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How to Stabilize and Strengthen the Wellbore during Drilling Operations

Dr. Fred Growcock

MI SWACO

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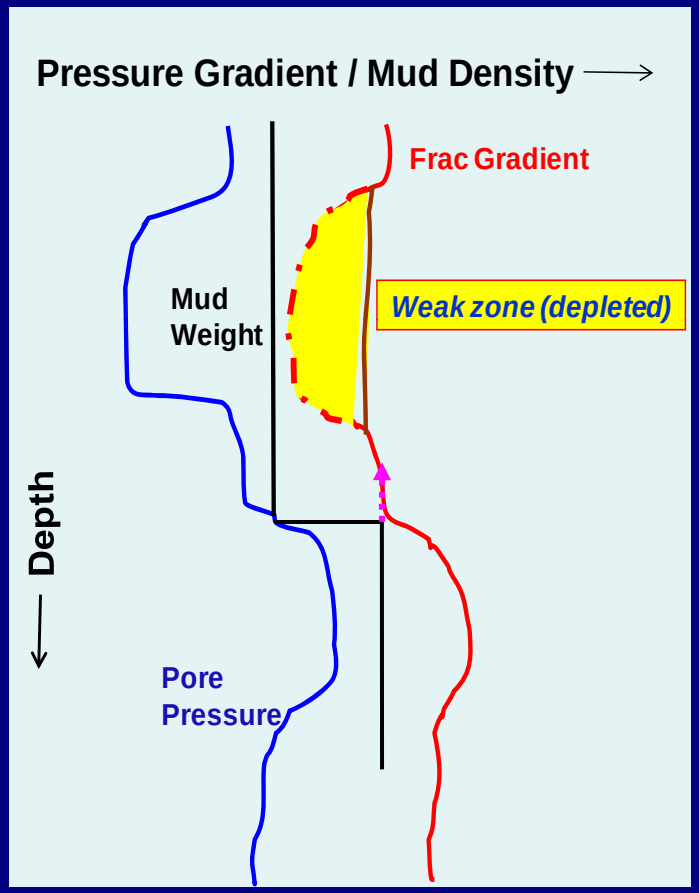
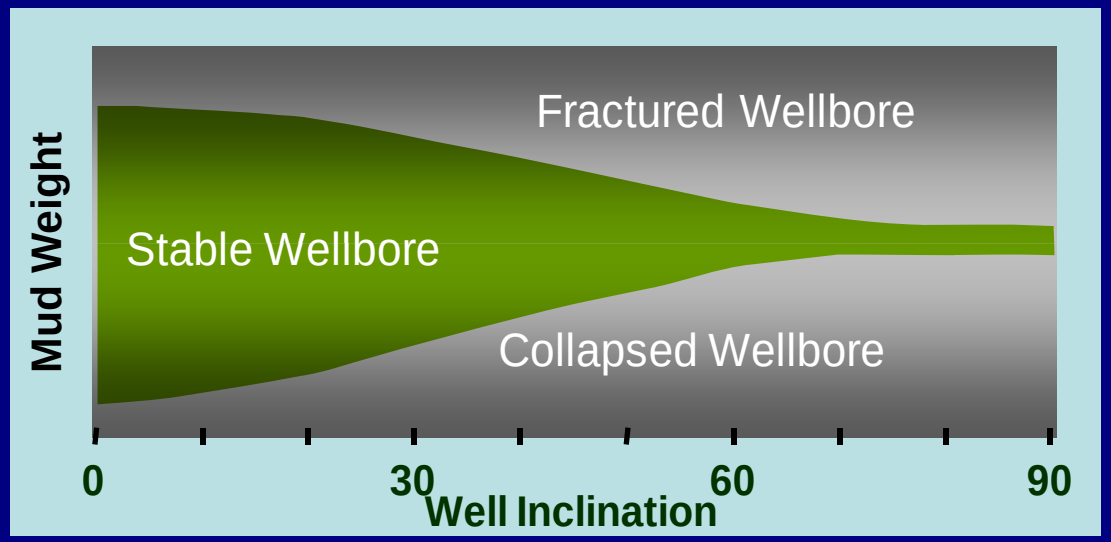
Presentation Outline

- The Lost Circulation Problem
- Strategy for Managing Lost Circulation
- Wellbore Strengthening
- Wellbore Stress Enhancement
- Application Strategies on the Rig
- Case History
- Summary

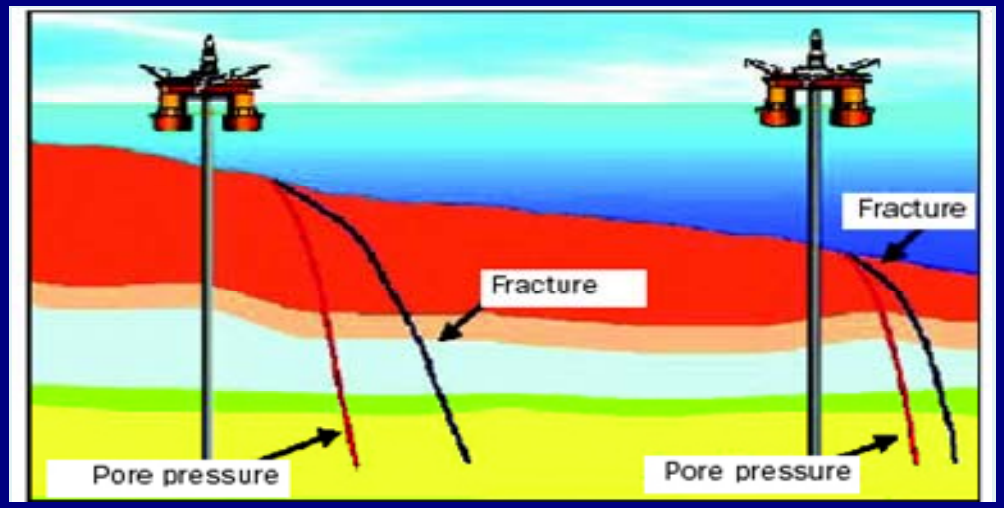
The Lost Circulation Problem: High-Risk Operations



Depleted Zones



Deviated Wellbores



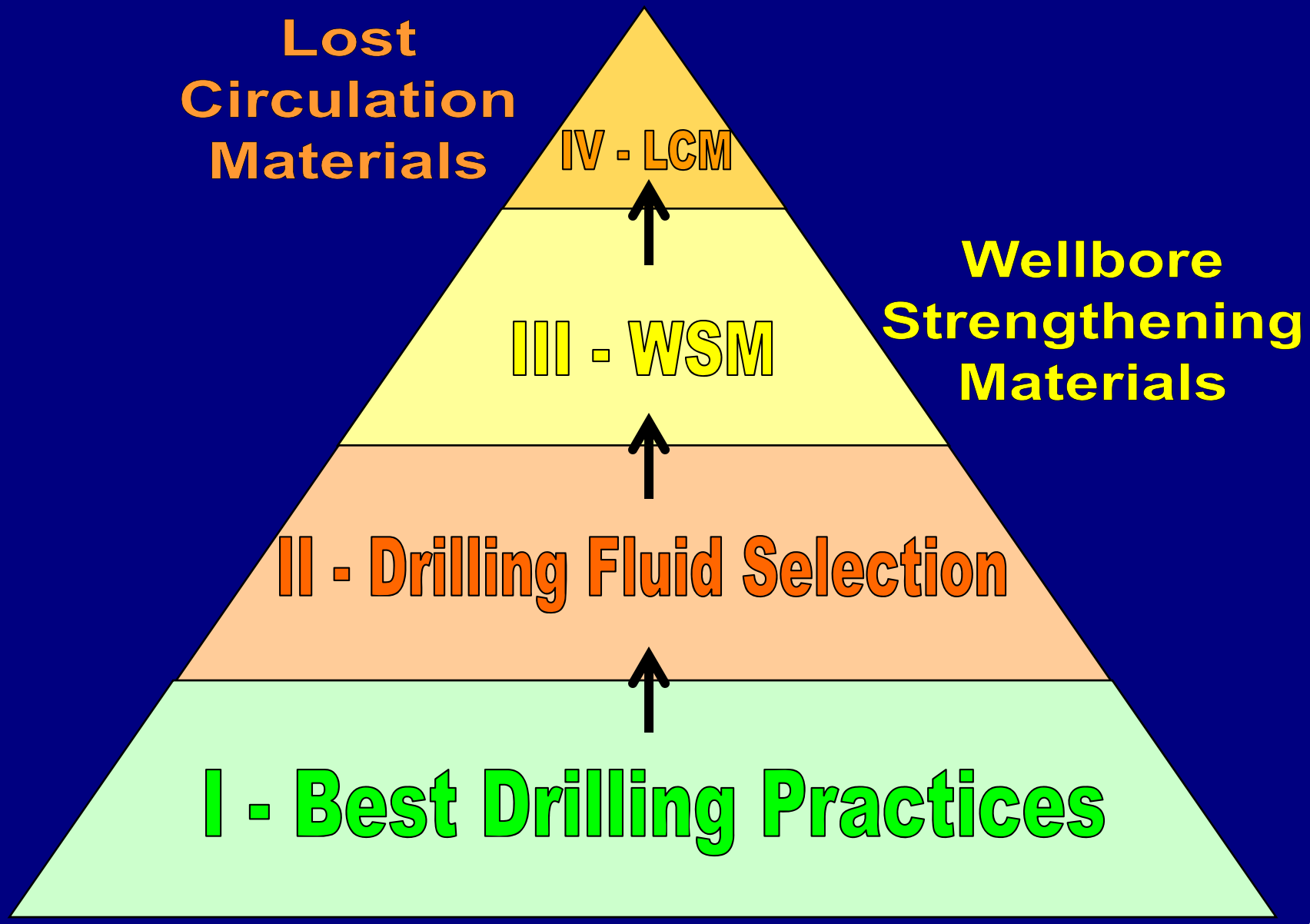
Deep Water

The Lost Circulation Problem

- Estimated industry cost in the Gulf of Mexico: $1 billion/yr. Worldwide: ~ $ 2 to 4 billion/yr.
- On average, 10-20% of the total cost of drilling an HTHP well is expended on mud losses (*U.S. Department of Energy*).
- No consistent approach to manage lost circulation.
- Nearly 200 products offered by 50 drilling fluid companies to control lost circulation.

