Fundamentals of Onshore Drilling

Fundamentals of Drilling

Principles of Drilling Fluid Technology

presentation No. 5

references:

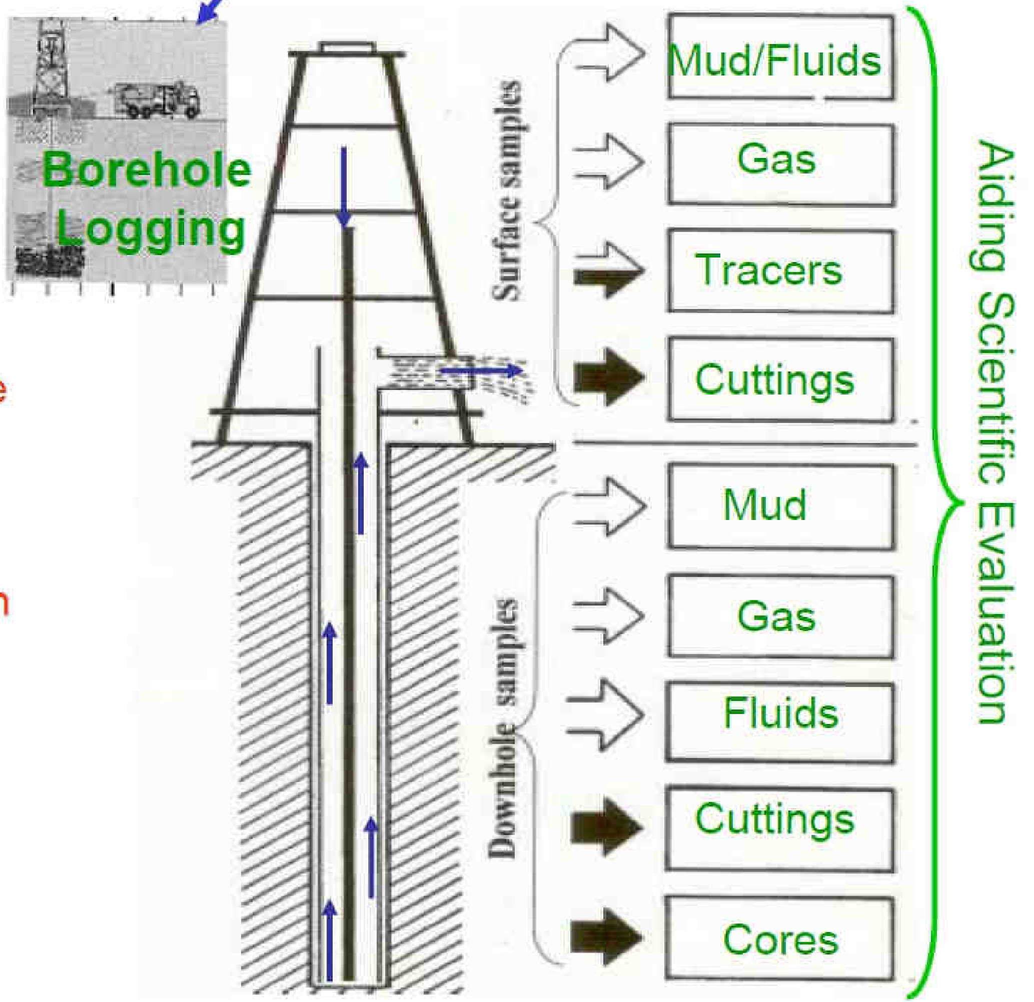
- Bernt S. Aadnoy, Iain Cooper, Stefan Z. Miska, Robert F. Mitchell, Michael L. Payne: ***Advanced Drilling and Well Technology***. SPE 2009, ISBN: 978-1-55563-145-1.
- Robello G. Samuel, Xiushan Liu: ***Advanced Drilling Engineering – Principles and Design***. Gulf Publishing Company, Houston Texas, 2009, ISBN: 978-1-933762-34-0.
- Boyun Guo, Gefei Liu: ***Applied Drilling Circulation Systems (Hydraulics, Calculations and Models).*** Gulf Publishing Company, Houston Texas, 2011, ISBN: 978-0-12-381957-4.
- ***Drilling Fluids Processing Handbook .*** Gulf Publishing Company, Houston Texas, 2004, ISBN: 978-0-7506-7775-2.
- Robello, R. G.: ***Downhole Drilling Tools***. Gulf Publishing Company, Houston, Texas 2007, ISBN: 978-1933762135.

Drilling Mud – Why do We Deal With?

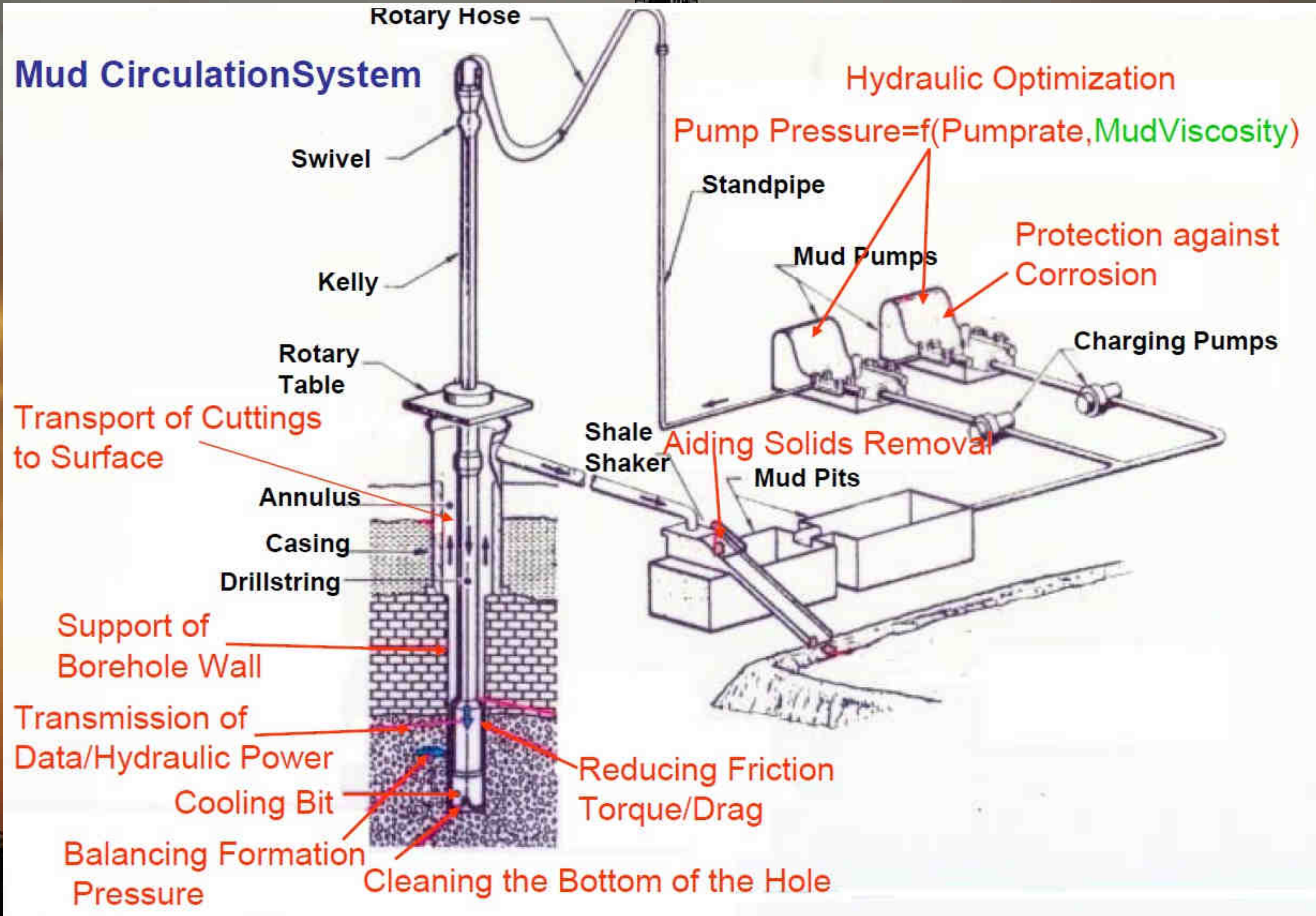
Engineers → ← Scientists

Drilling Tasks → Mud ← Information Carrier

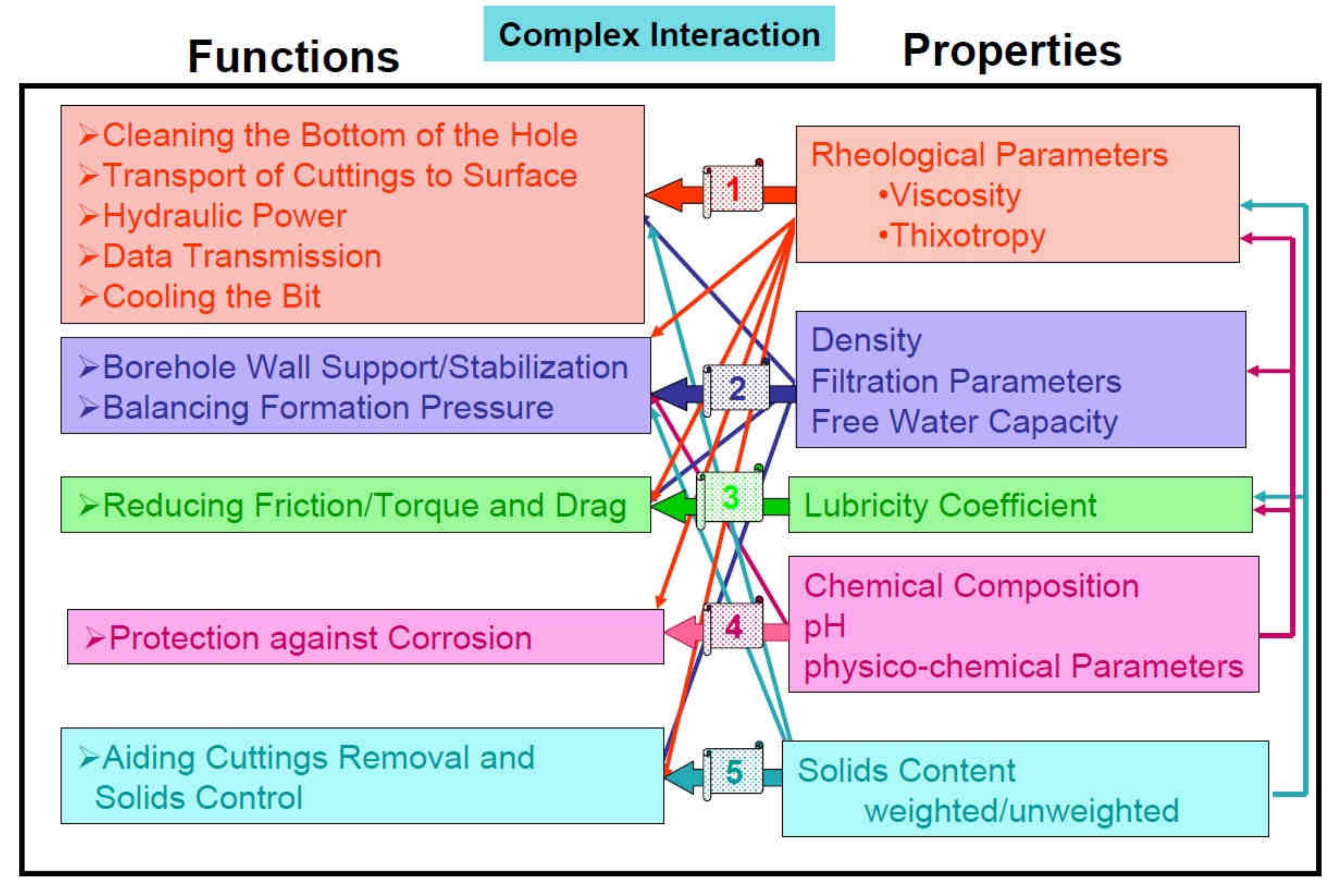
- Bottomhole Cleaning
- Cuttings Transport
- Borehole Wall Support
- Balancing Formation Pressure
- Cooling the Bit
- Hydraulic Power Transmission
- Data Transmission (MWD)
- Reducing Friction
- Corrosion Protection



