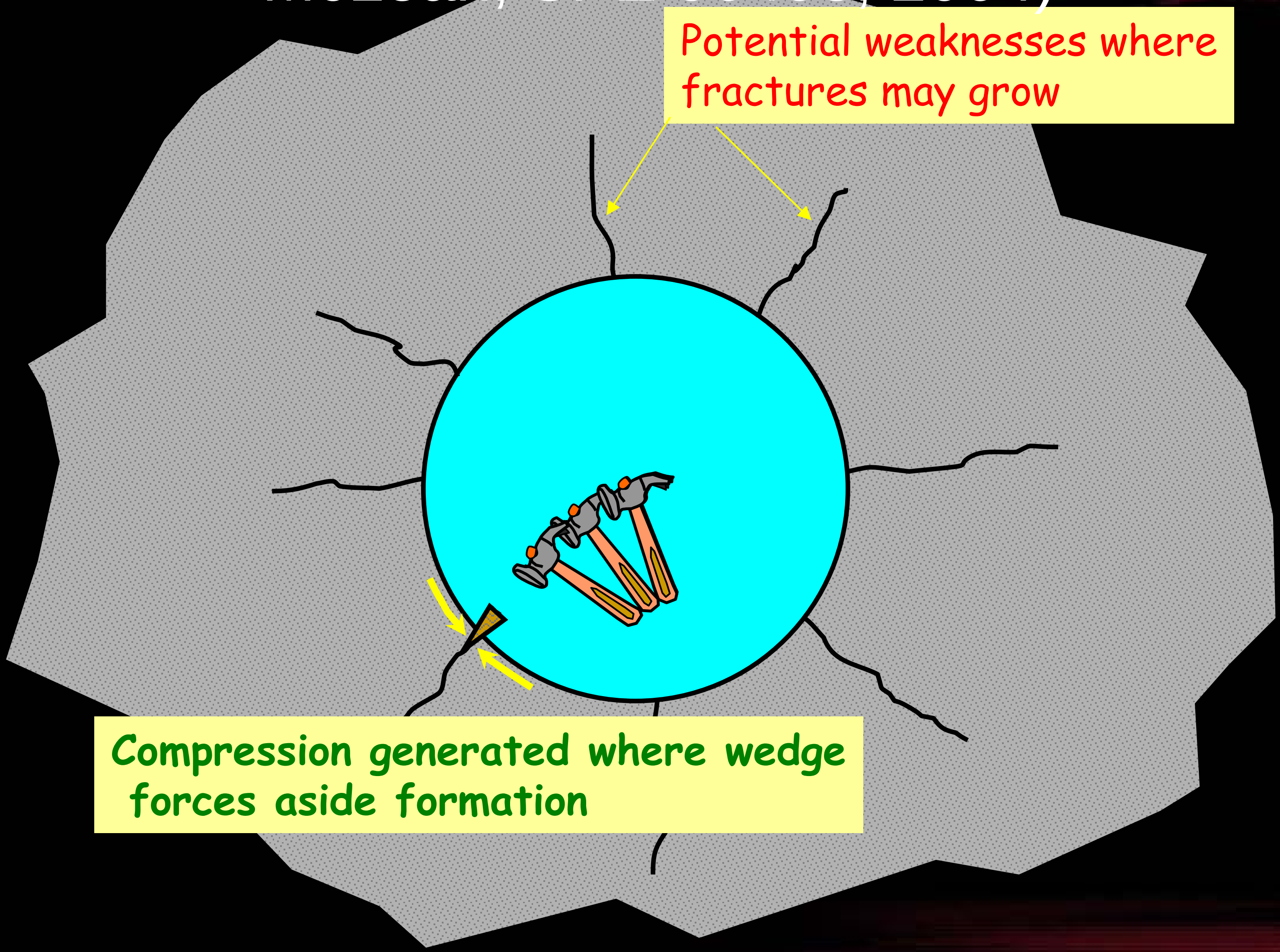
Wellbore strengthening concepts were sidetracked in the late1990’s

Best explained by Scott Adams
in his Dilbert Cartoons!

Wellbore strengthening concepts were “rediscovered” in the 2000’s

- **2001 Fracture Gradients in Depleted Reservoirs – Drilling Wells in Late Reservoir Life**
  - **SPE/IADC 67749; Alberty and McLain**
- **2001 Formation Pressure Integrity Treatments Optimize Drilling and Completion of HTHP Production Hole Sections**
  - **SPE 68946; Sweatman, et. al.**
- **2004 Drilling Fluids for Wellbore Strengthening**
  - **SPE/IADC 92192; Aston and Alberty**
- **2004 A Physical Model for Stress Cages**
  - **SPE 92192; Alberty and McLean**

A Physical Model for Stress Cages; Alberty and McLean, SPE 90493, 2004)