A comprehensive Lost Circulation mitigation <u>and prevention</u> program is required.

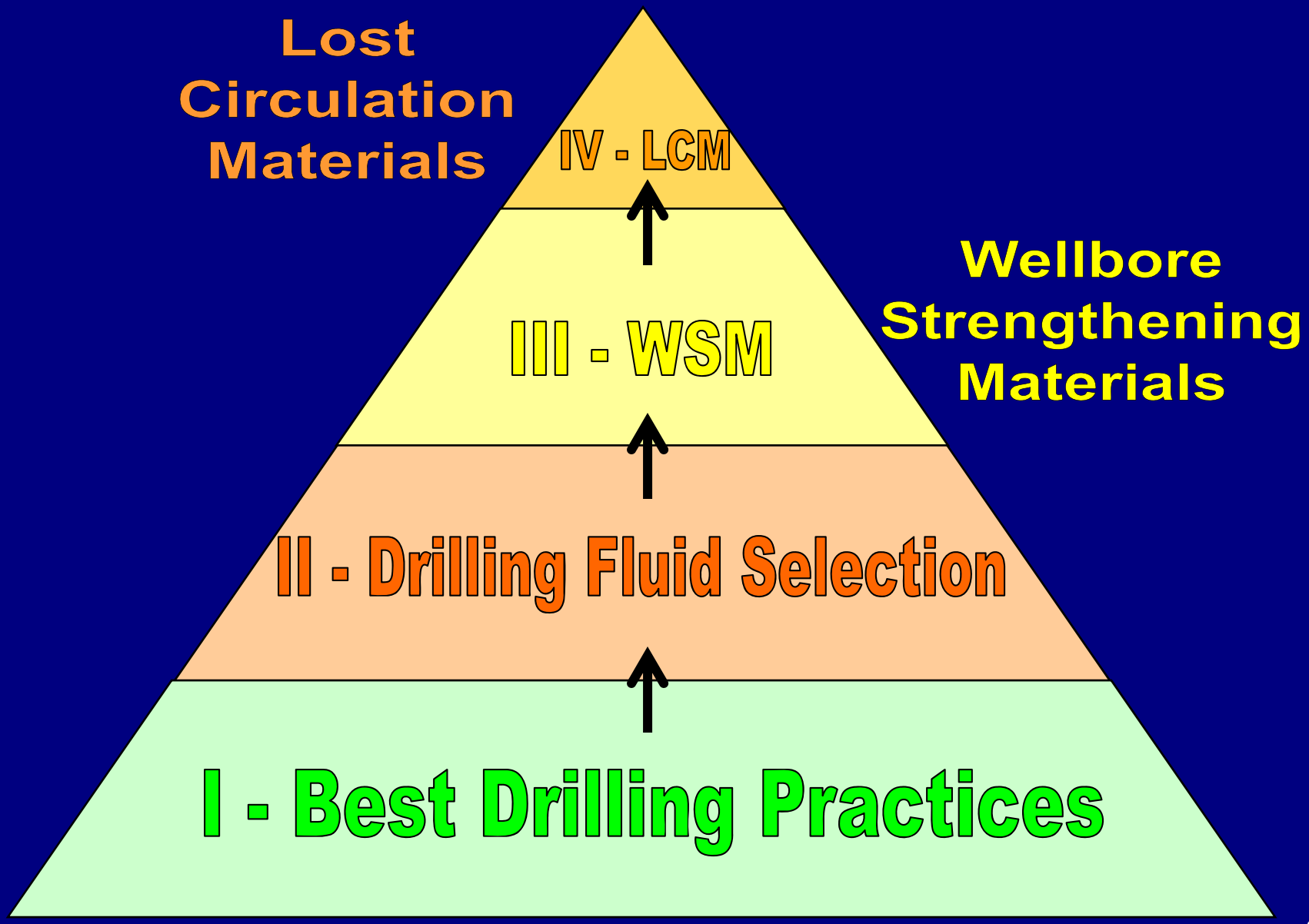
Managing Lost Circulation: A 4-Tiered Strategy



Tier I. Best Current or New **Drilling Practices**

- Accurate, precise Geomechanics Model, esp. Pore Pressure / Fracture Gradient
- Minimum and invariant Equivalent Circulating Density (ECD)
  - Accurate hydraulics profile for pre-drilling & at well site
  - Good hole-cleaning practices
  - Optimized solids control equipment
- Managed Pressure Drilling
- Casing While Drilling
- Expandable Casing/Liner

Managing Lost Circulation: A 4-Tiered Strategy

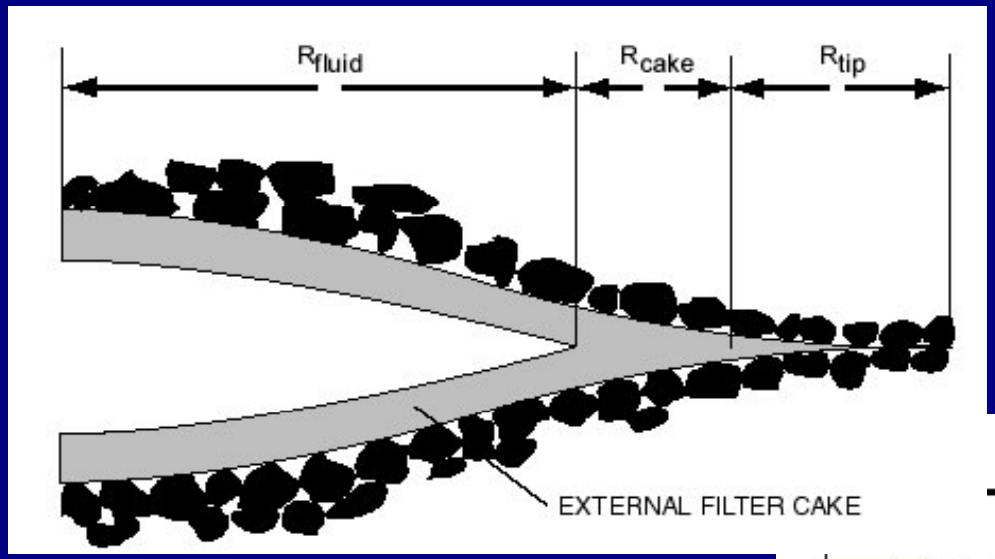


Tier II. Drilling Fluids which Minimize Losses:

WBM Form Thick, Tight Filter Cakes

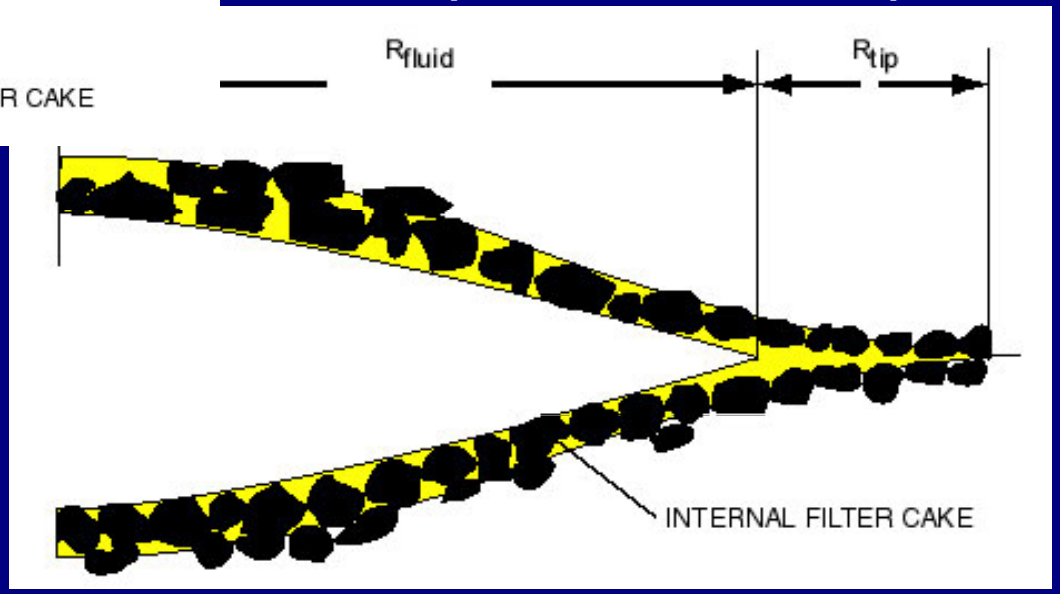
WBM:

Full pressure shielded from tip by solids filter cake buildup.



OBM/SBM:

Full pressure at fracture tip.