Technical Key Functions of Drilling Fluids



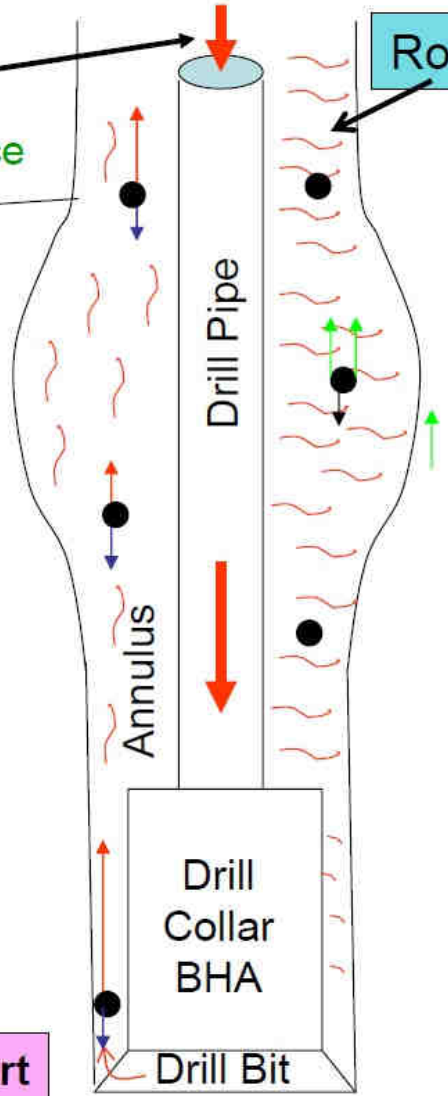
Mud Properties Controlling Technical Key Functions



Fundamentals of Cutting Transport

Drilling/Mud Circulation

Roundtrip/Circulation Break



Transporting of Cuttings to Surface

↑ V_{ann}: Mud Velocity in Annulus depends on:
- •Pumprate,
- •Annular Geometry

↓ V_{sett}: Cutting Settling Velocity depends on:
- •Mud Parameters
  - - Rheology (Viscosity)
  - - Density
- •Cutting Parameters
  - -Density
  - -Diameter
  - -Shape

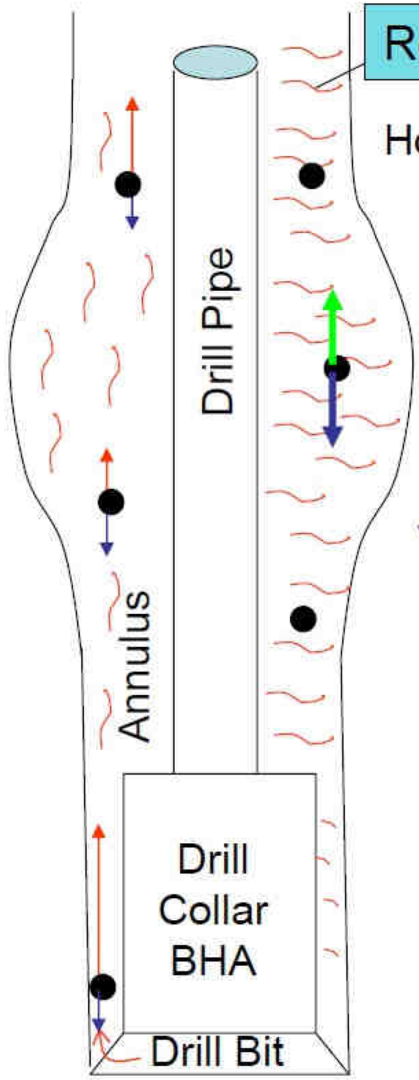
$$V_{ann} >> V_{sett}$$

Basic Law of Cuttings Transport

$$(V_{ann} - V_{sett})/V_{ann} > 50\%$$

Fundamentals of Cutting Transport

Drilling/Mud Circulation



Roundtrip/Circulation Break

Holding Cuttings in Suspension

τ_0: Yield Strength of Mud depends on:

- •Rheological Behaviour
- •Gel Strength, Thixotropy

τ_{cutt}: Tangential/Normal Stress due to Cutting Weight depends on:

- -Cutting Diameter (d_c)
- -Cutting Density (ρ_c)
- -Cutting Shape
- -Mud Density (ρ_m)

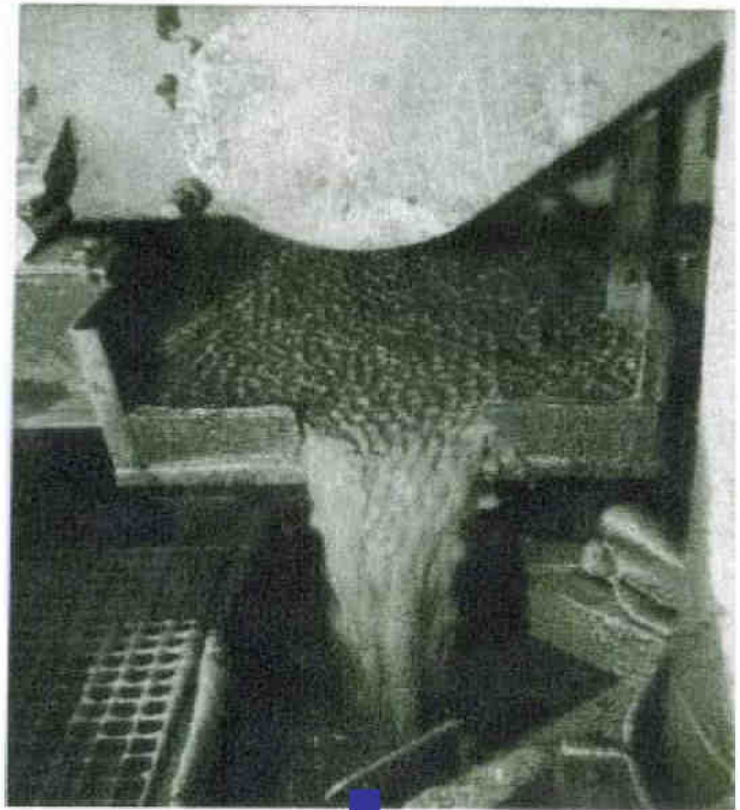
$$\tau_{cutt}=(d_c*g(\rho_c-\rho_m))/6$$

$$\tau_{cutt}<\tau_0$$

Cutting Transport – The Role of Drilling Fluid Rheology

1

Circulation/Drilling
Dynamic Carrying Capacity



Rheological Behaviour while Flowing
Viscosity dependent on Shear Rate

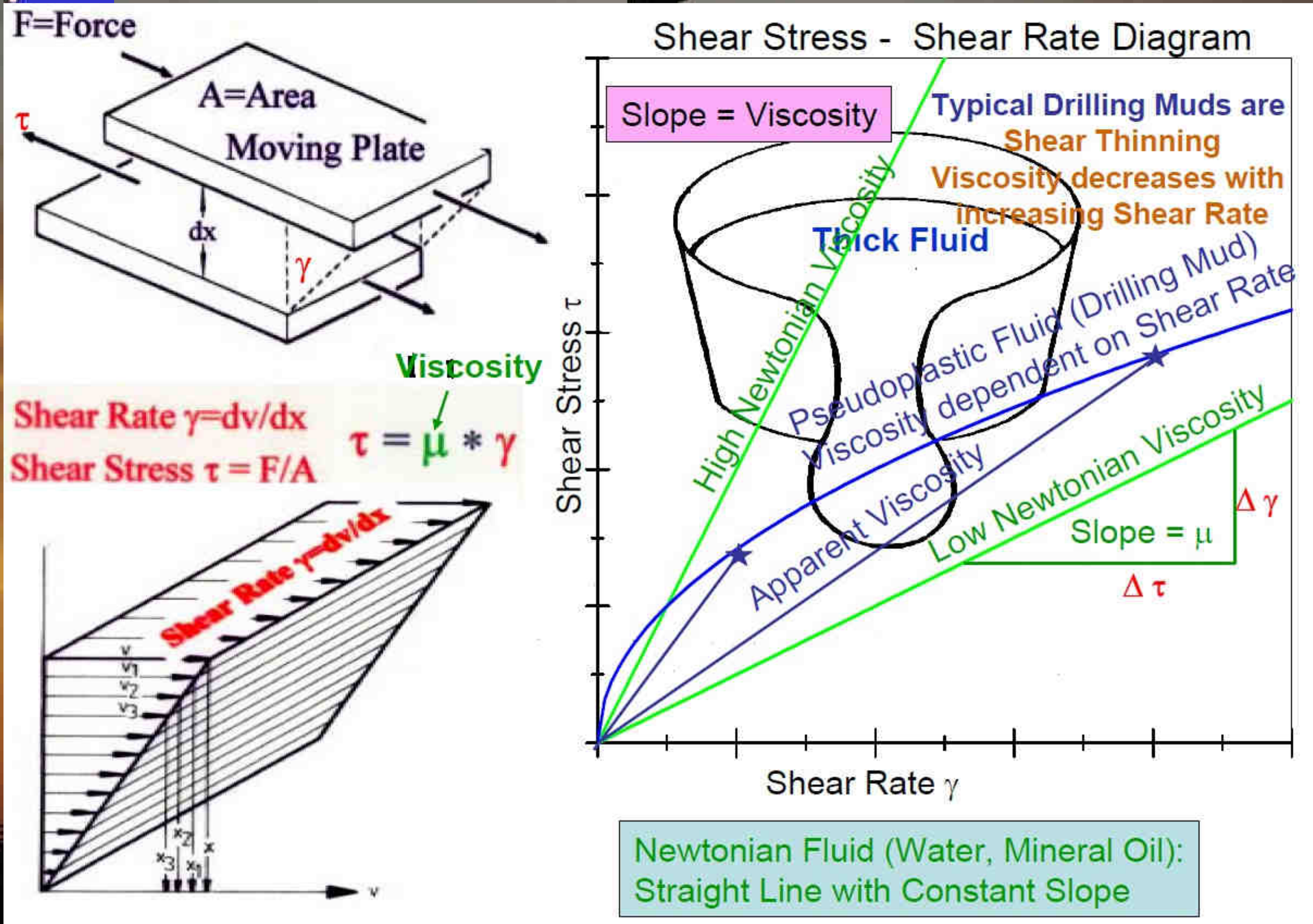
Circulation Break/Roundtrip
Static Carrying Capacity

Rheological Behaviour while Stationary

Thixotropy: Fluid ⇄ Gel reversible

Cutting Transport – The Role of Drilling Fluid Rheology

Theory of Fluid Rheology



Drilling Mud Viscosity – Measuring Equipment

1

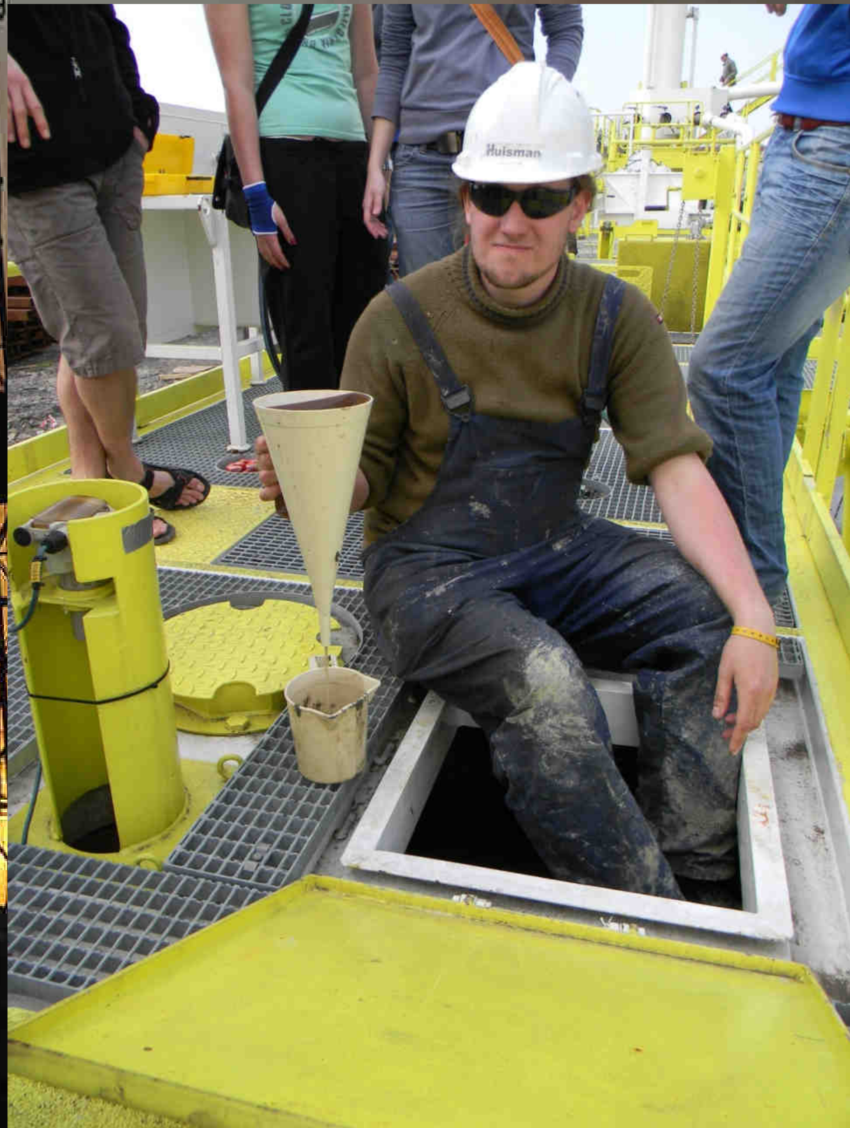
Rotational Viscosimeter

Determination of Shear Dependent Viscosity by Measuring Flow Curve at different Rotational Speeds