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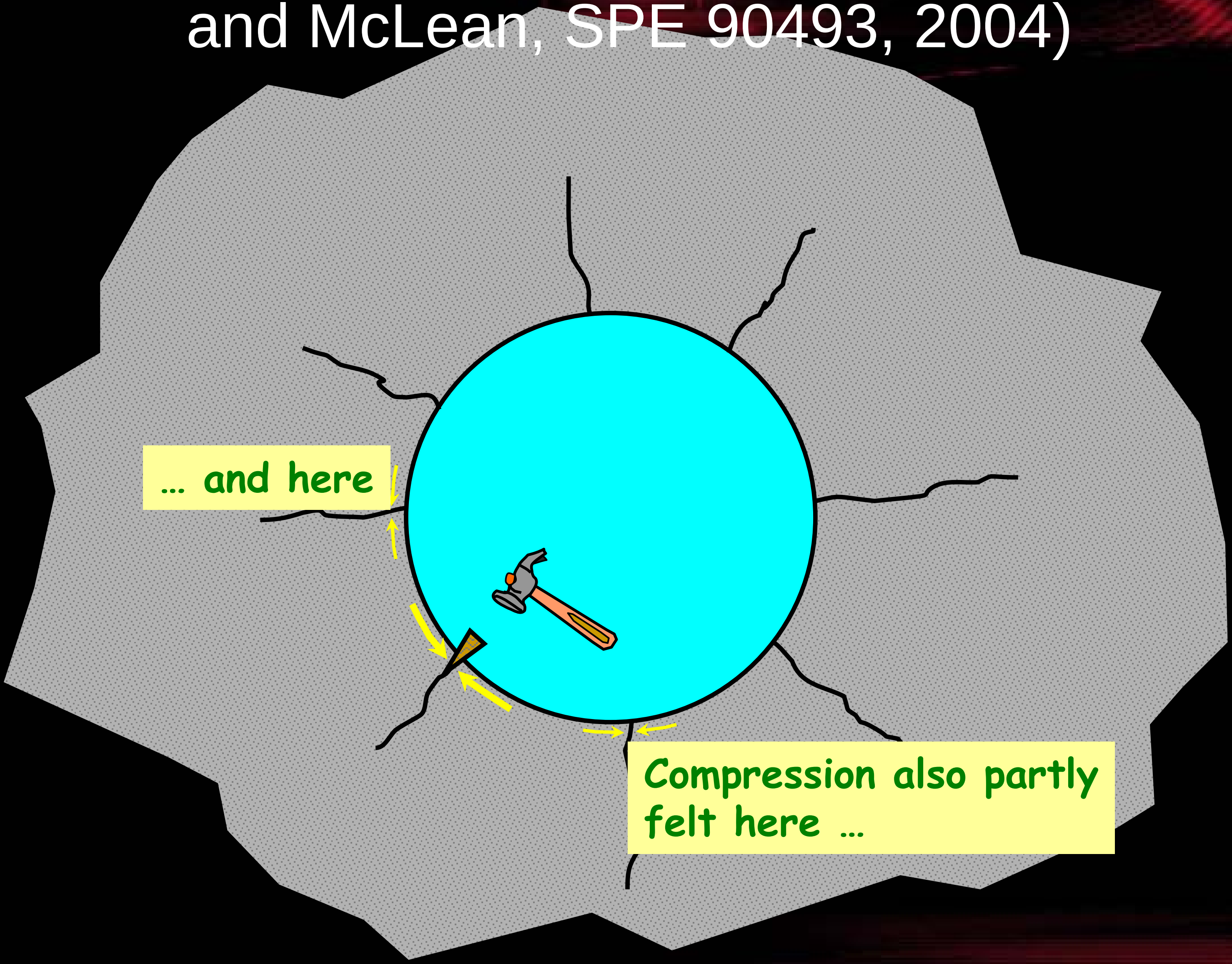

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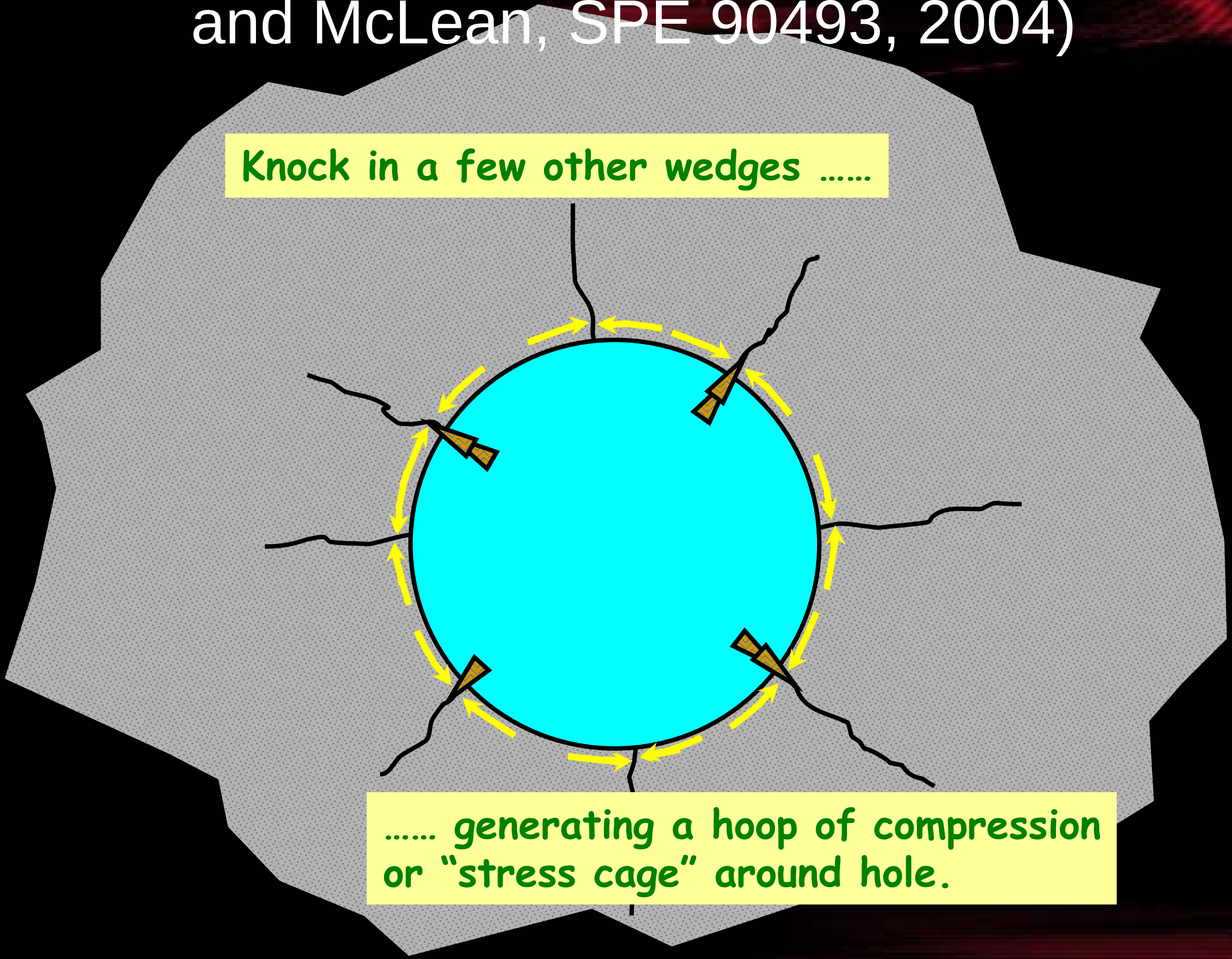