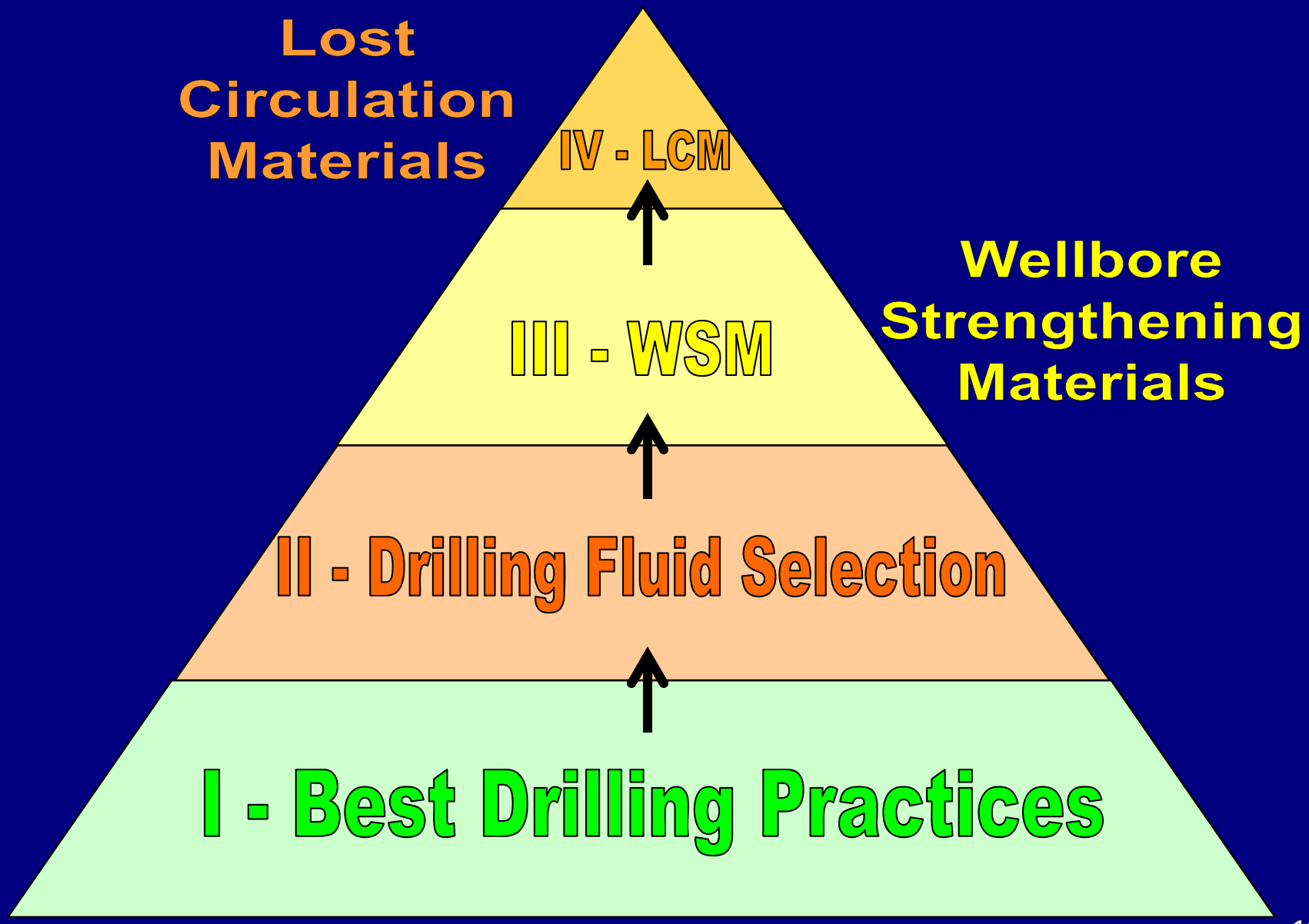


based on Morita et al, SPE 20409

Tier II. **Drilling Fluids** which Minimize Losses:

- High Low-Shear-Rate Viscosity (LSRV)
  - ✓ Reservoir Fluids
  - ✓ Underbalanced Fluids
  - ✓ Aphron and Mixed Metal Fluids
- Minimum and Invariant ECD
  - ✓ Soluble or Micronized Weighting Material
  - ✓ Temperature-Insensitive Rheology
- Wellbore Isolation
  - ✓ Silicate, Gilsonite Fluids

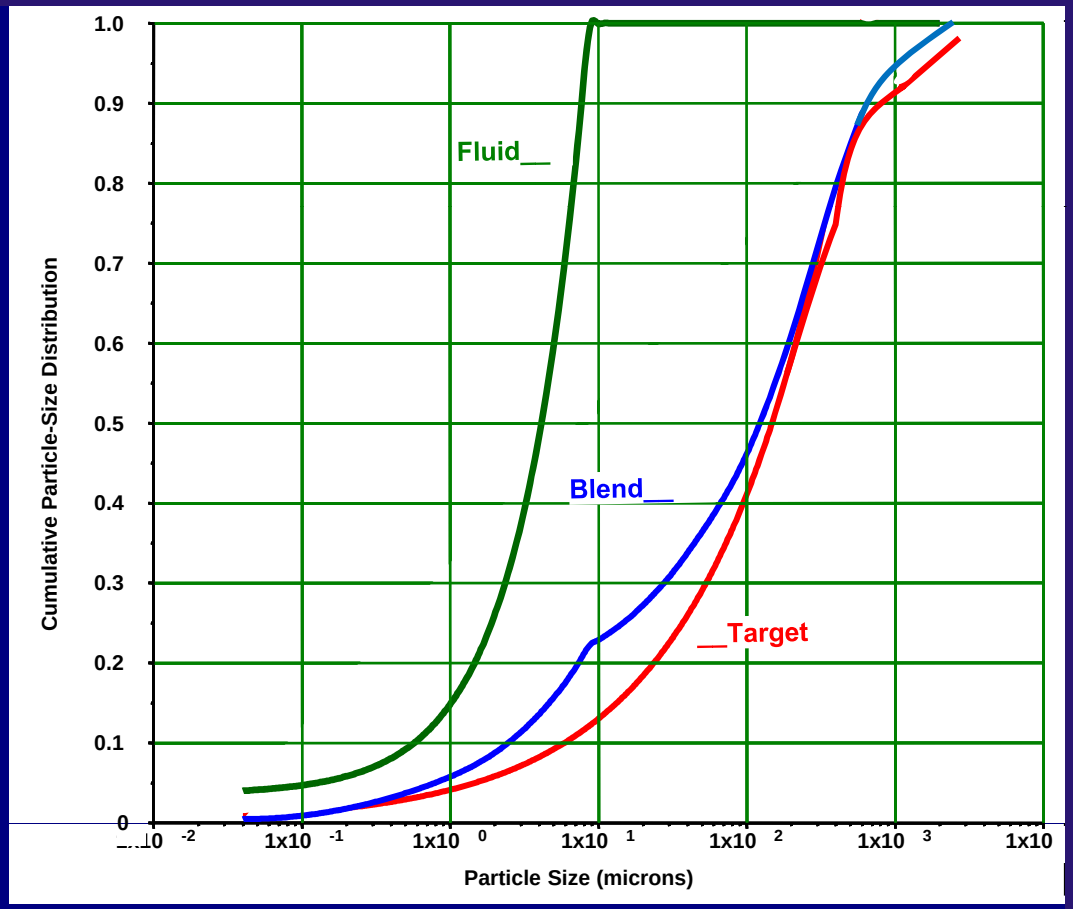
Managing Lost Circulation: A 4-Tiered Strategy