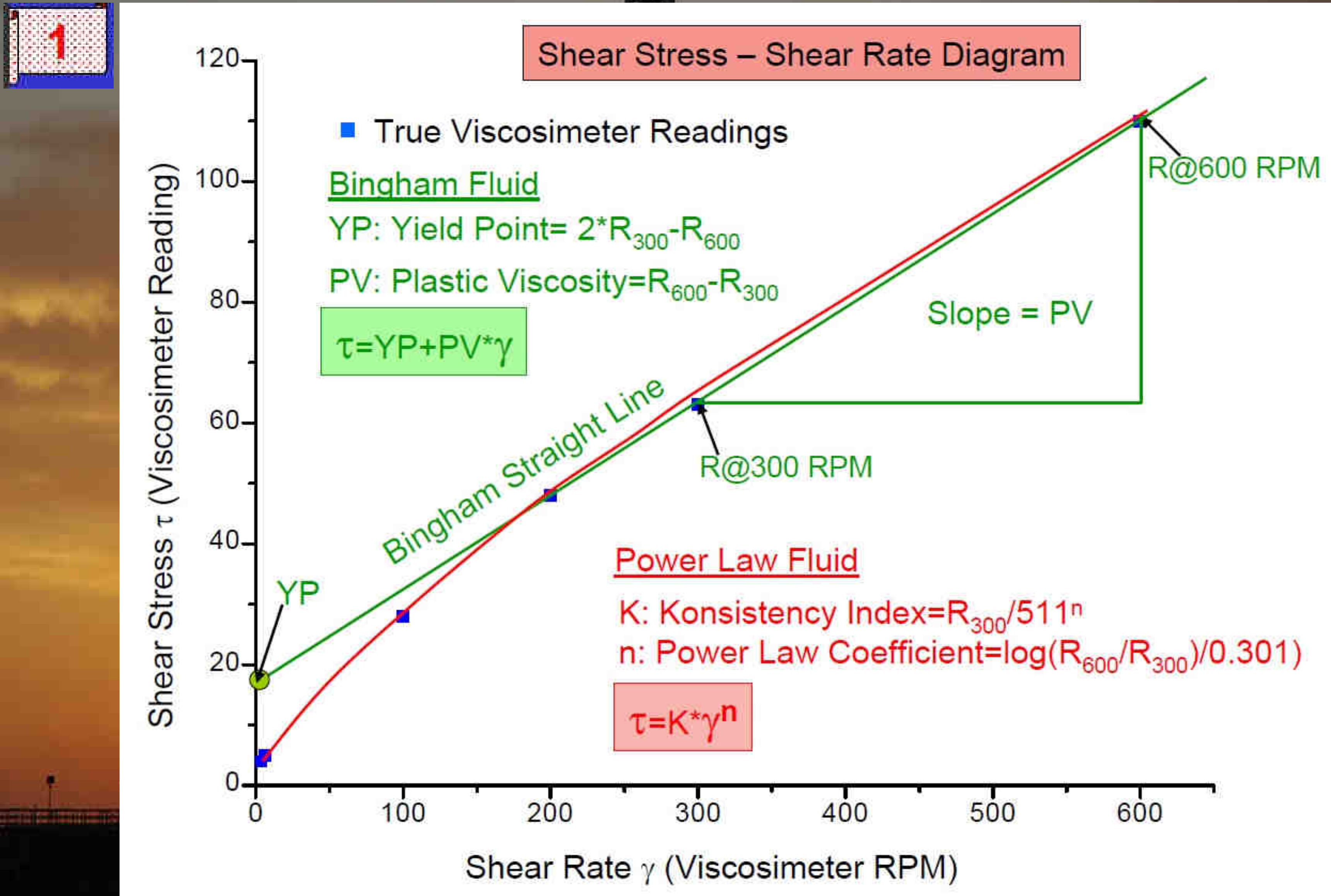
Marsh Funnel

Measuring Outflow time (s)
Water: 26 s

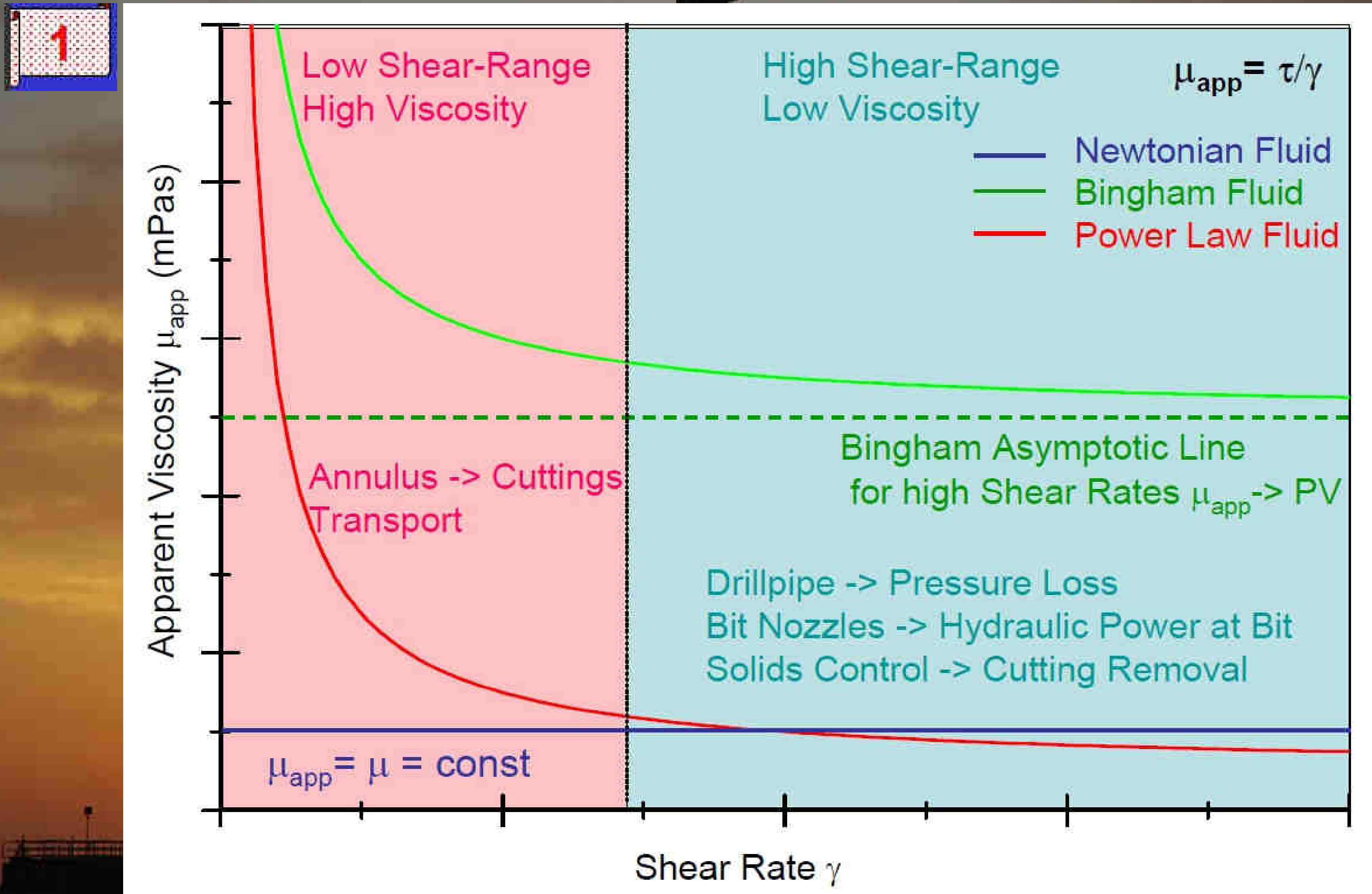
Drilling Mud Viscosity – Measuring Equipment



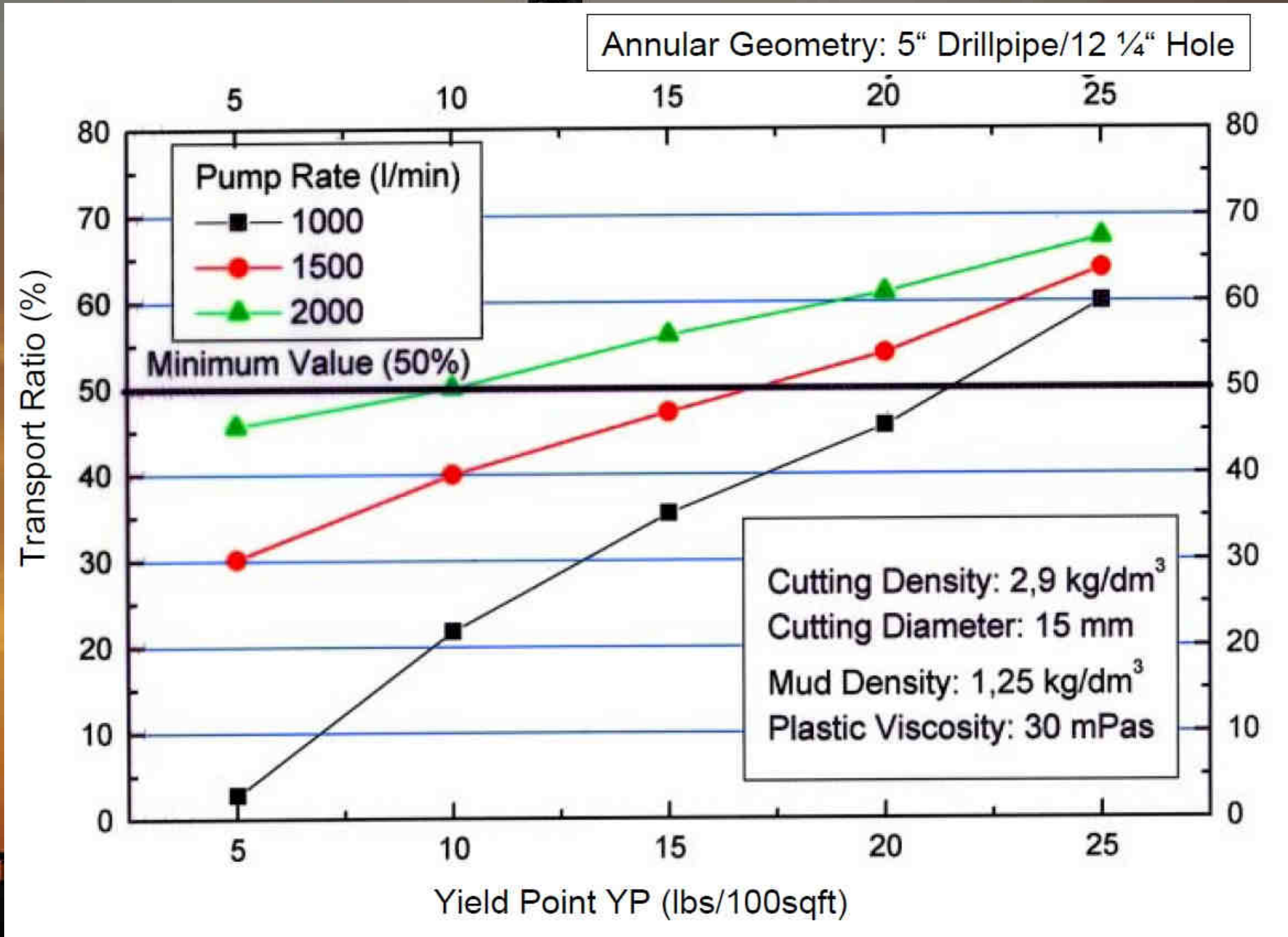
Flow Models Describing Pseudoplastic Drilling Fluid Rheology