Wellbore strengthening concepts merged with lost circulation mitigation

- **2005 Fracture Closure Stress and Lost Returns Practices**
  SPE/IADC 92192
  Dupriest

- **2005 The Key to Successfully Applying Today's Lost Circulation Solutions**
  - **SPE 95895; Wang, et. al.**
- **2006 Preventing Mud Losses by Wellbore Strengthening**
  - **SPE 101593; Song & Rojas**
- **2006 New Design Models and Materials Provide Engineered Solutions to Lost Circulation**
  - **SPE 101693; Whitfill, et. al.**

And – The Beat Goes On!

- **2007** Fractured Wellbore Stress Analysis; Sealing Cracks to Strengthen a Wellbore
  - SPE 104947; Wang, et. al.
- **2007** Further Development, Field Testing, and Application of the Wellbore Strengthening Technique for Drilling Operations
  - SPE 105809; Fuh, Beardmore, Morita
- **2007 A New Treatment for Wellbore Strengthening in Shale**
  - **SPE 110713; Aston, et. al.**

-And On!

@SPE/IADC Drilling Conference, Orlando

- **2008 Investigation of Factors for Strengthening a Wellbore by Proppiing Fractures**
  - **SPE/IADC 112629; Wang, et. al.**

- **2008 Method to Eliminate Lost Returns and Build Integrity Continuously with High-Filtration-Rate Fluid**
  - **SPE/IADC 112656; DuPriest, et. al.**

Lost Circulation Strategy – Plan Ahead

- **Preventive**
  - Pretreatment
  - Borehole Stress Treatment
    - Strength Enhancing Technology
- **Corrective**
  - Particulate Solutions
  - Chemical Sealants

Wellbore Strengthening Treatment

- For increasing the "hoop stress" in the near wellbore region.
  - Place a plugging material in an induced fracture:
  - prevent further pressure and fluid transmission to the fracture tip
  - widen and prop the fracture.

Wellbore Strengthening Treatment

- Fundamental Question – How wide is the fracture that we may create?
- Other Issues
  - What is the permeability of the formation?
  - What is the optimum particle size distribution and materials to use.

Fracture Prediction Example

- **Model Data**
  - **Hole Size – 12.25-in**
  - **Fracture Length – 6-in**
  - **Mud Weight – 14.5 ppg**
  - **TVD – 10,000-ft**
  - **Minimum Horizontal Stress – 7000 psi**
  - **Poisson's Ratio – 0.33**
  - **Young's Modulus – 1,500,000 psi**
- **Estimated Fracture Width – 341 microns**

→ 7540 psi

Data for Wellbore Stress Management™ Analysis

- **Off-set well drilling reports to know**
  - **Leakoff Test/Extended Leakoff Test/Formation Integrity Test**
  - **Mud loss volume, mud properties**
  - **Lost Circulation Rates vs. Pressures**
  - **Lost Circulation Treatments and Results**
- **Logs**
  - **Full Wave Sonic (Compressional & Shear)/other sonic**
  - **Density/Neutron/GR**
  - **Other logs**