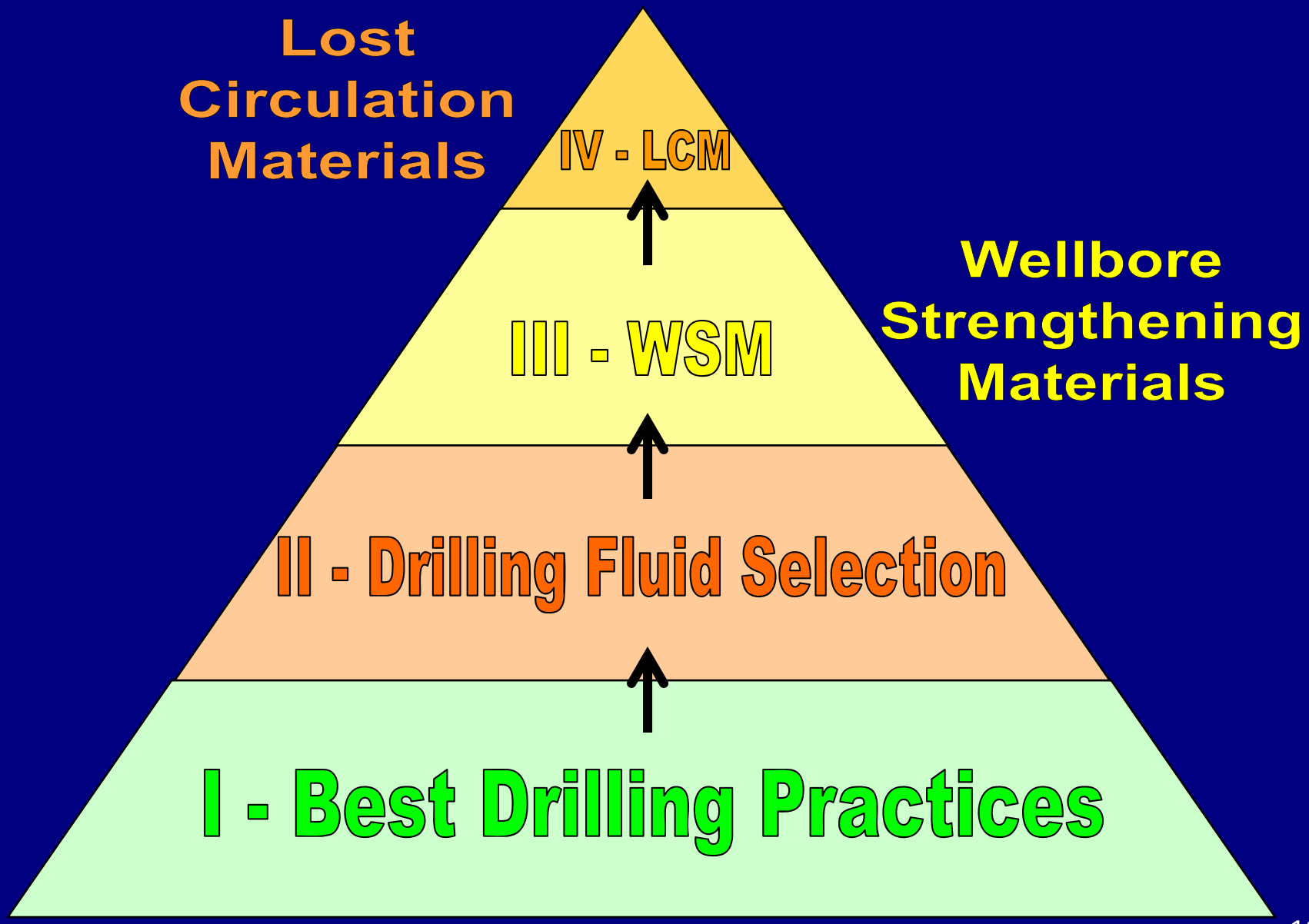
Tier IV. LCM in Pills or Whole Mud

Contingency: losses in high-perm zones/fractures

- Blends of materials of different sizes, shapes and properties;
- Particle size distribution matches distribution of openings in rock;
- Used in squeeze or sweep treatments;
- May be used one time or on regular basis while drilling ahead.



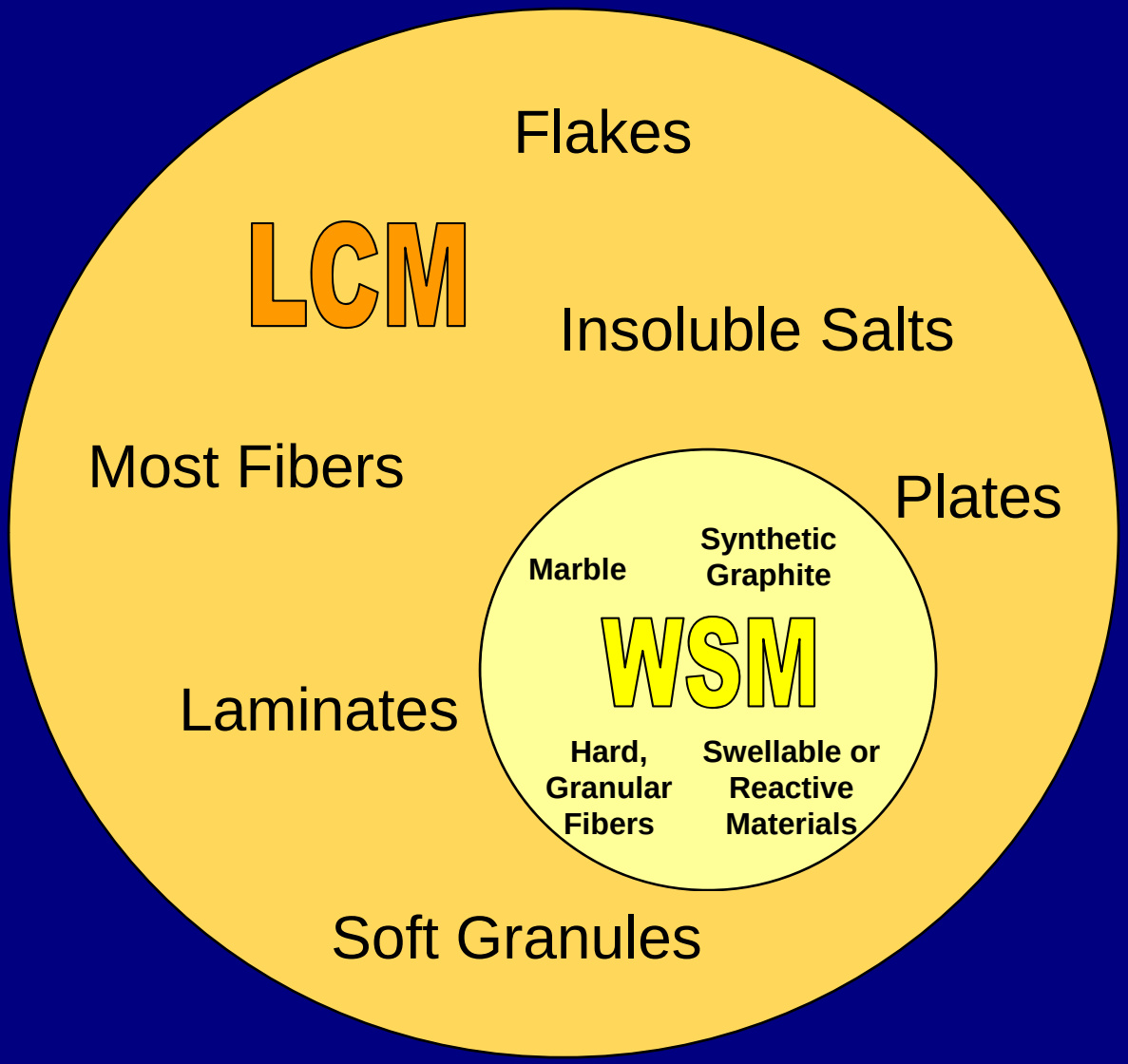
Managing Lost Circulation: A 4-Tiered Strategy



WSM vs LCM

Lost Circulation Materials - All materials that stop mud loss

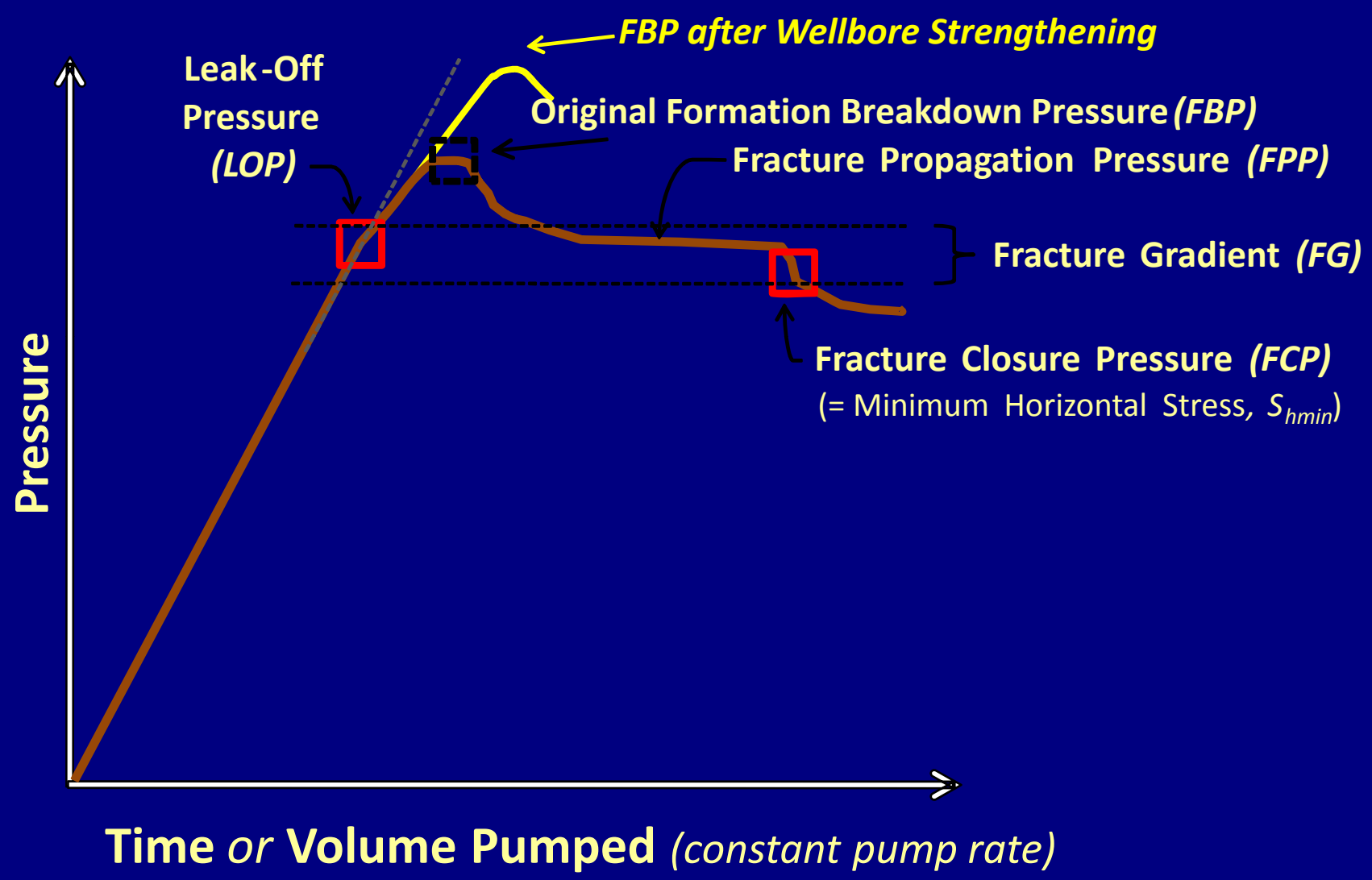
Wellbore Strengthening Materials - tough, granular solids or sealants