Shear Thinning of Drilling Fluids – Influence on Drilling Process

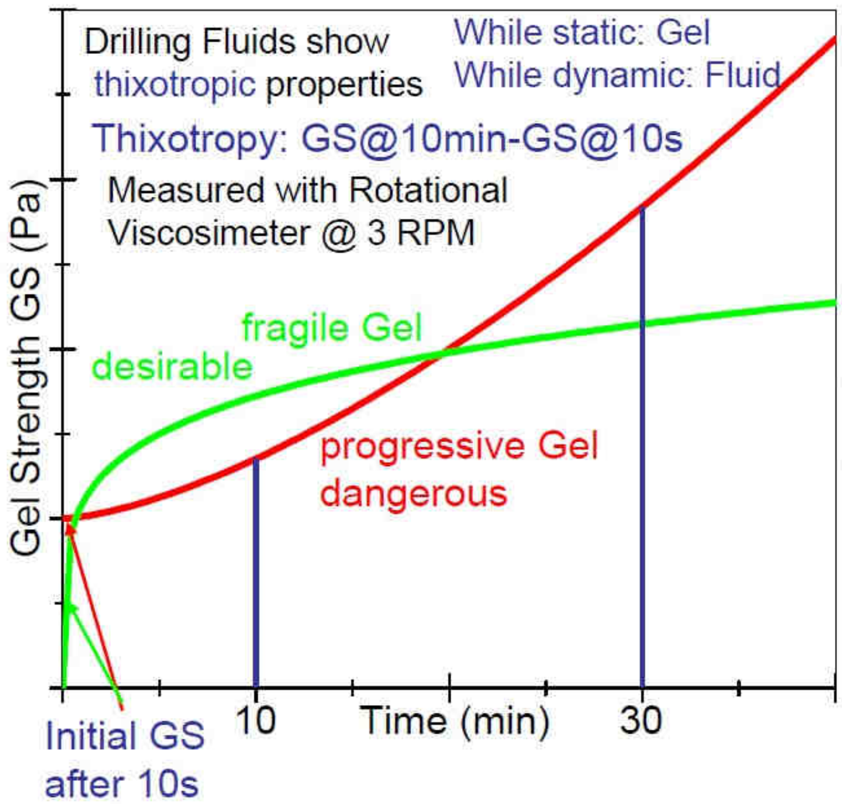


Influence of Yield Point on Cuttings Transport Efficiency

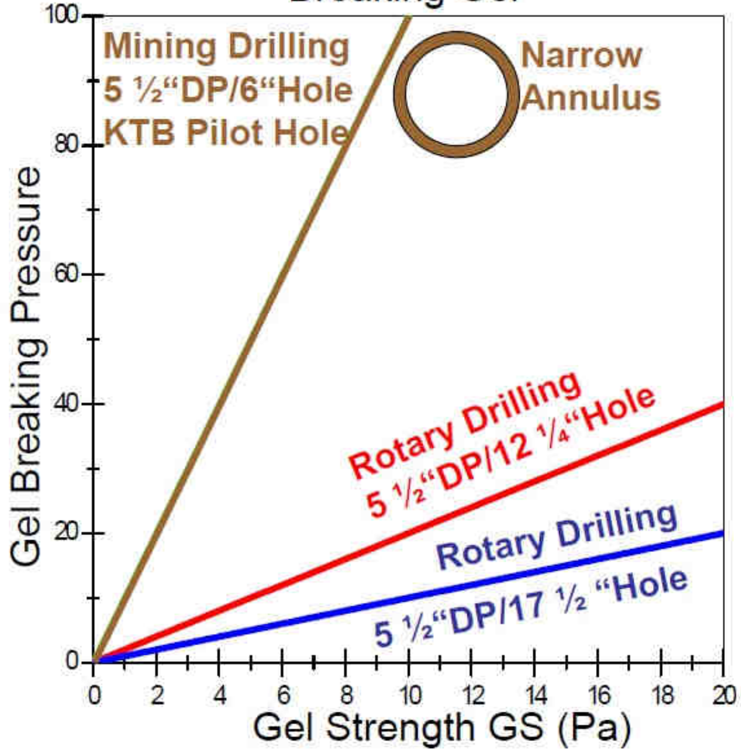


Gel Building Properties of Drilling Fluids

Time dependent Gel Strength



Pump Pressure necessary for Breaking Gel



GS too high ➡ high Surge/Swab Pressures ➡

- Excessive Pump Pressures
- Formation Fracturing/Lost Circulation
- Borehole Instability
- Uncontrolled Influx of Formation Fluids

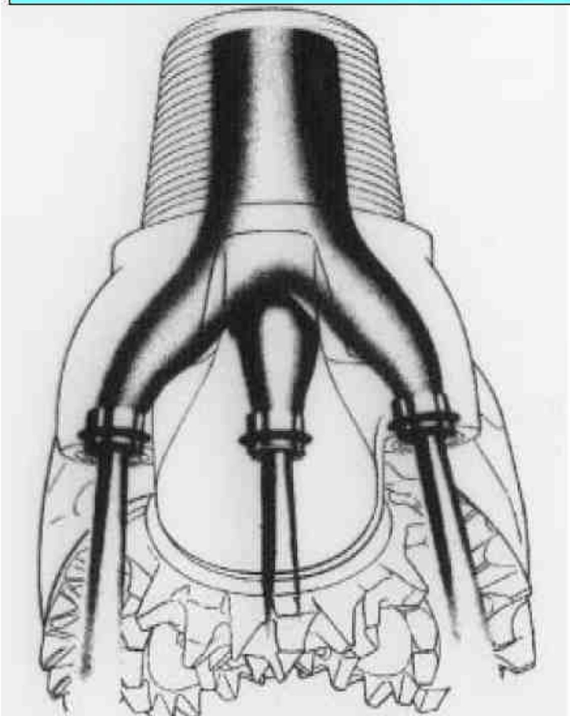
GS too low ➡ Insufficient Static Carrying Capacity for Cuttings

Optimizing Drilling Hydraulics

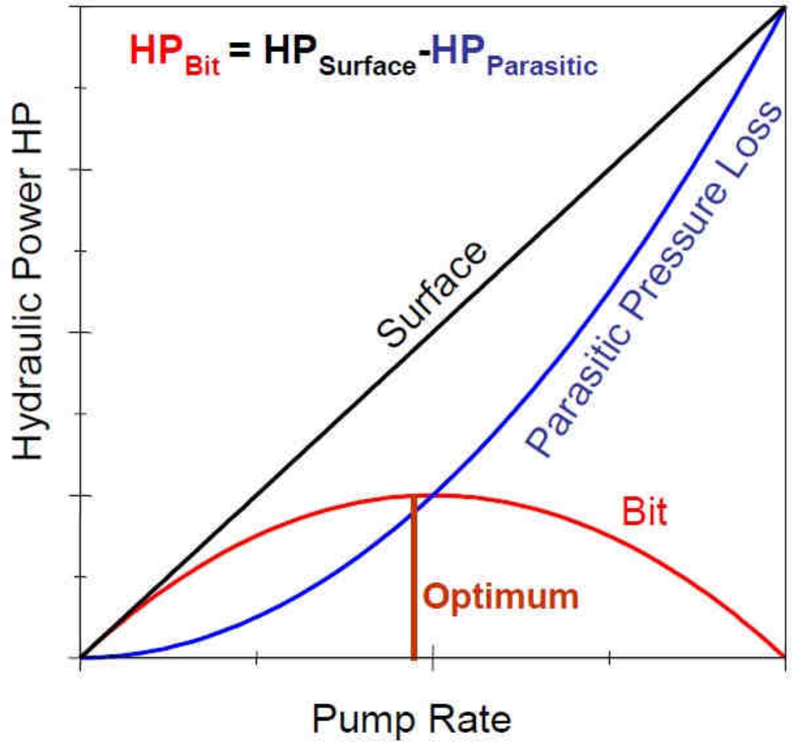
1

Objective: Maximizing Hydraulic Power at Bit

Rule of Thumb for Rotary Drilling:
2/3 of total Pressure Loss at Bit



Jet Nozzles in a Roller Cone Bit



Minimizing Parasitic Pressure Losses ⇨ Drillpipe, Annulus, Surface

PV as low as possible,
YP as high as necessary for Cuttings Transport

Impact Parameters on Parasitic PL

- Annular Geometry
- Surface Equipment
- Drillpipe Size
- Mud Rheology (YP and PV)

Mud Additives Controlling Rheology

1

Viscosifiers

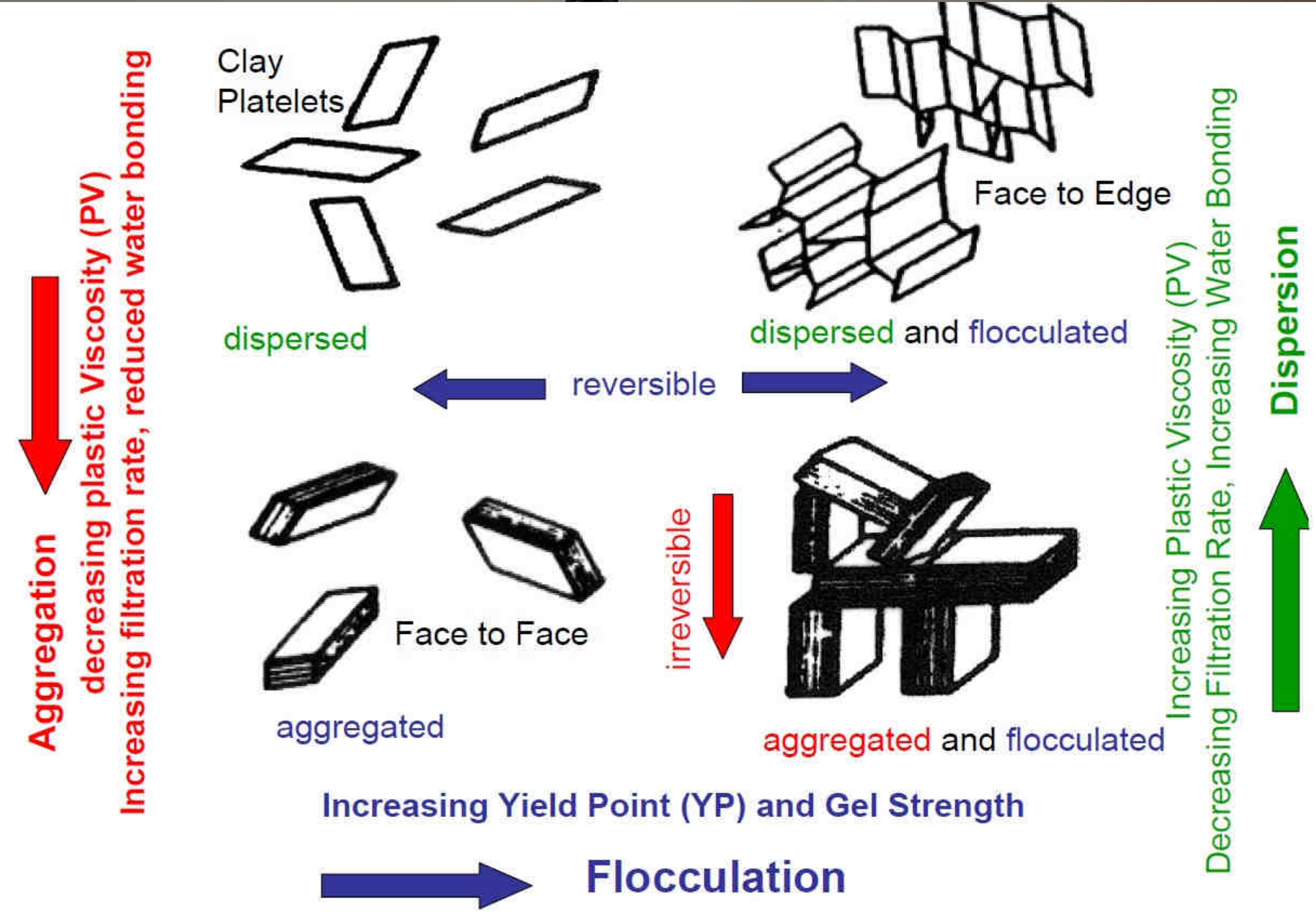
- Clays
  - **Bentonite**
  - Attapulgite
  - Sepiolite
  - Hectorite
- Polymers
  - Biopolymers
    - -**Xanthan**
    - - Guar Gum
  - Polyacrylate/Polyacrylamides
  - HEC (Hydroxyethylcellulose)
  - CMC (Carboxymethylcellulose)