Data for Wellbore Stress Management™ Analysis

- **Stay Tuned for Part 2**
  - **Dr. Hong (Max) Wang**

Wellbore Stress Management™ Service

1

Model Data
- Hole Size – 12.25-in
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- Mud Weight – 14.5 ppg
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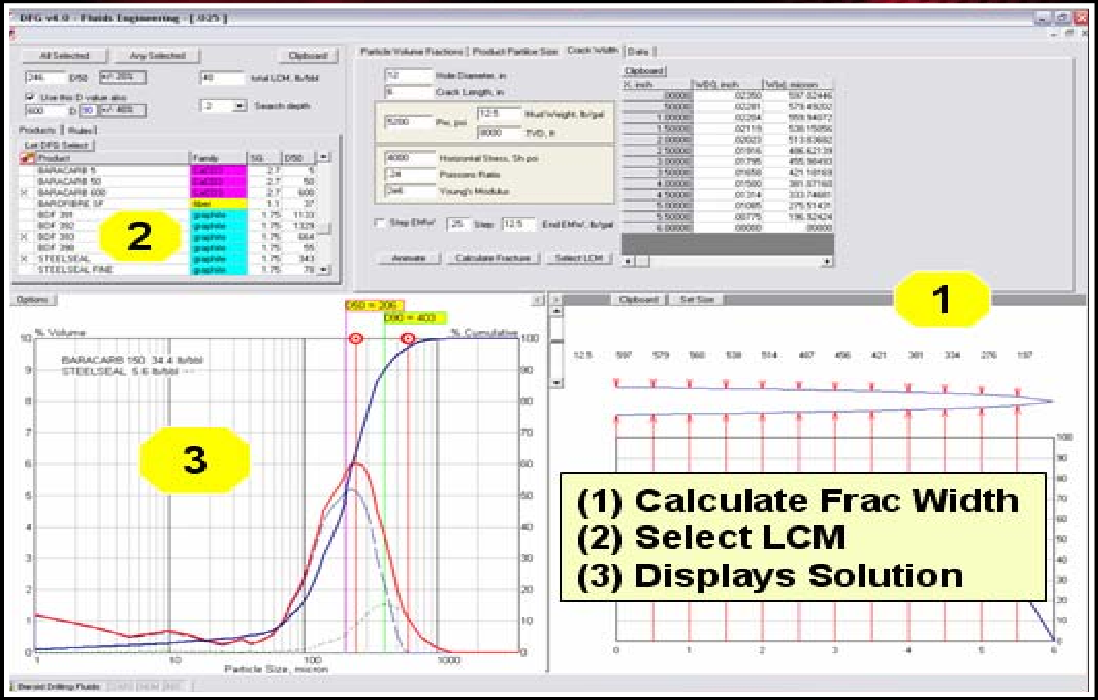
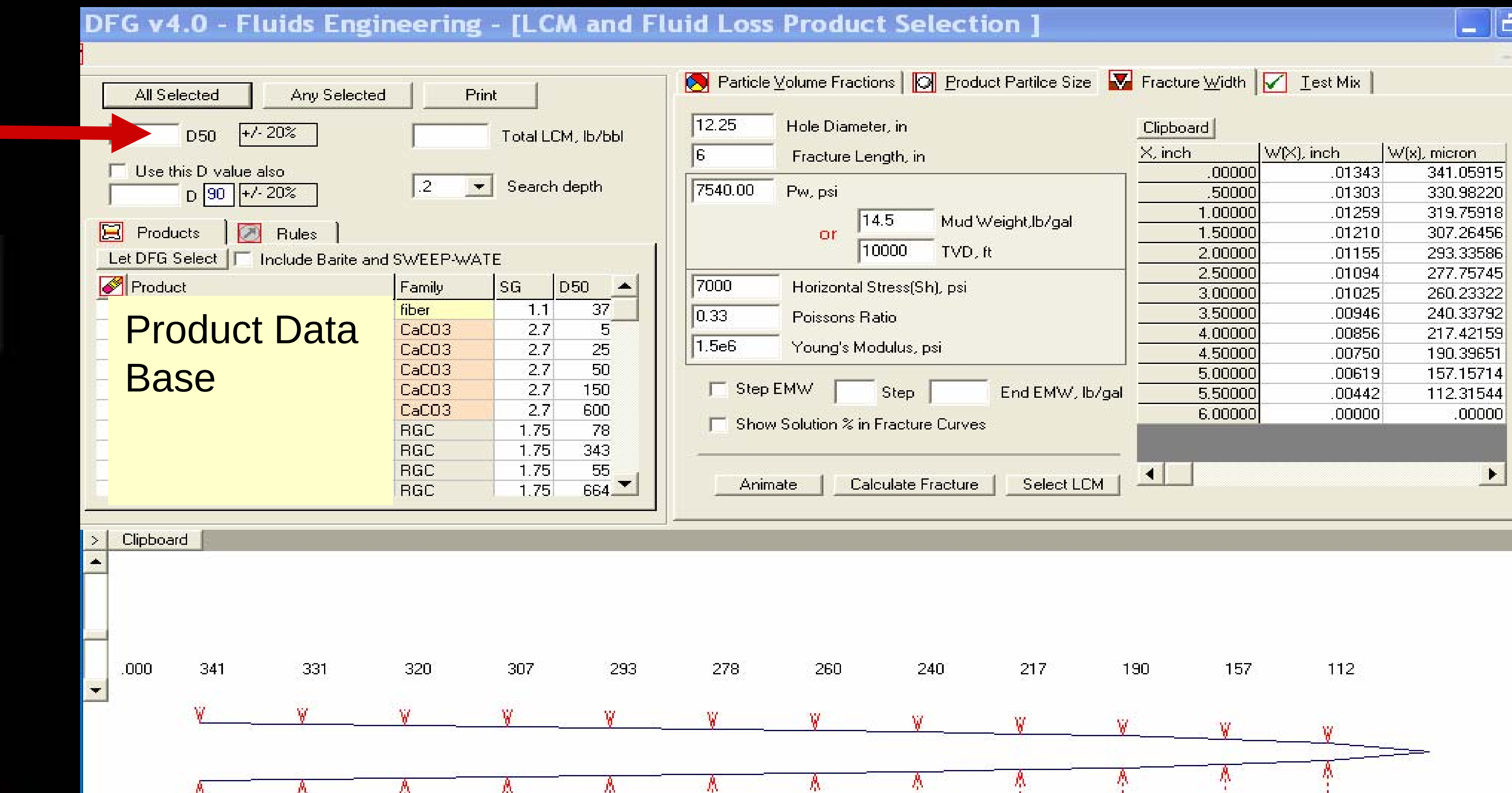