Strategies for Strengthening the Wellbore

- Physical
  - Wellbore Isolation: Swellable or Reactive Materials
  - Fracture Tip Isolation (Fracture Propagation Resistance)
- Chemical
  - Decrease clay swelling pressure (inhibitors such as K+ and invert emulsions)
- Thermal
  - Increase temp of drilling fluid above bottom-hole static temp: stiff formations, high thermal expansion
- Mechanical
  - Fracture Closure Stress
  - Hoop Stress Enhancement (Stress Cage)

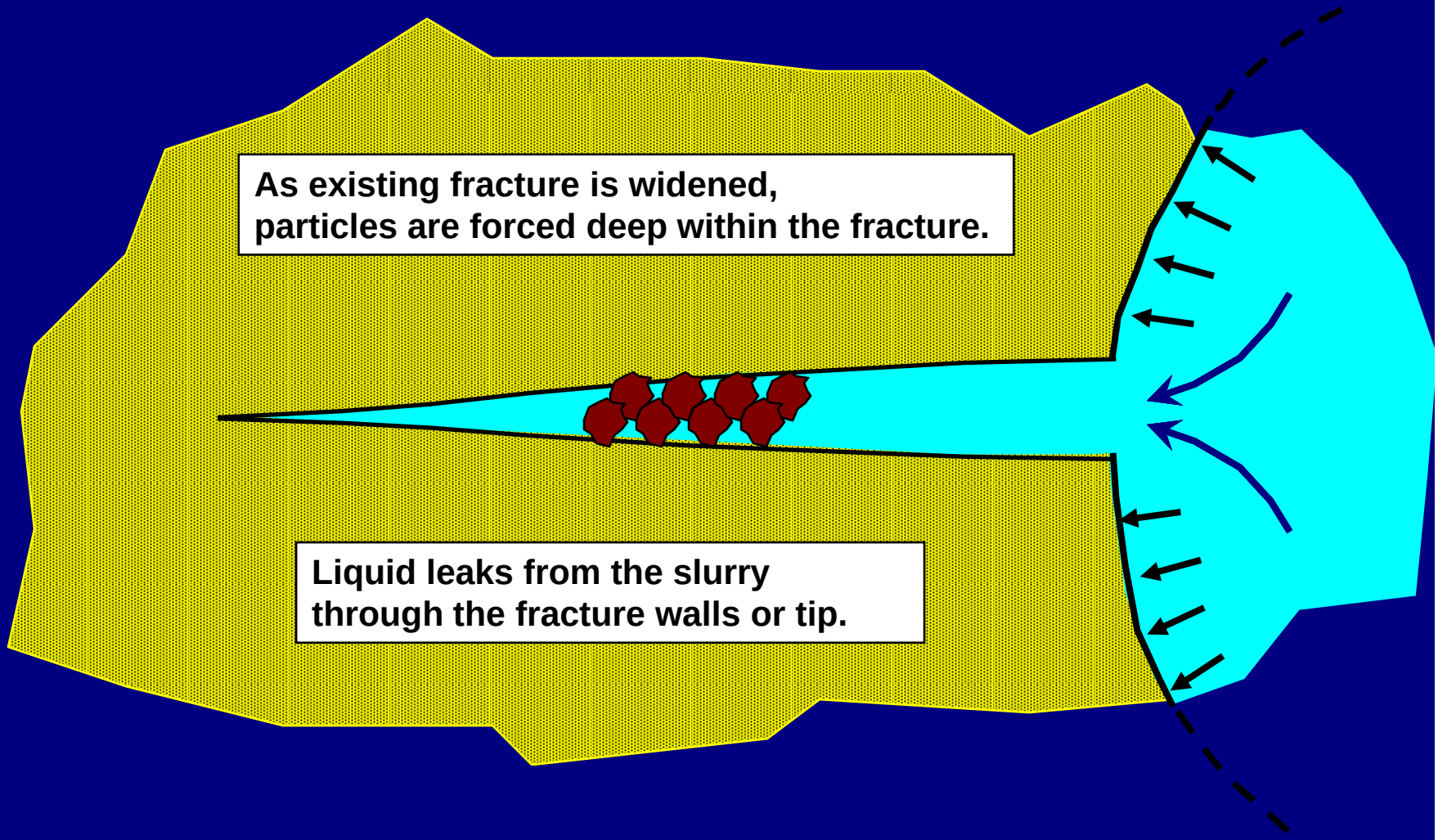
Extended Leak-Off Test – only FBP changes



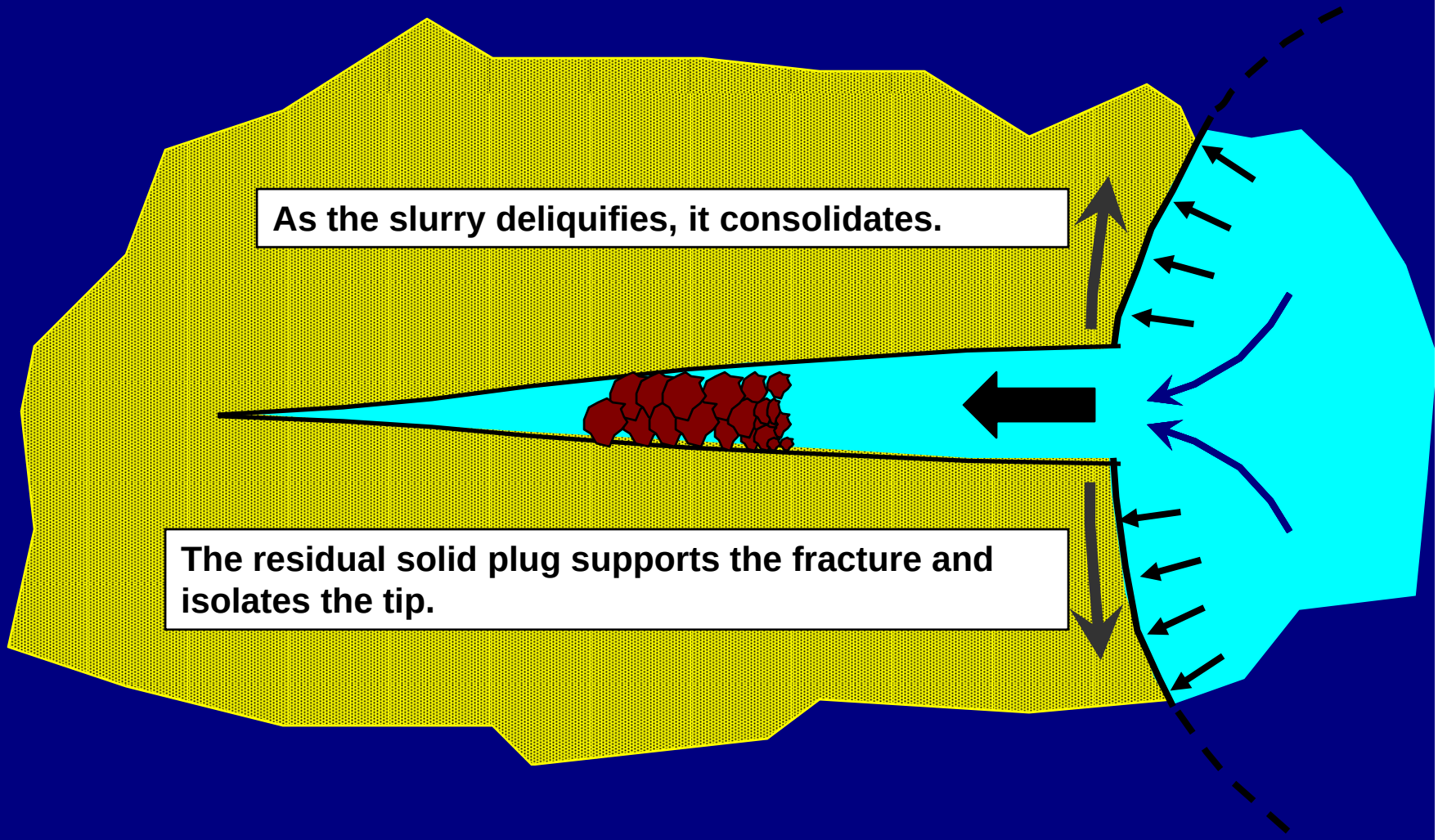
Fracture Closure Stress

- High-fluid-loss treatment for existing fractures
- Applied as high-fluid-loss pills or whole mud treatment (Drill-n-Stress)
- Pill may be water-based in a non-aqueous system
- May follow with cross-linked polymer plugs or cement