Dispersants/Deflocculants

- Lignosulfonates
- Lignites
- Phosphates
- SSMA (Styrene Sulfonate Maleic Anhydride)

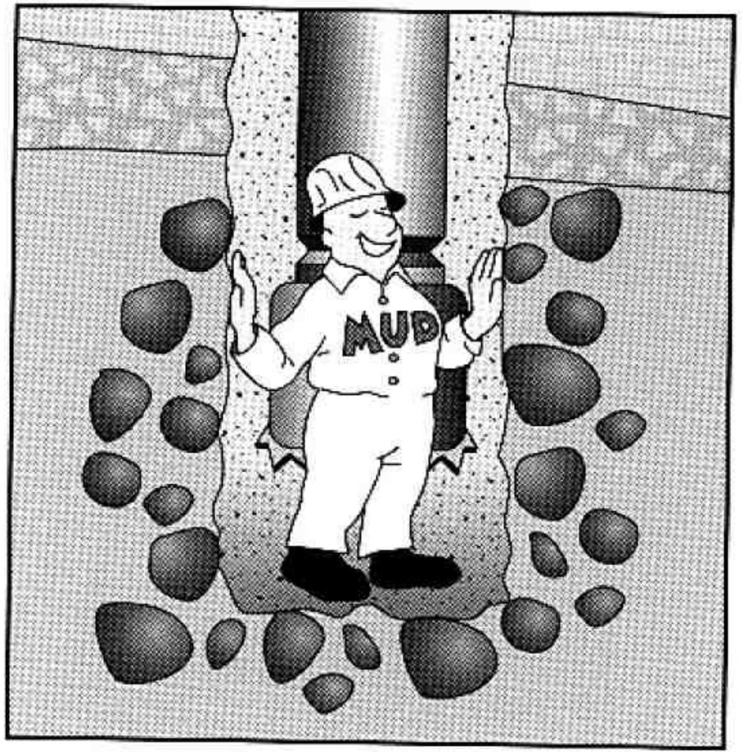
(important for High Temperature Applications)

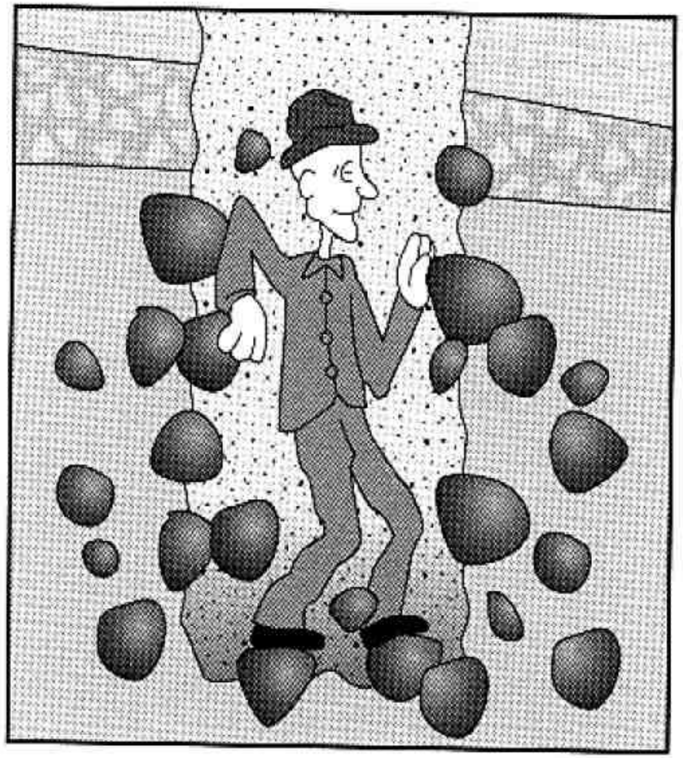
State Diagram of Colloidal Montmorillonite Suspension in Water



Support of the Borehole Wall – Balancing Formation Pressure

2





While Drilling Open Hole
Mud Column should act as **„Hydraulic Casing“**

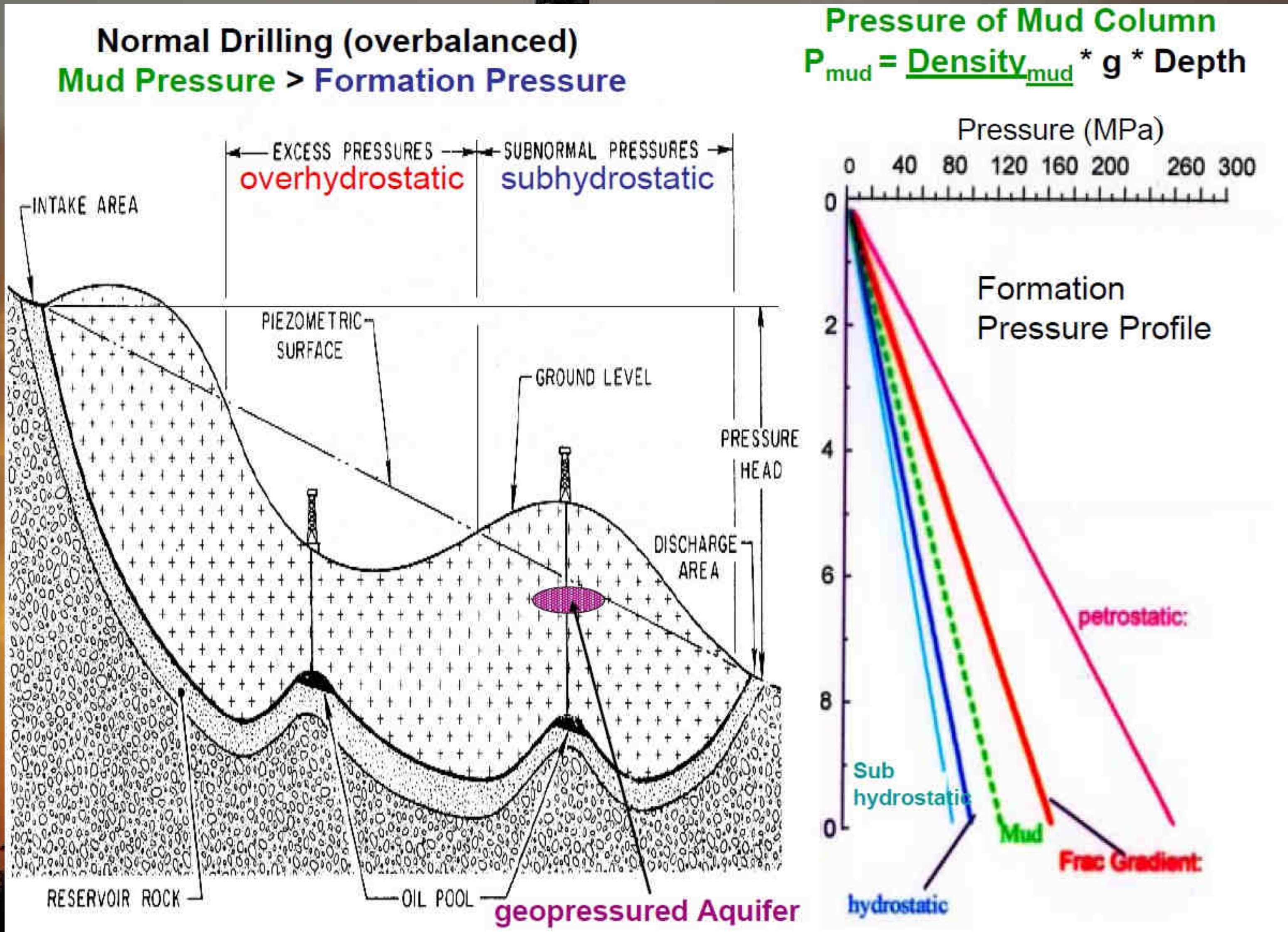
Sufficient Mud Density
Good Filtration Properties