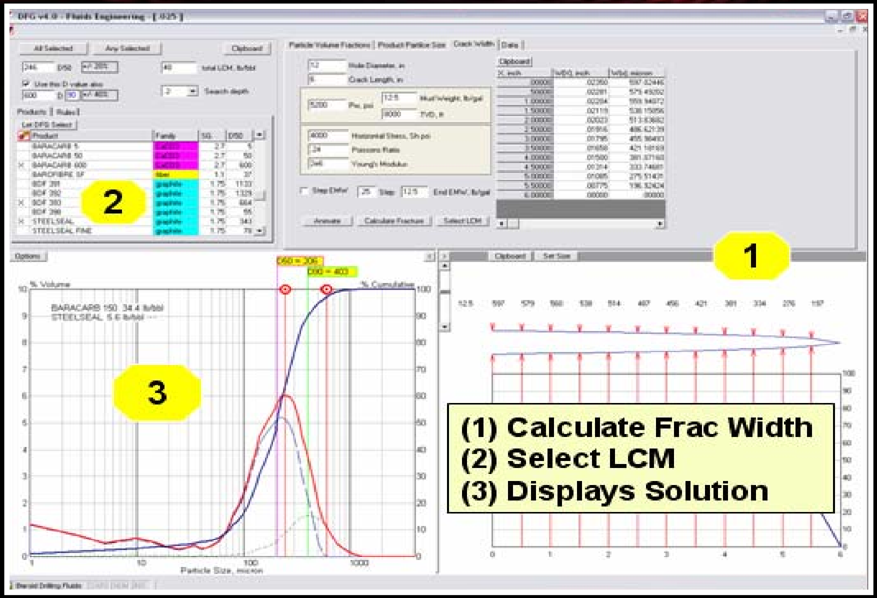
Fracture Width Prediction



Wellbore Stress Management

Model Data
Hole Size – 12.25-in
Fracture Length – 6-in
Mud Weight – 14.5 ppg
TVD – 10,000-ft
Minimum Horizontal Stress – 7000 psi
Poisson's Ratio – 0.33
Young's Modulus – 1,500,000 psi

1



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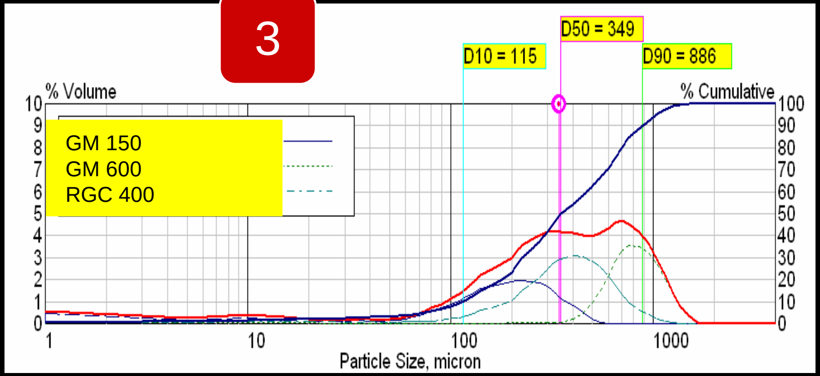
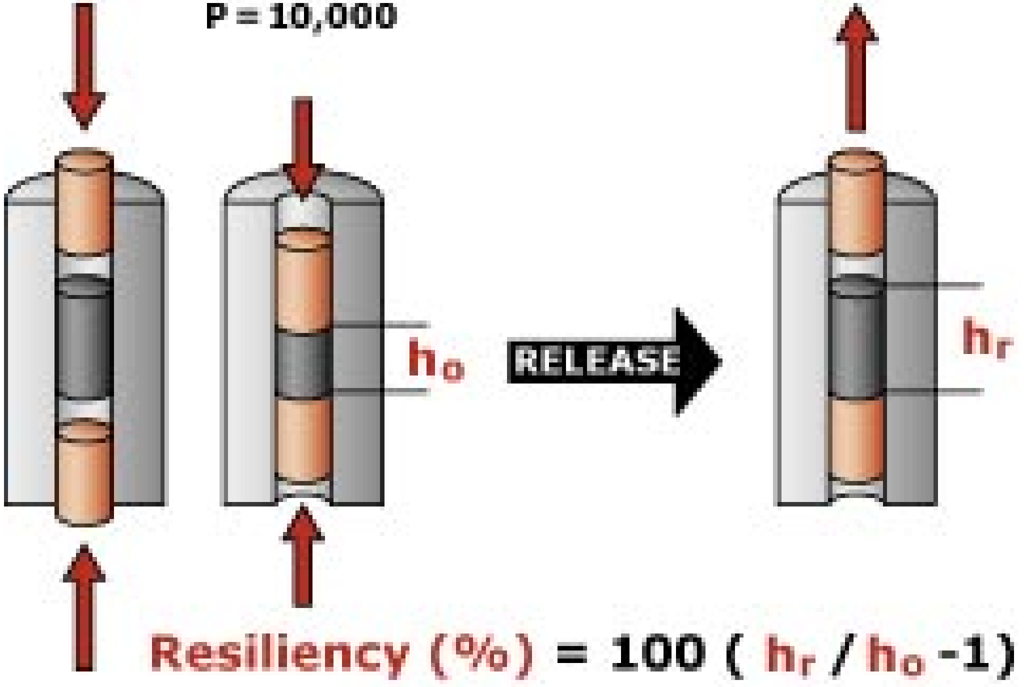