Fracture Closure Stress



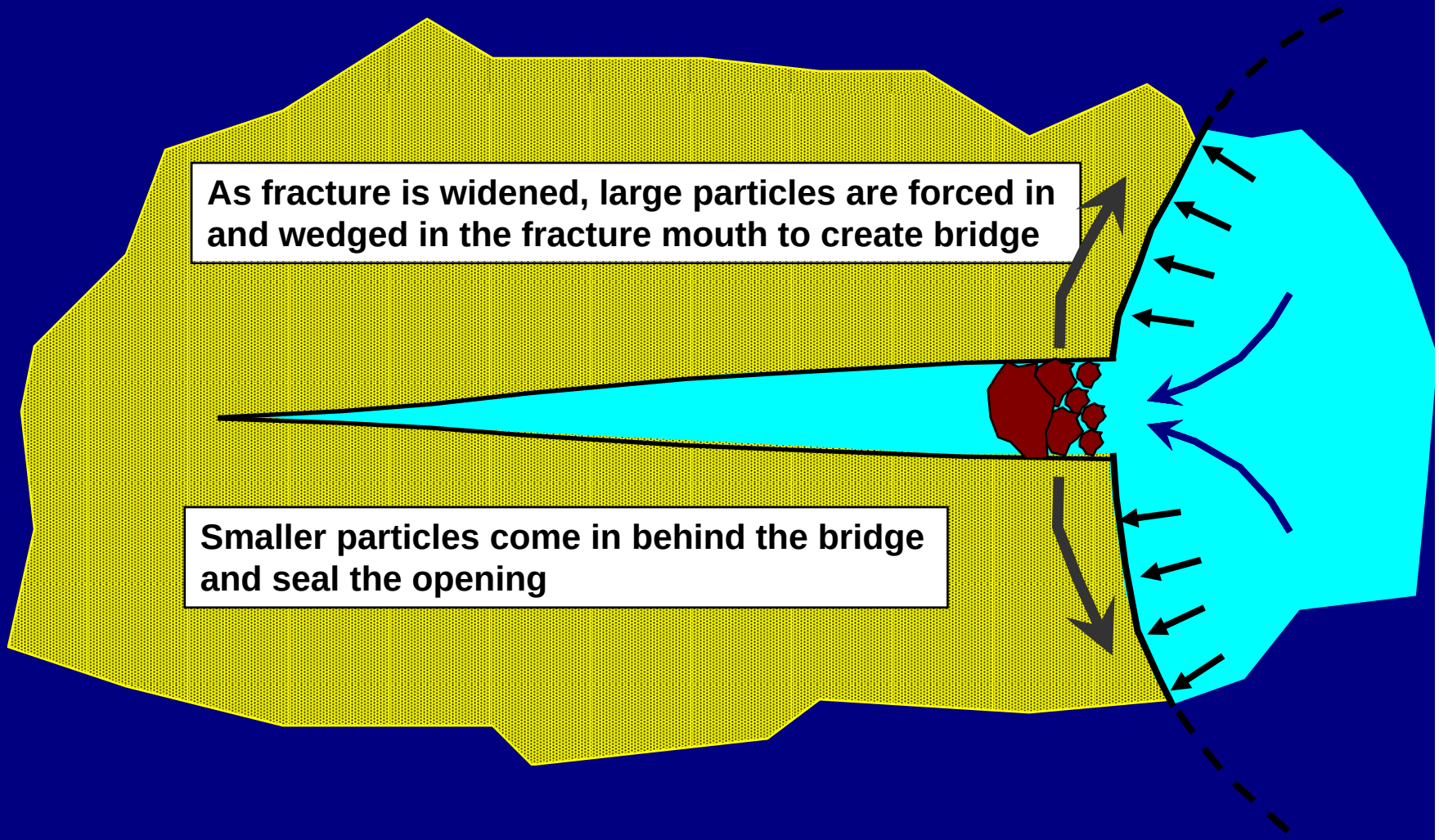
Fracture Closure Stress



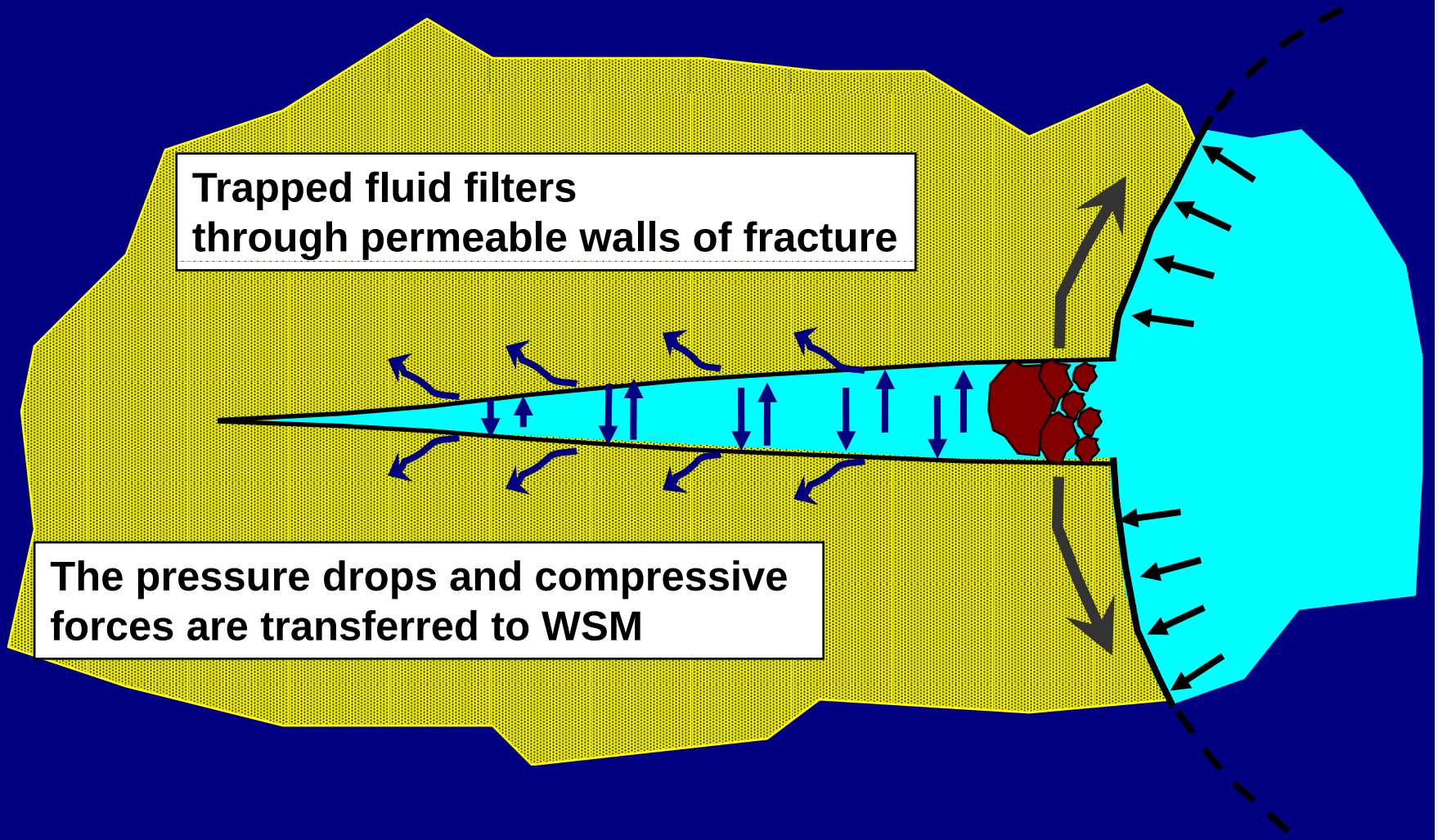
Hoop Stress Enhancement

- Wellbore is pre-fractured and sealed to prevent subsequent fracturing
- Mathematical models are used to design the **WSM** : calculate the required fracture width and particle size distribution of **WSM**
- **WSM** is added at moderate concentration while drilling (involves solids control management): Continuous addition is much more effective than pills
- The formation is pressured every stand to build hoop stress, or ECD is raised to desired level