Insufficient Mud Density
Bad Filtration Properties

-Uncontrolled Fluid Entry
-Borehole Instabilities
-Differential Sticking

Balancing FormationPressures

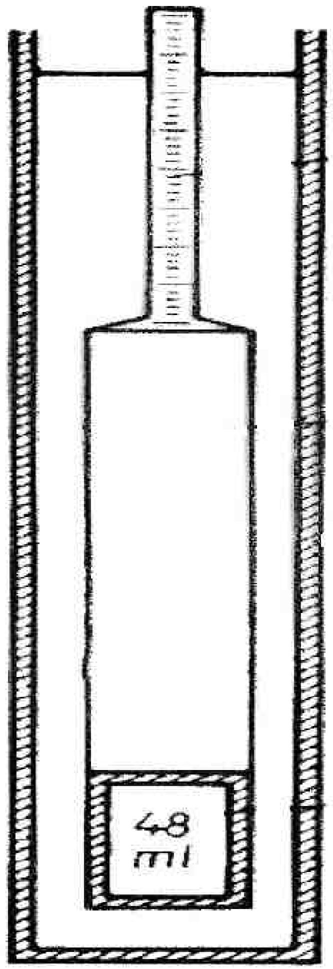
2



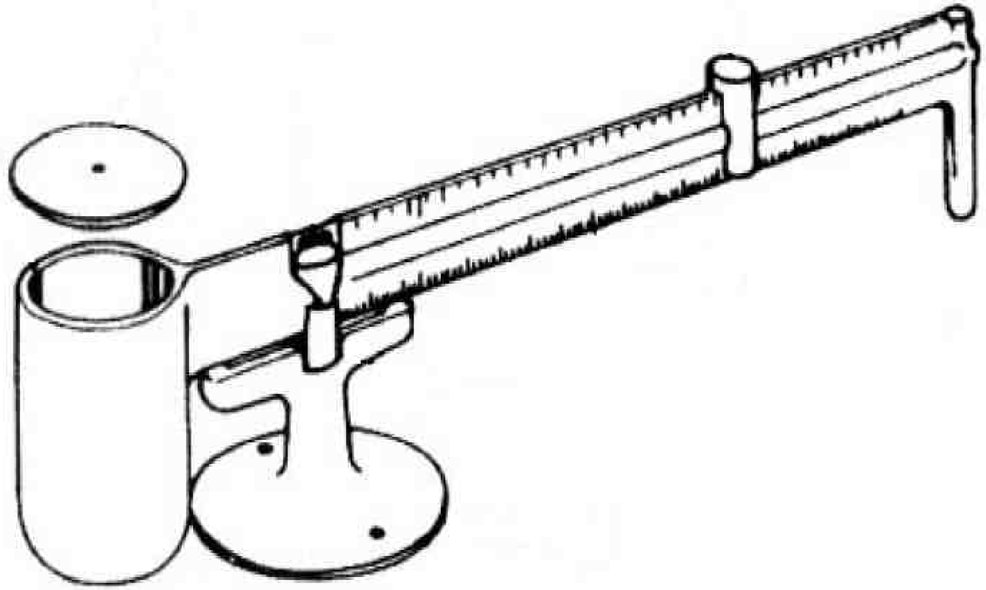
Instruments for Measuring Mud Density

2

Hydrometer

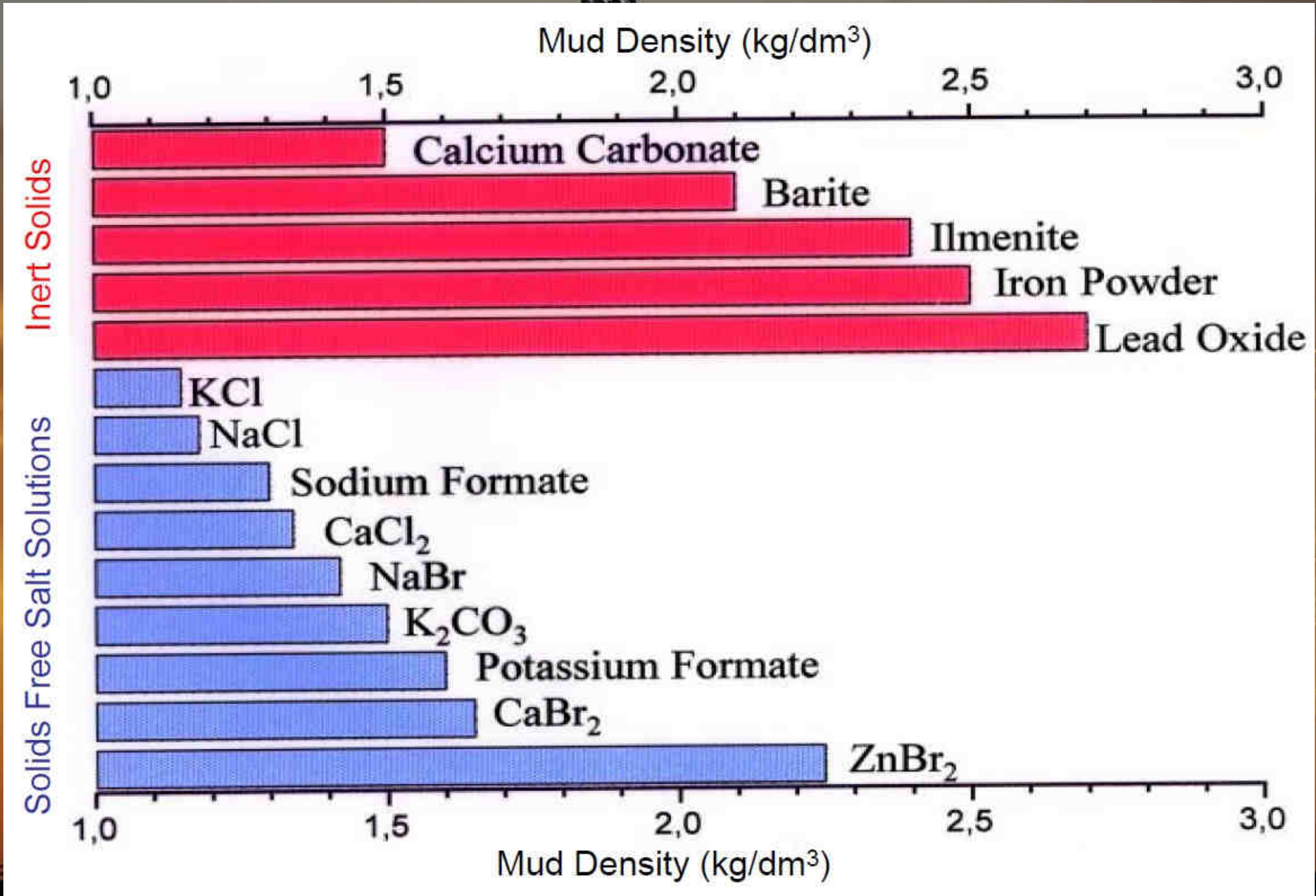


Mud Balance



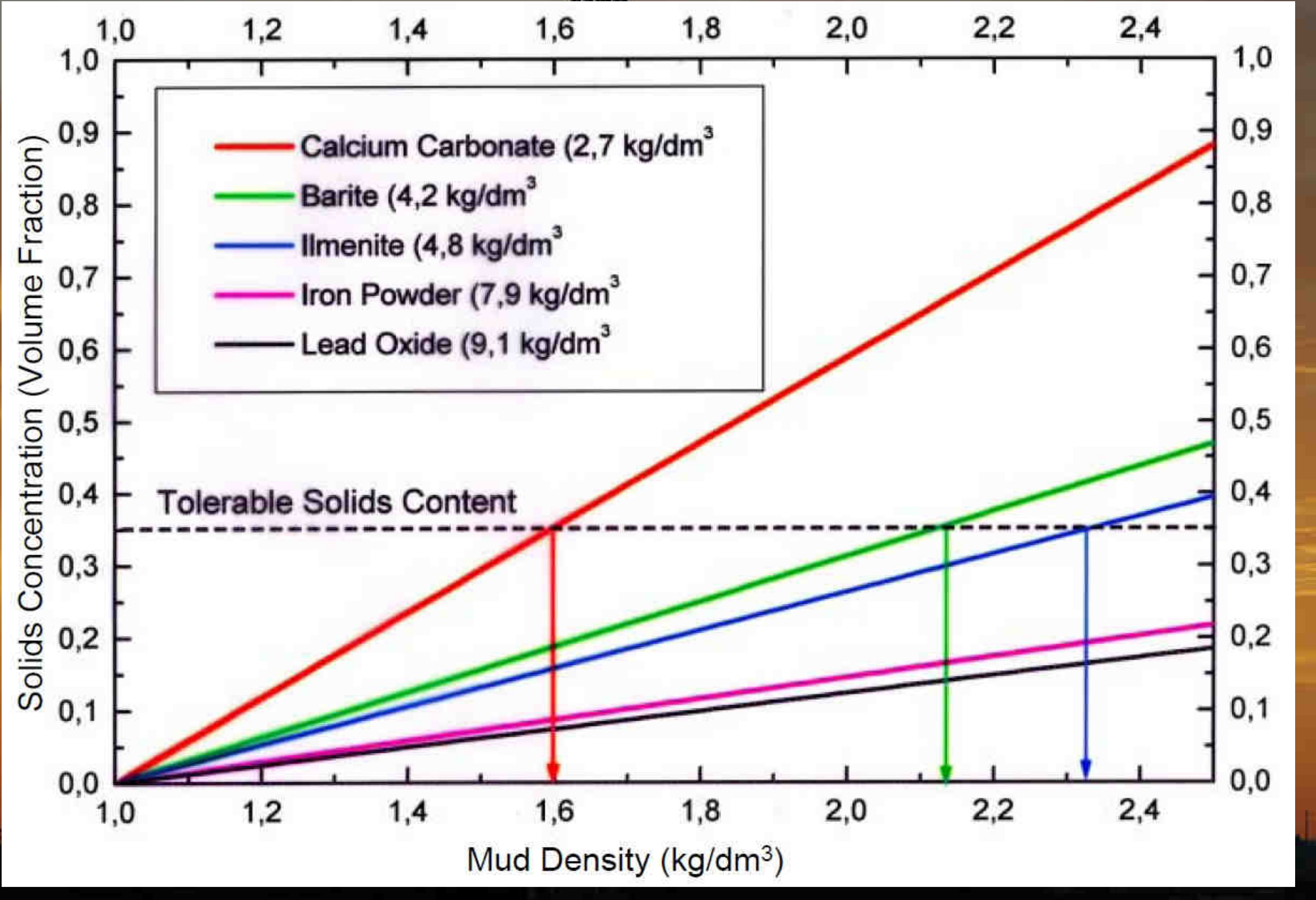
Instruments for Measuring Mud Density

Weighting Materials for Drilling Muds



Solids Content and Mud Density for Various Weighting Materials

2

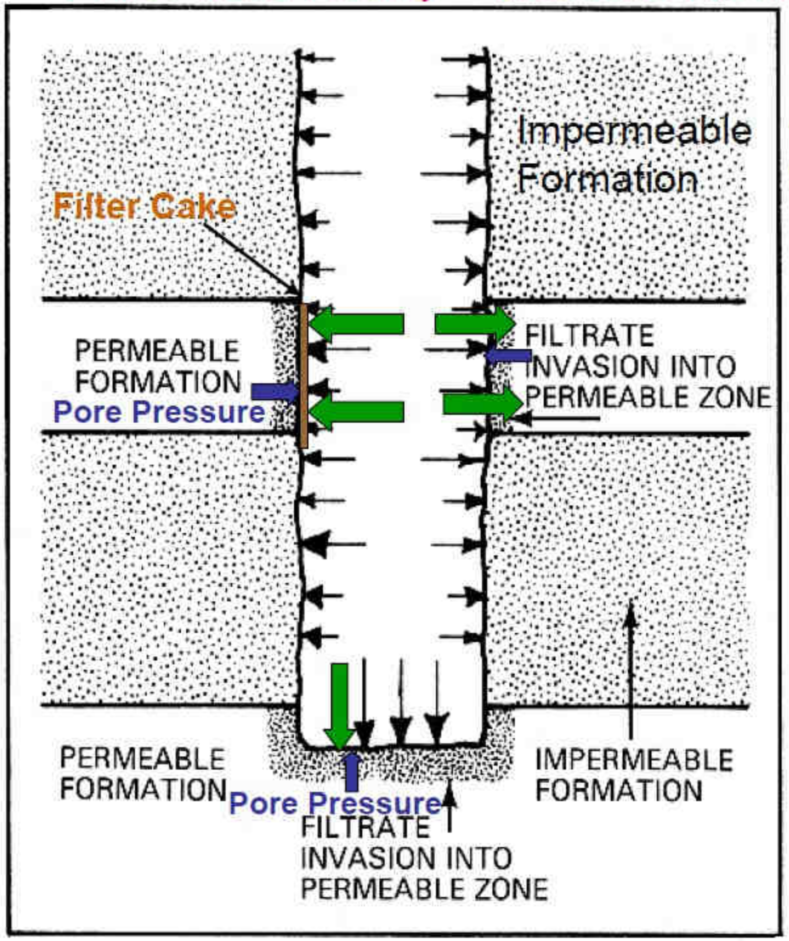


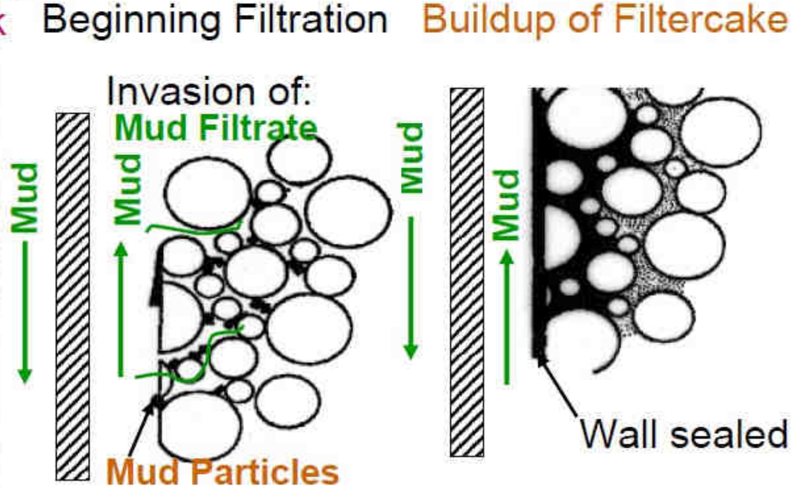
Supporting the Borehole Wall – Hydraulic Casing Effect

2

Mud Properties

- ➢Mud Density -> Pressure Support
- ➢Filtration Characteristics -> Wall Sealing
- ➢Free Water Activity -> Interaction Rock