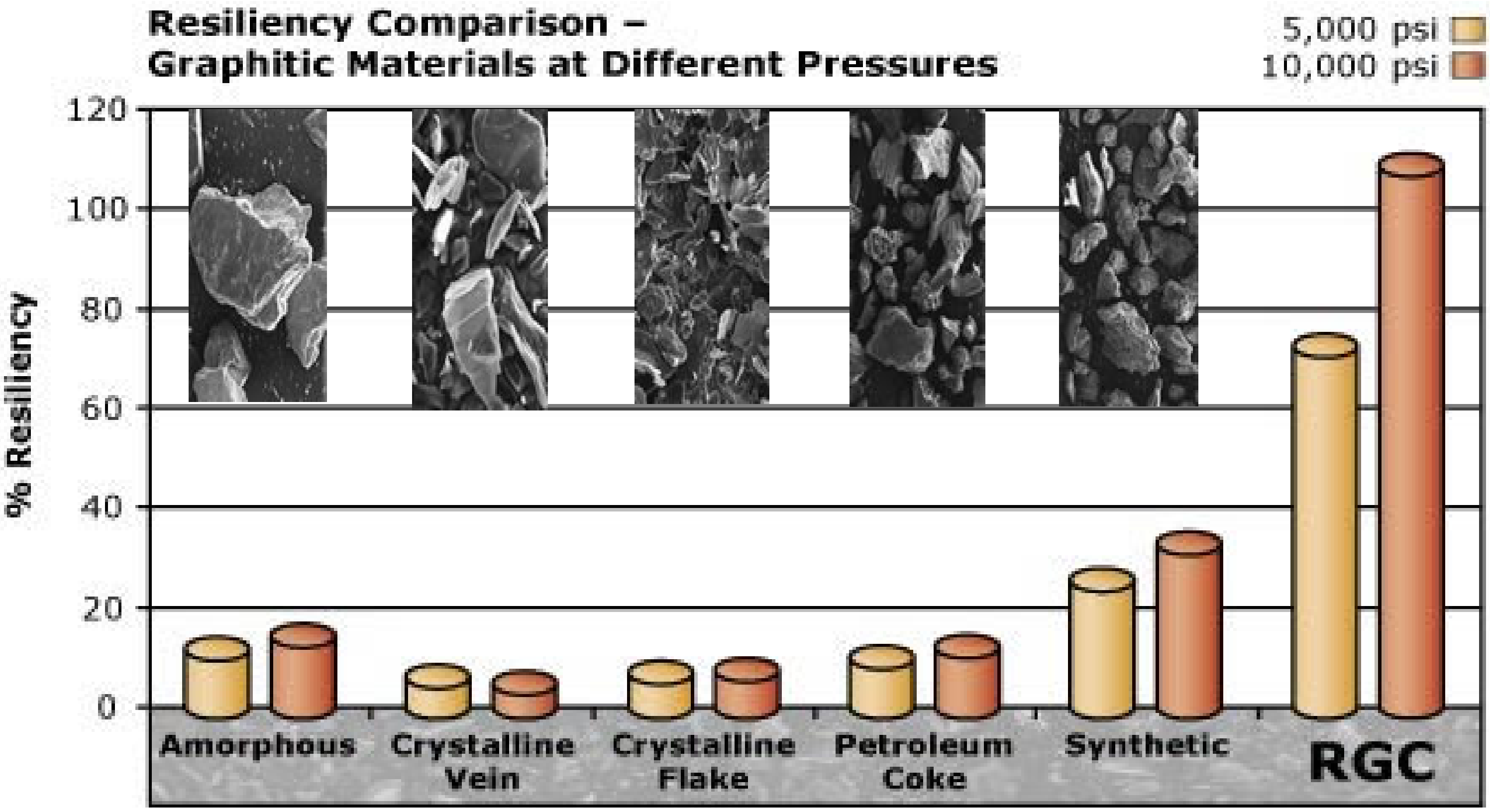
2

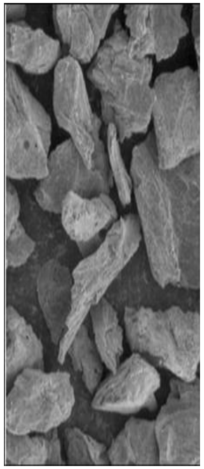
Resilient Graphitic Carbon
1000
400
100
50
Ground Sized Marble
1200
600
150
50
25