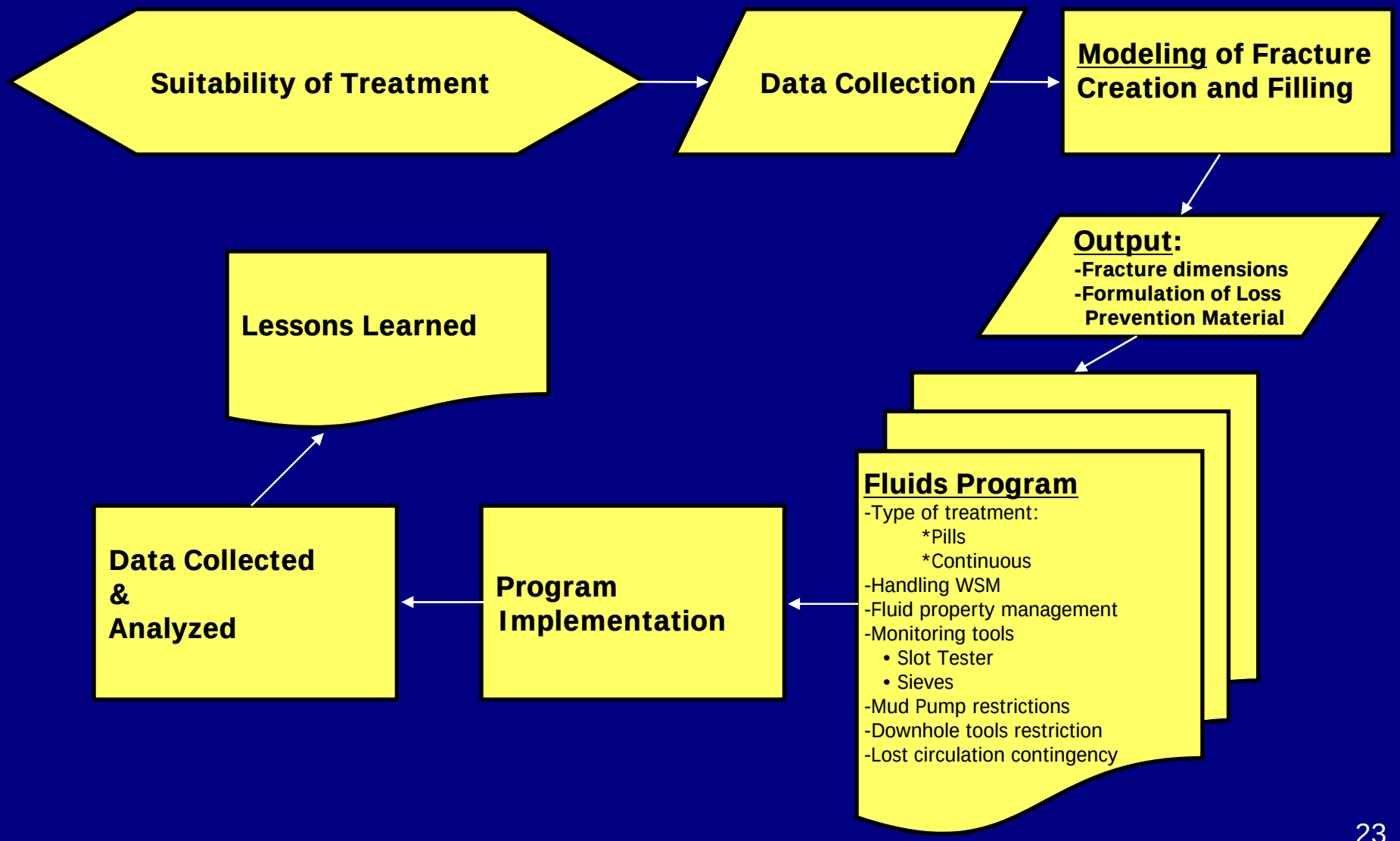
Hoop Stress Enhancement



Hoop Stress Enhancement



Hoop Stress Enhancement Application Cycle

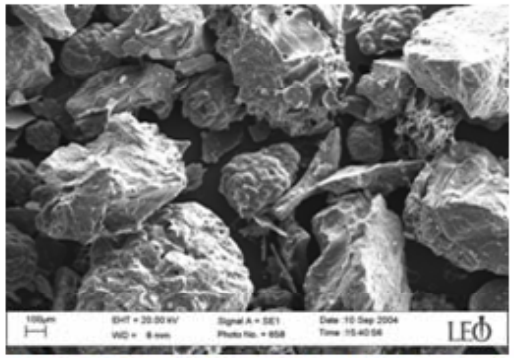


Design of Hoop Stress Enhancement

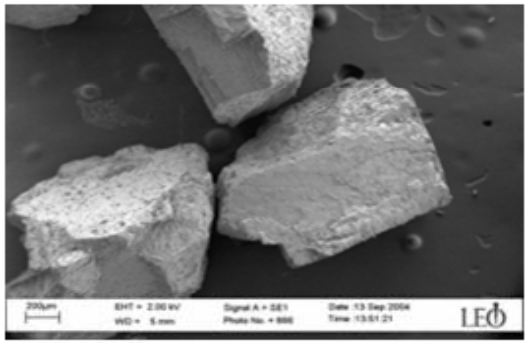
- ***Fracture Width*** required to achieve desired wellbore pressure – elastic model:
  - Desired Equiv. Circ. Density, or Wellbore Pressure
  - Rock Properties – Poisson's Ratio, Young's Modulus, Minimum Horizontal Stress (or Fracture Gradient)
  - Well Geometry – Depth, Inclination, Hole Size
- Acceptable ***types of WSM***
- ***WSM particle size distribution (PSD)*** and ***concentration***

Acceptable **WSM**

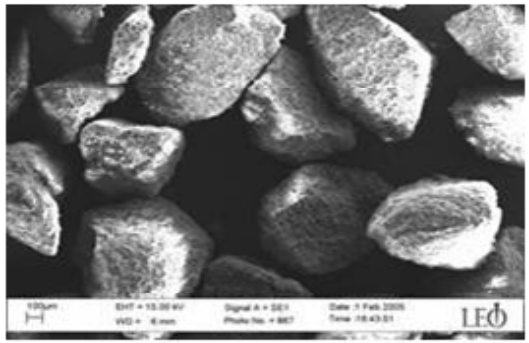
Large, Tough and Granular



Proprietary Graphitic Blend

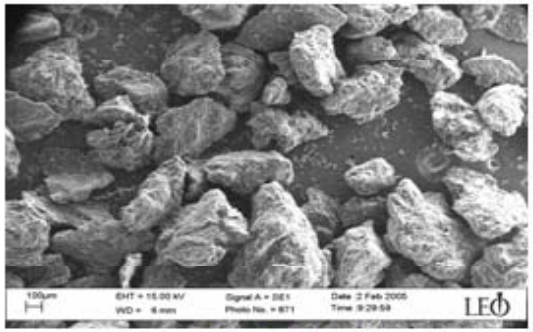


Marble



Nut Husks

Ground petroleum coke

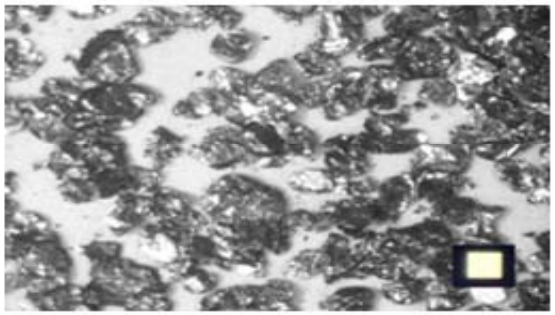


Graphite

Proprietary Cellulosic Blend

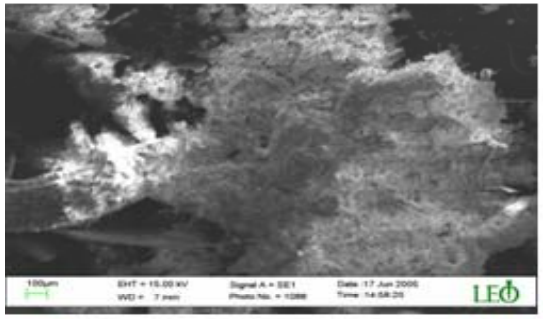
Unacceptable **WSM**

bagasse

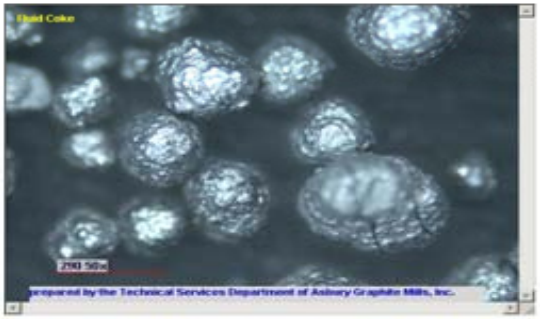


flake graphite

proprietary cellulosic blend



flake calcium carbonate



spherical materials cokes, graphites, proppants

mica

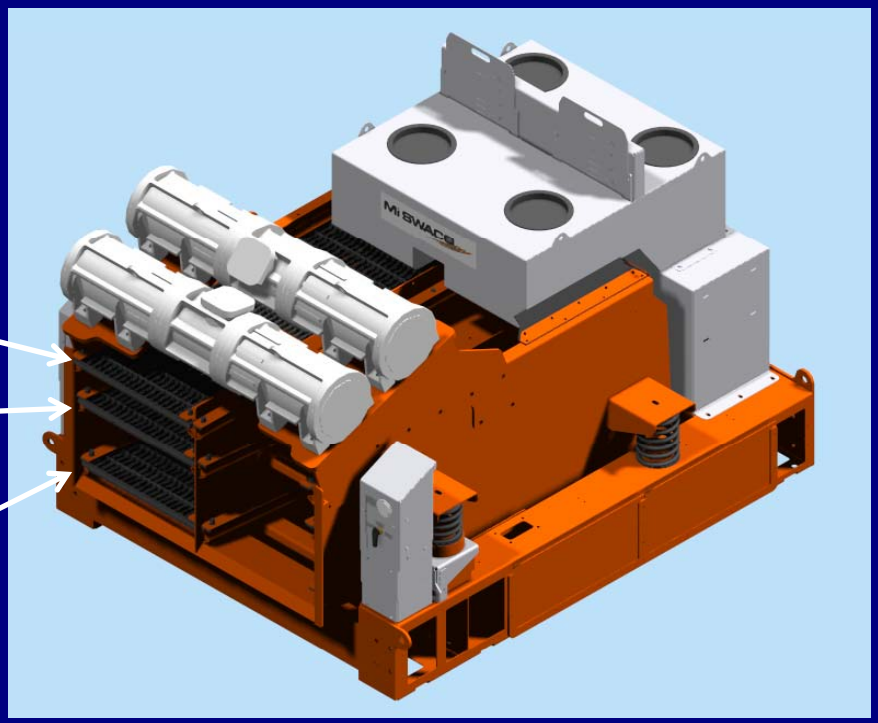
Continuous Addition of **WSM** to whole mud is best