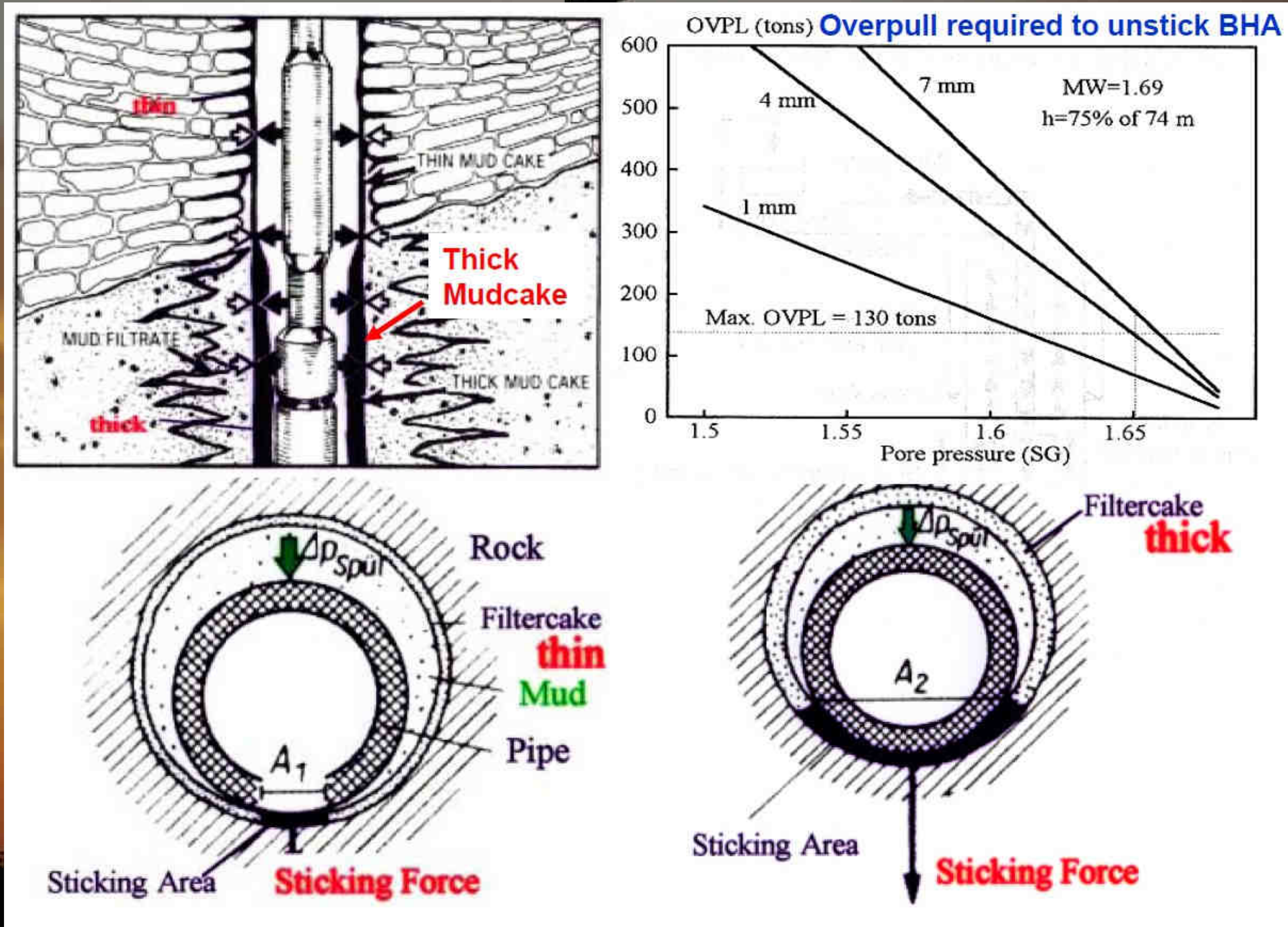


Good Filtration Characteristics

- ➢Quick Filtercake Buildup
- ➢Low Filtration Rate
- ➢Filtercake
  - -thin
  - -impermeable
  - -slick

Minimizing Formation Damage

Filtercakes and Differential Sticking Mechanism



Destabilisation of Red Shale Caused by Contact with Water

2

Original Sample

Sample after 20 min in Water

Sample after 24h in Dehydril HT (2%)

Destabilisation Process is favoured by High Free Water Activity

High Free Water Activity <-> Low CST
Low Free Water Activity <-> High CST

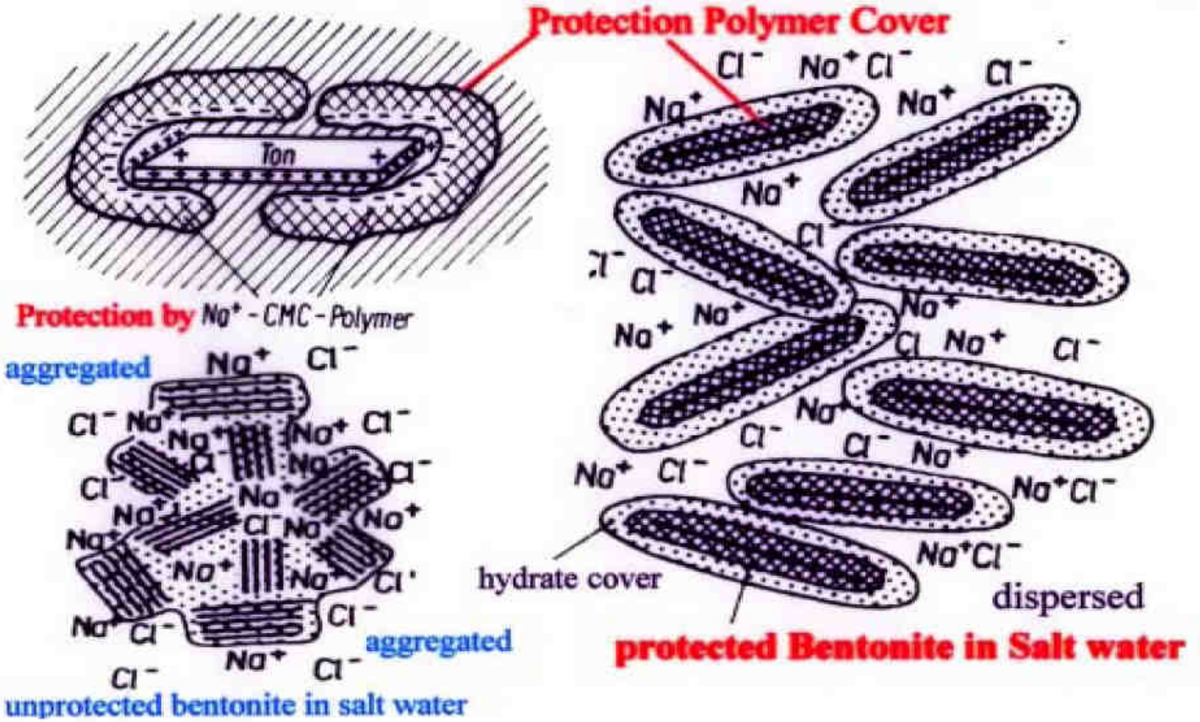
Additives Controlling Filtration Properties and Free Water Activity

2

Bentonite ⇄ Polymers

Polymers act as Protection Colloids
Preventing Aggregation of
Clay Particles

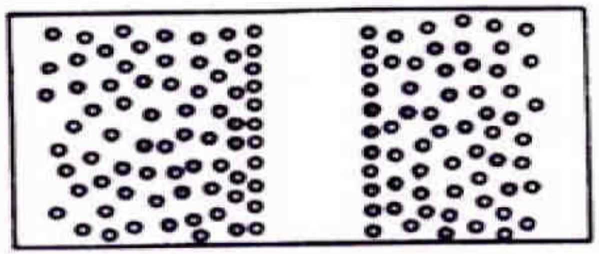
- Starch
- Polyanionic Cellulose (PAC)
- Sodium Carboxymethylcellulose(CMC)
- Hydroxyethylcellulose(HEC)
- Polyacrylates/Polyacrylamides
- Vinylsulfonate/Vinylamide-Copolymers (VS/VA)



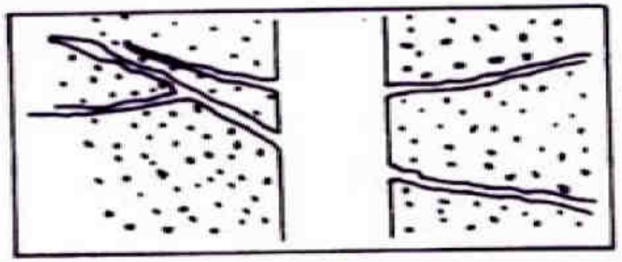
Prevention of Lost Circulation – Factors to Consider

2

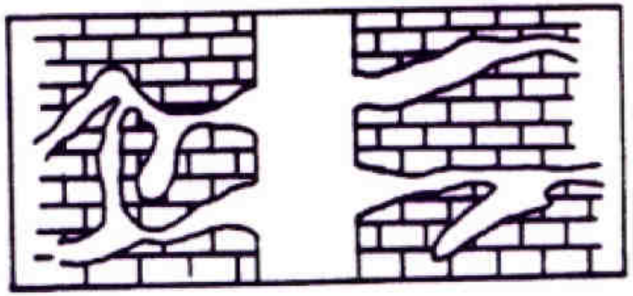
Types of Lost Circulation Zones



High Permeable Gravel



Natural/Artificial Fractures



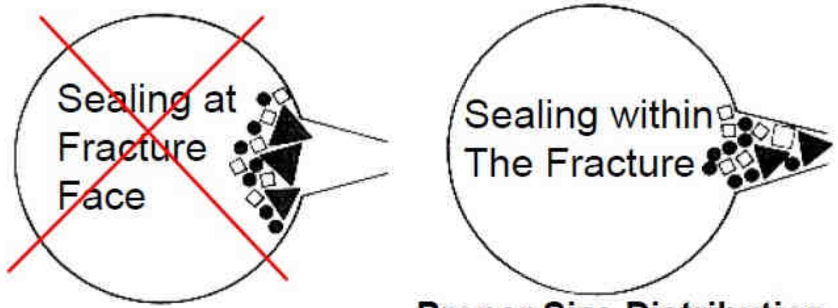
Caverneous Formation

Preventive Methods

- Reducing Mud Density
- Avoiding Pressure Surges
- Lowering Gel Strength
- Lowering Equivalent Circulation Density (ECD)