Testing Resiliency of Graphitic Materials

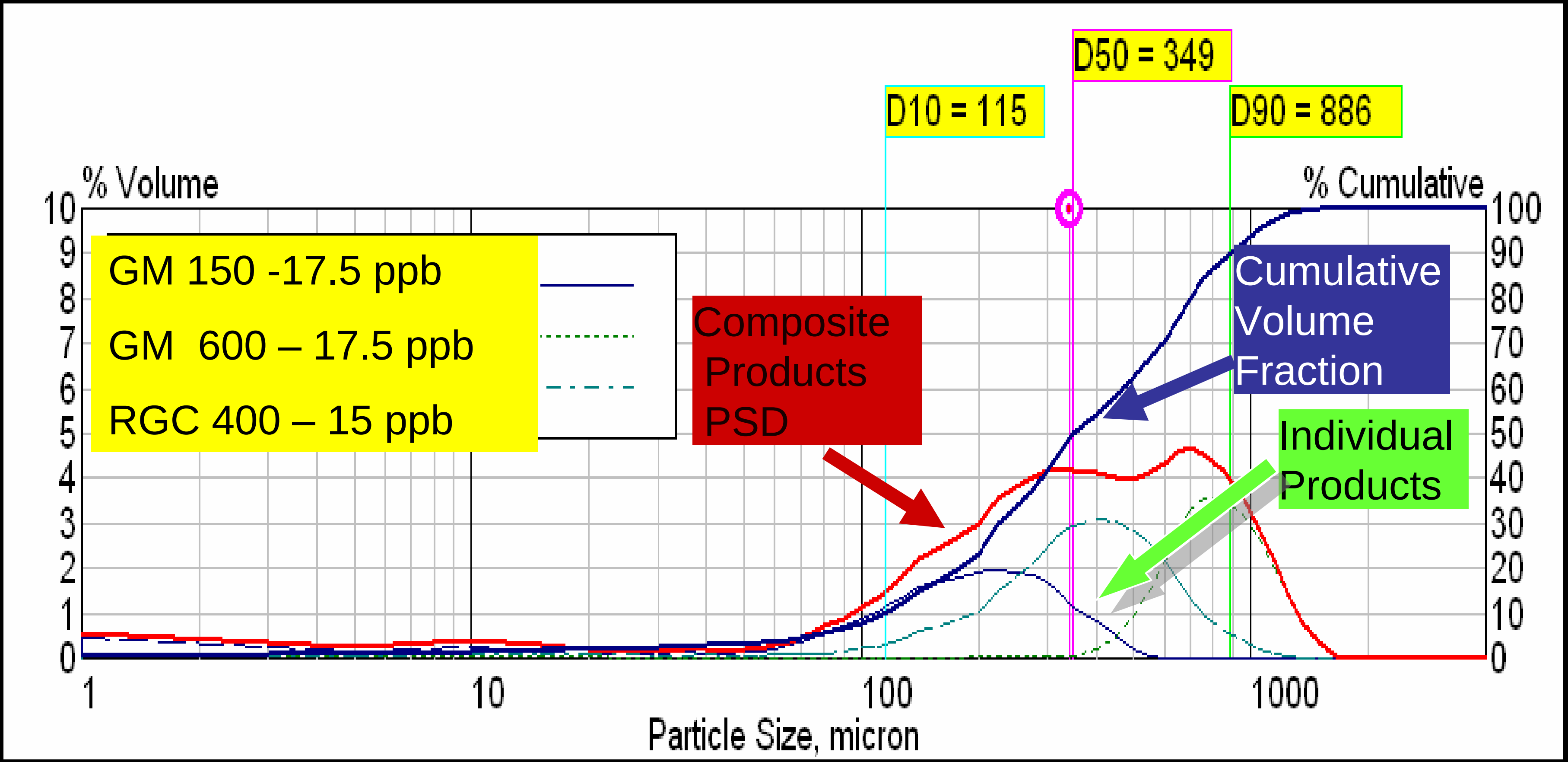
RGC's show a unique spring-back effect, greater than all other graphite materials.




Resiliency Comparison –
Graphitic Materials at Different Pressures
5,000 psi
10,000 psi
% Resiliency
120
100
80
60
40
20
0
Amorphous
Crystalline Vein
Crystalline Flake
Petroleum Coke
Synthetic
RGC