- For short intervals, bypass the shale shakers
- For long intervals, screen out the WSM with the shakers
- The most effective solution: an **WSM Recovery System**

Screens out drilled cuttings

Recovers and recycles WSM

Screens out fines

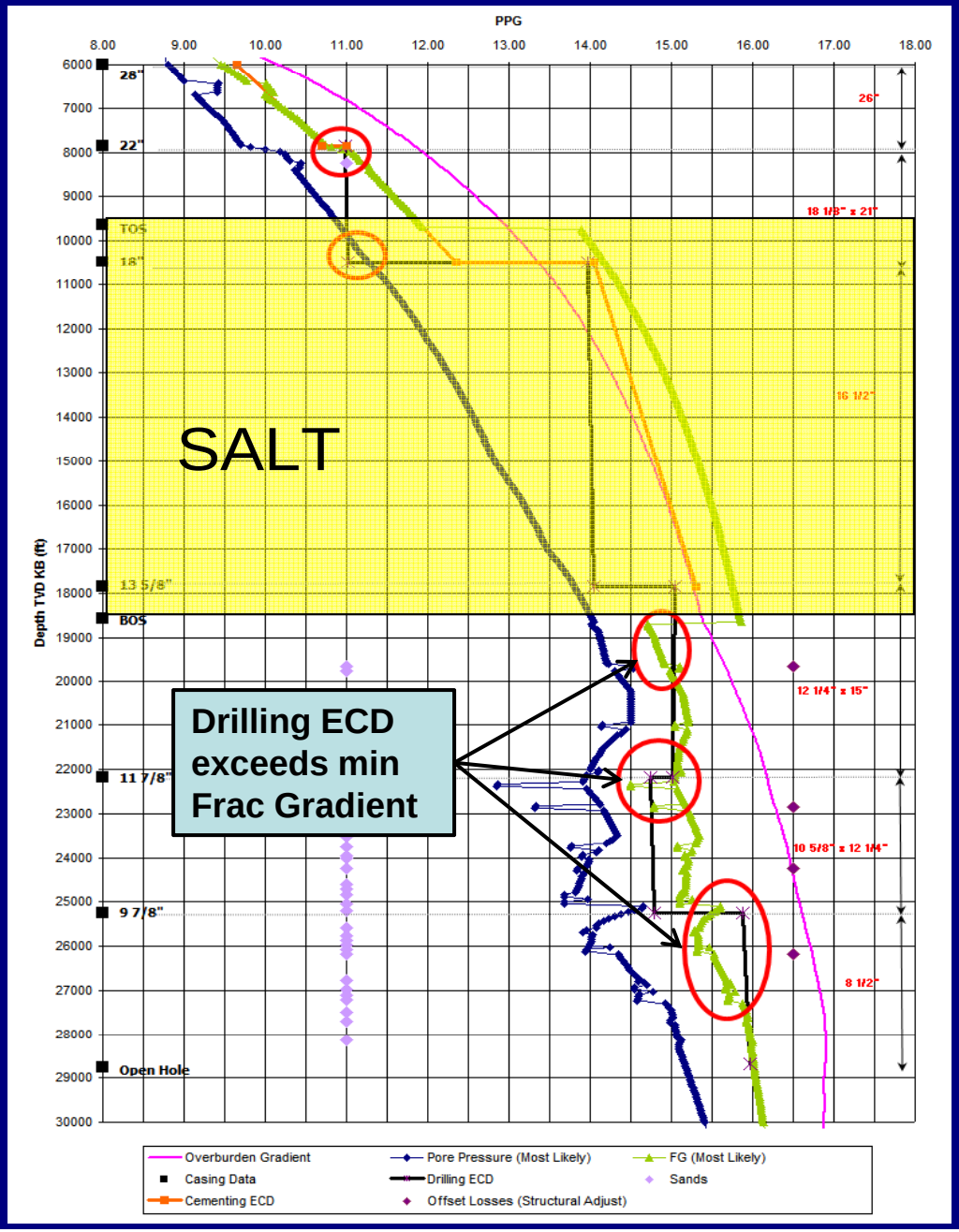


Monitoring Hoop Stress Enhancement

- Techniques to be used at the rigsite:
  - **Permeability Plugging Tests**
  - **Wet Sieve Analysis**
  - Sand kit determination

- Techniques available at shore bases:
  - Laser Light-Scattering Particle Size Distribution
  - **Fracture Sealing and Wellbore Strengthening tests**

Case History – Deepwater Gulf of Mexico



Major challenges

- Mud losses…> 15,000 bbl/well on previous wells, especially in intervals below the salt!
- Wellbore stability

Solution

- Strengthen five intervals
  - One above the Salt
  - One in the Salt
  - Three below the Salt
- Shakers dressed with 14/20 mesh screens
- [WSM] ~ 15 to 30 lb/bbl
- WSM Design
  - Sized Marble
  - Granular Synthetic Carbons

Case History – Deepwater Gulf of Mexico

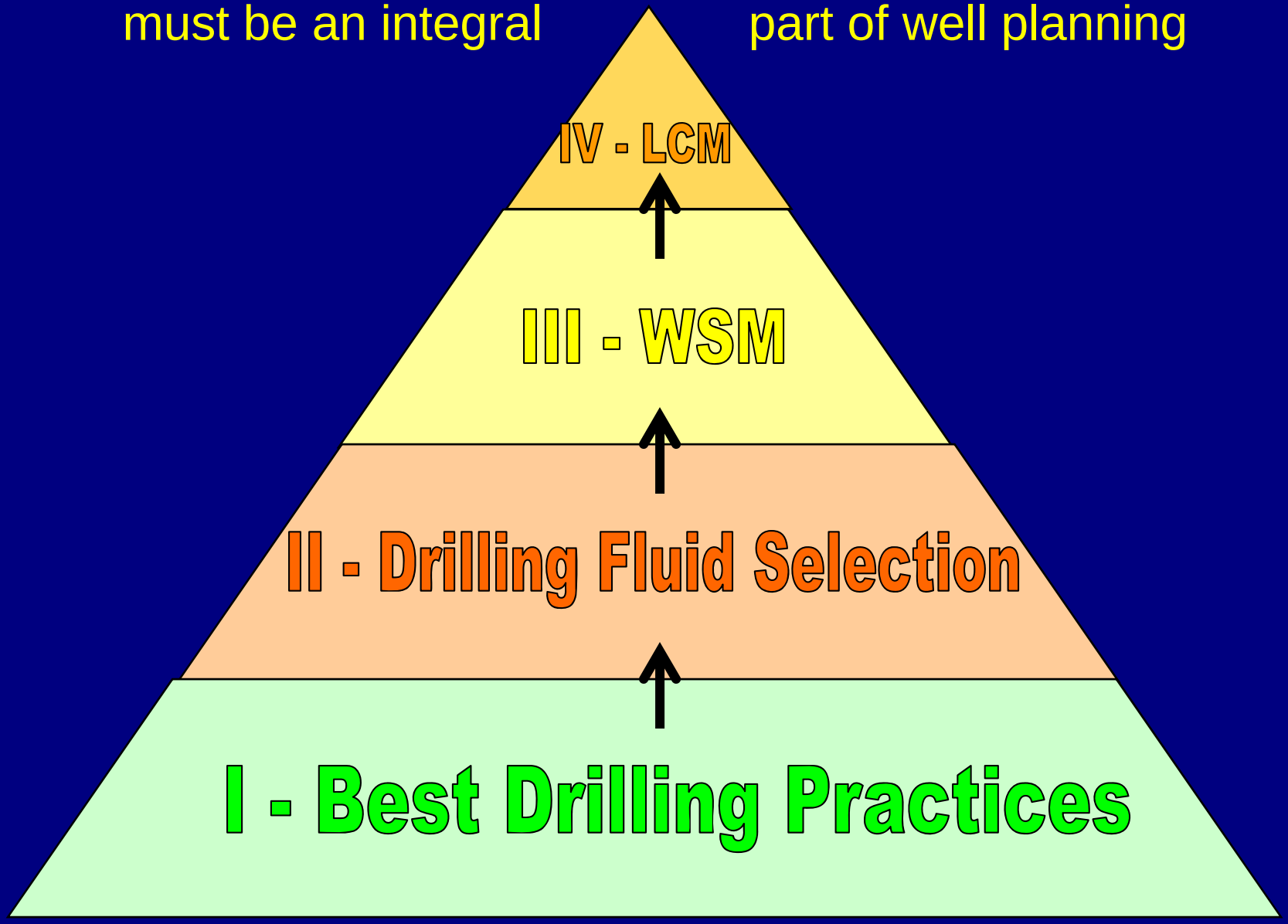
- ✓ No losses in 2900 ft sand section above salt
- ✓ No losses in 7500 ft salt section, screened up
- ✓ No losses in 9200 ft sand section below salt (where majority of losses occurred in offset wells)

Savings

- Total cost for the WSM ~ $ 0.7 MM. Previous mud losses ~ $ 2.7 MM. Net savings ~ $ 2.0 MM on materials alone.
- On subsequent 4 wells, similar net savings of ~ $ 2.0 MM on materials alone.

Summary

The 4-tier strategy for managing lost circulation must be an integral part of well planning



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