Example PSD Solution

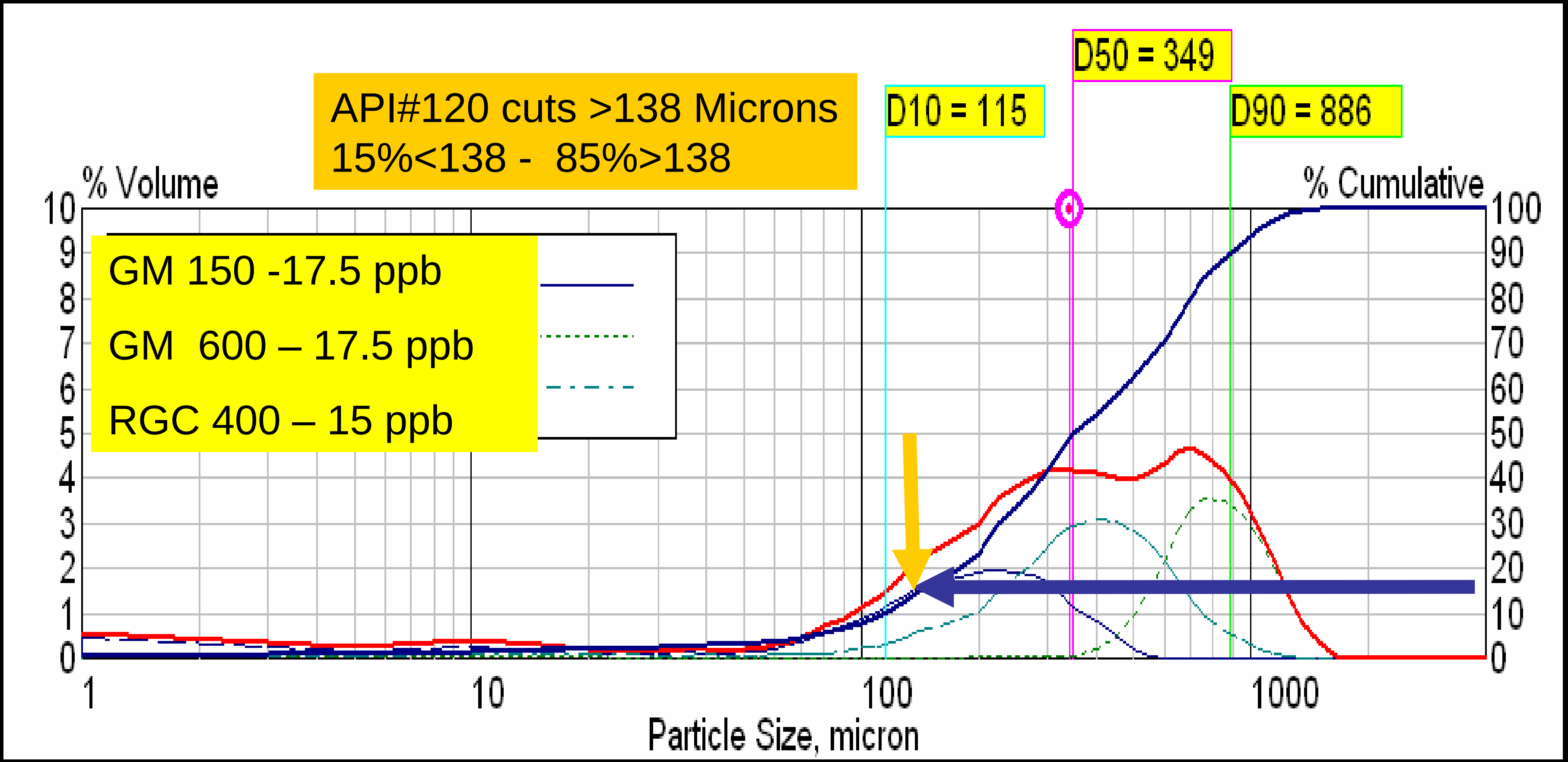


API RP 13C pp40-41

D100 Separation Microns	API Screen Number
>780 to 925	10
>655 to 780	25
>550 to 655	30
>462.5 to 550	35
>390 to 462.5	40
>327.5 to 390	45
>275 to 327.5	50
>231 to 275	60
>196 to 231	70
>165 to 196	80
>137.5 to 165	100
>116.5 to 137.5	120
>98 to 116.5	140
>82.5 to 98	170
>69 to 82.5	200
>58 to 69	230
>49 to 58	270
>41.5 to 49	325
>35 to 41.5	400
>28.5 to 35	450
>22.5 to 28.5	500
>18.5 to 22.5	635

API #120
Cut-point >138 Microns

Example PSD Solution



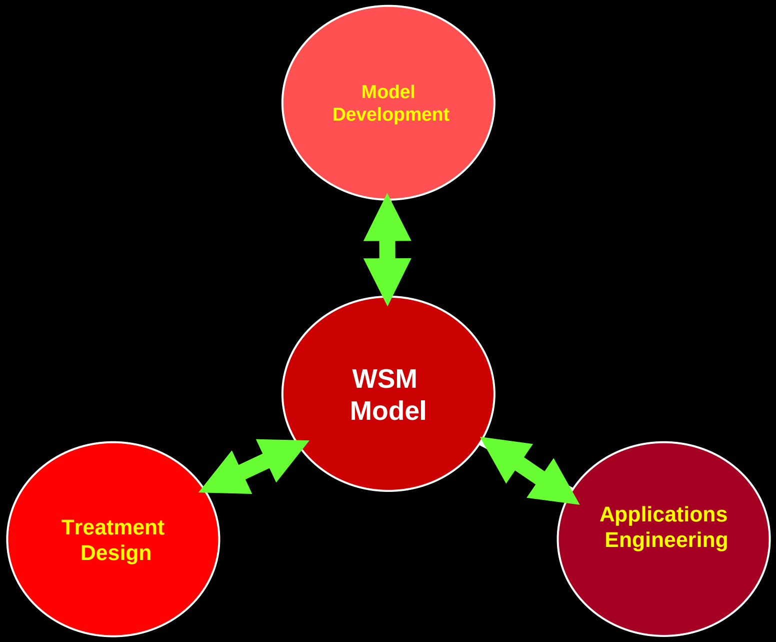
Example Plan

- Pre-treat with as large a particle size distribution as practical - based on pore and/or fracture size versus screen size.
- Run sweeps with larger size particles – such as using a d50 = 0.41*Fracture Width
  - How Often (minimum of each stand)
  - What Size (minimum of 270-ft annular volume; ie three times the annular hole volume generated since the previous sweep)
- Prior to running casing- apply a borehole stress treatment over the entire open hole interval with FIT pressure as great as the largest ECD expected for that interval.

Borehole Stress Treatment East Cameron – Gulf of Mexico

Depth (ft)	**Mud Weight (ppg)**	**Overbalance (psi)**	**Estimated Fracture Width (microns)**	**Background treatment 20 ppb d10/d50/d90 (microns)**	**Sweep Treatment 50 ppb d10/d50/d90 (microns)**
5850	10.0	1095	306	20/110/289	126/346/793
9950	11.3	5221	787	20/110/289	439/694/1073
10475	11.5	4100	519	20/110/289	201/516/957

The Value of a Common Model



- **Common language**
- **More consistent approach**
- **Less variation in application**
- **Develop more "experts"**

Comments/Questions?