Fighting Against Lost Circulation

Application of Sealing Material

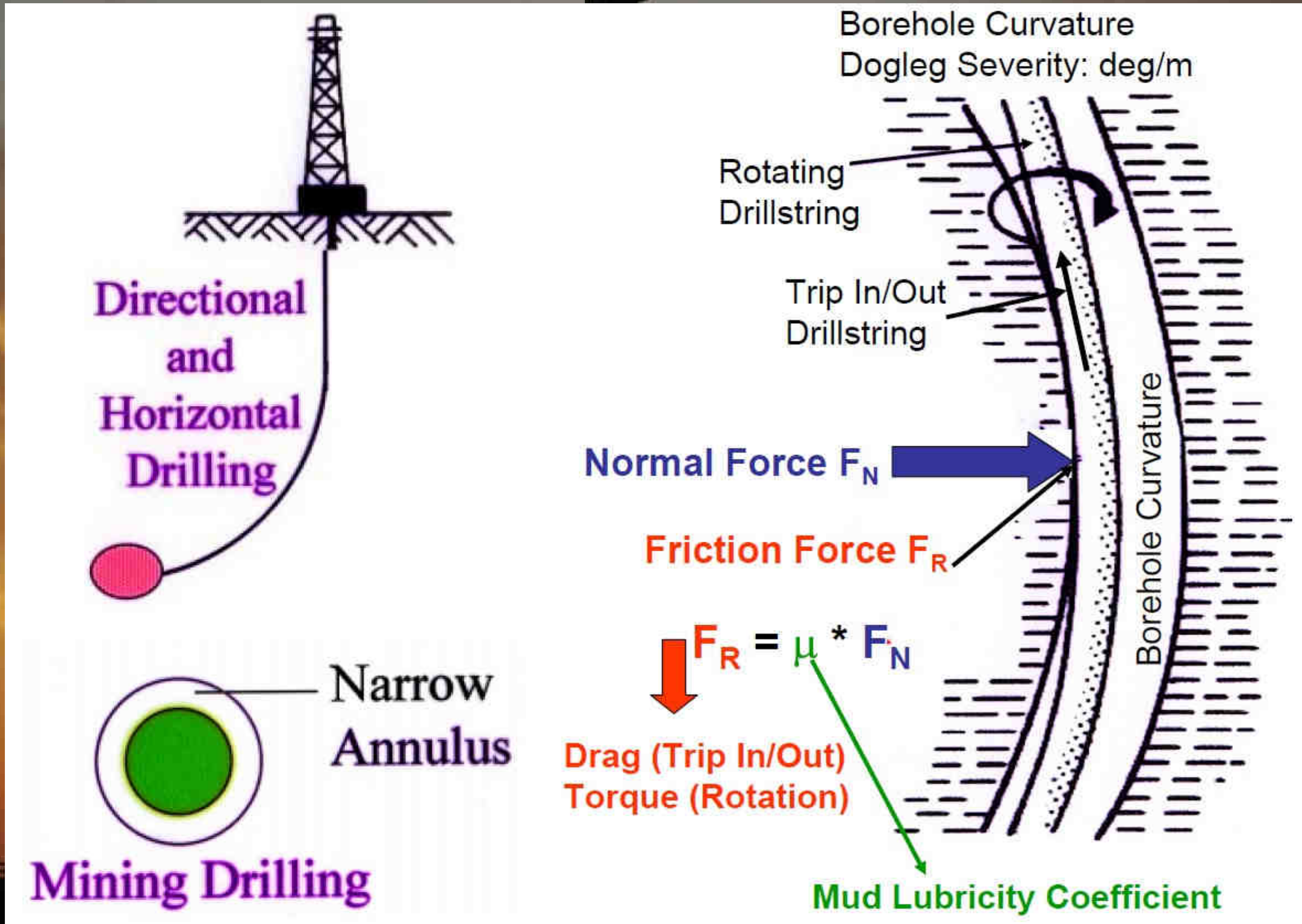


Proper Size Distribution

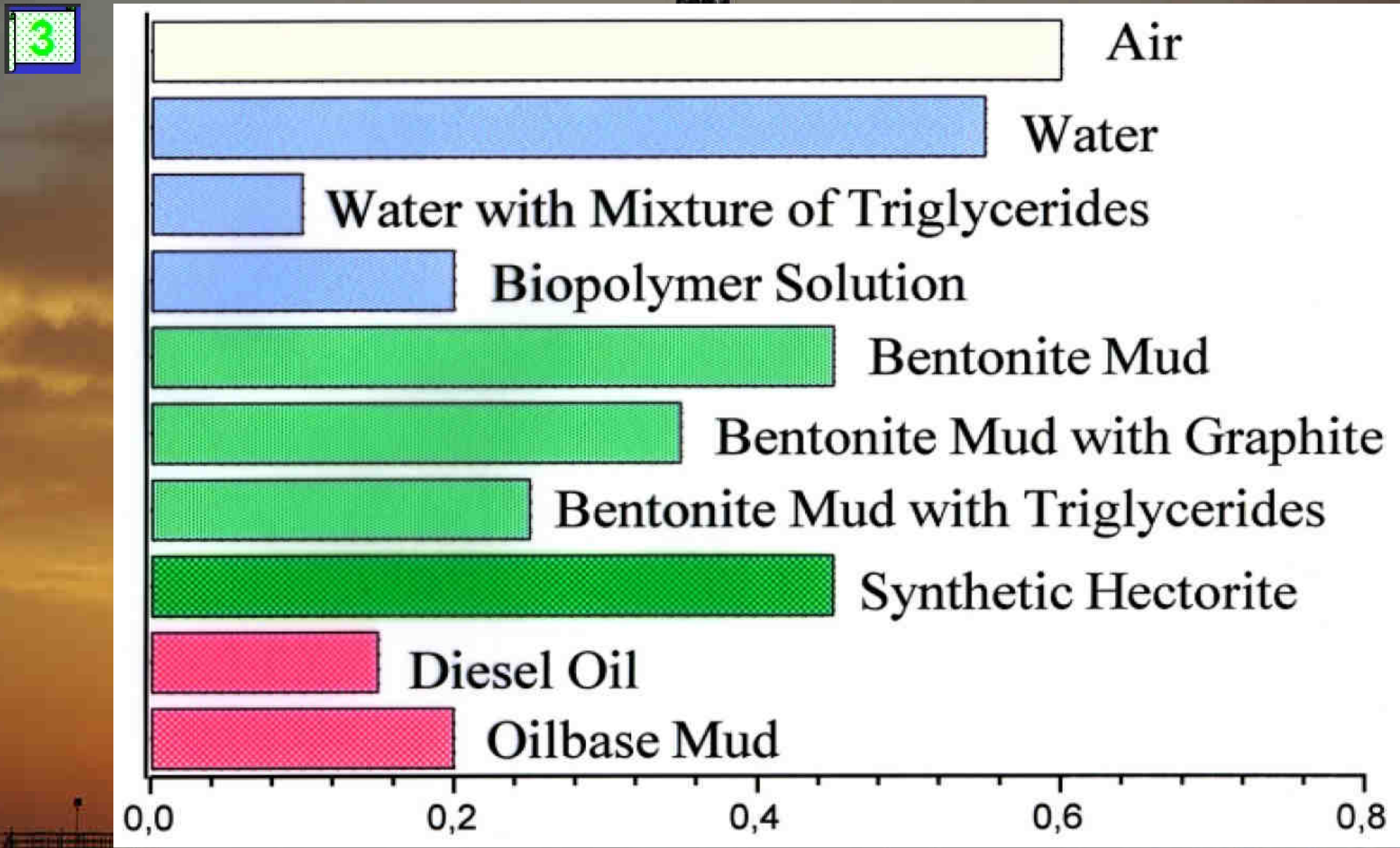
Types of Materials used:

- **Fibrous (Raw Cotton, Mineral Fibers, Glass Fibers)**
- **Flaky (Cellophane, Mica, Cotton Seed Hulls)**
- **Granular (Perlite, Ground Plastic, Nut Shells, Wood)**
- **Thick Slurry Pills (Bentonite/Polymer, Cement)**

Reducing Friction – Controlling Torque / Drag



Lubricity Coefficients of Drilling Muds



Inhibiting Corrosion

4

Pitting Corrosion Inside Drillpipe

Stress Corrosion at DP-Tooljoint

Corrosion is the Major Cause of Drillpipe Failures

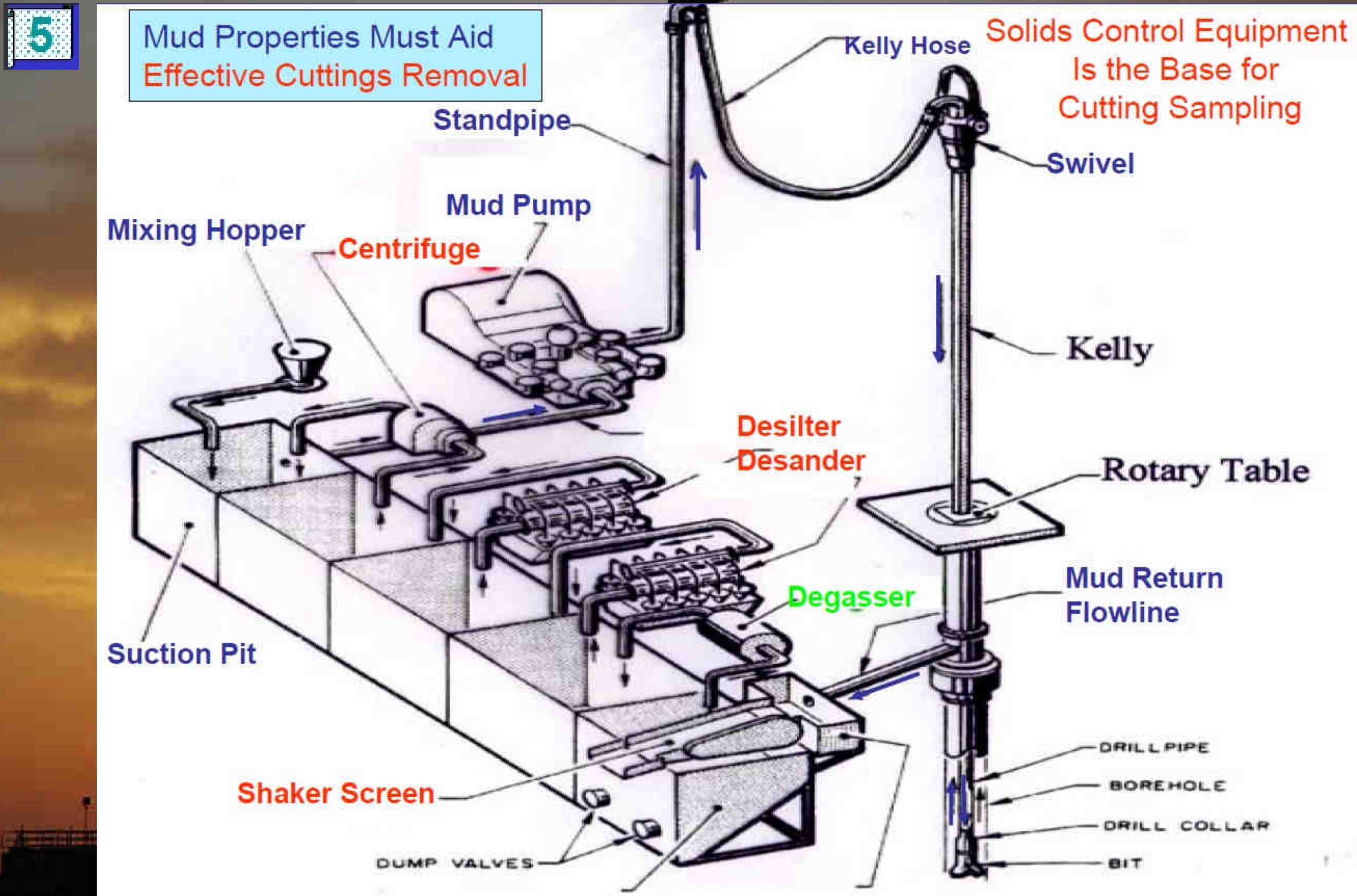
Forms of Corrosion

- Uniform Corrosion
- Localized Corrosion (Pitting)
  - •Bimetallic Corrosion
  - •Oxygen Concentration Cells
    - -Crevice Corrosion
    - -Air/Water Interface
    - -Oxygen Tubercles
    - -Scaling/Sludges
- Corrosion Fatigue
- Stress Corrosion
  - •Sulfide Cracking
  - •Hydrogen Embrittlement

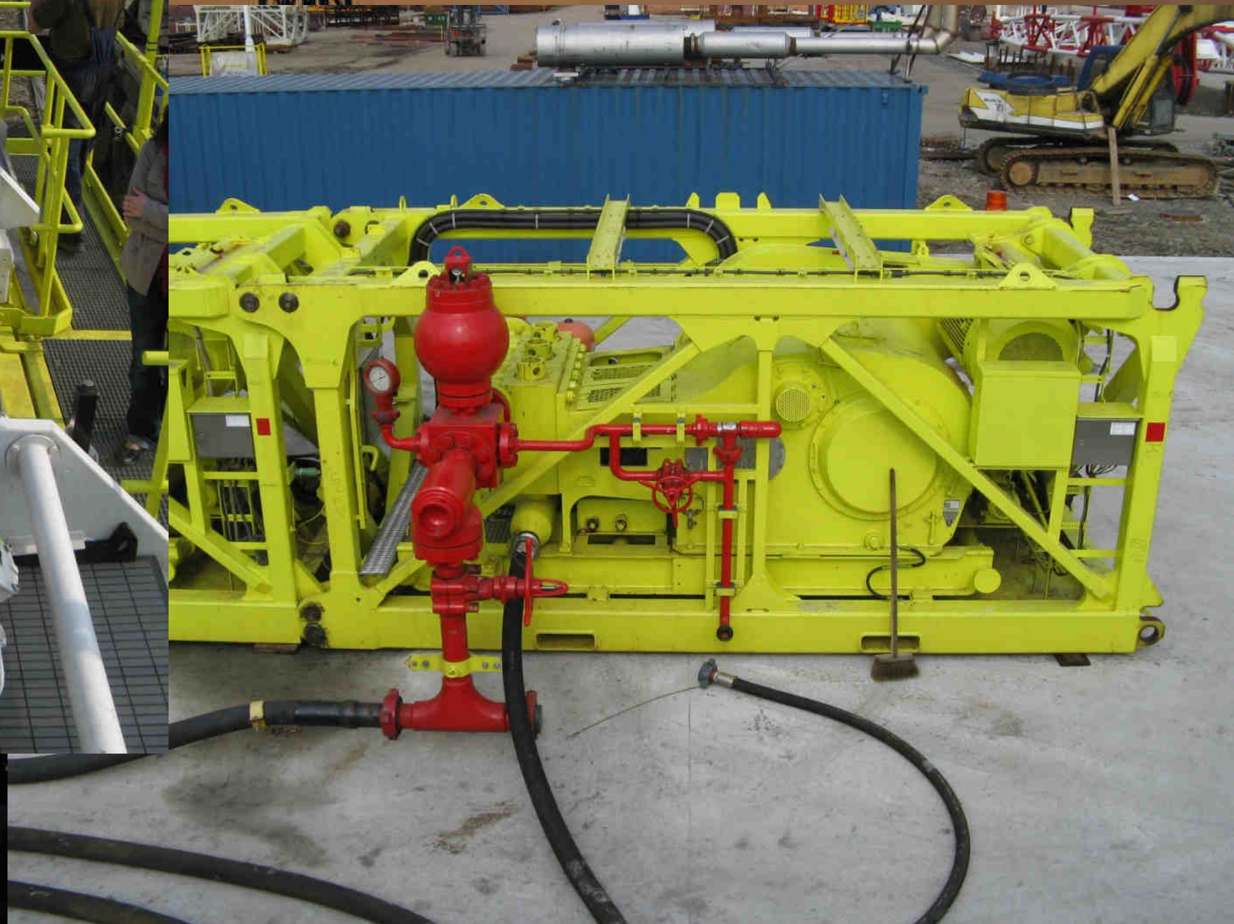
Measures

- Raising pH of Mud
- Reducing dissolved Oxygen in Mud
  - •Vacuum Degassing
  - •Oxygen Scavengers
    - -Sodium Sulfite
    - -Sodium Nitrite
- Addition of Corrosion Inhibitors
  - •Filming Amines
  - •Sulfide Scavengers
  - •Zinc Carbonate
  - •Sodium Molybdate

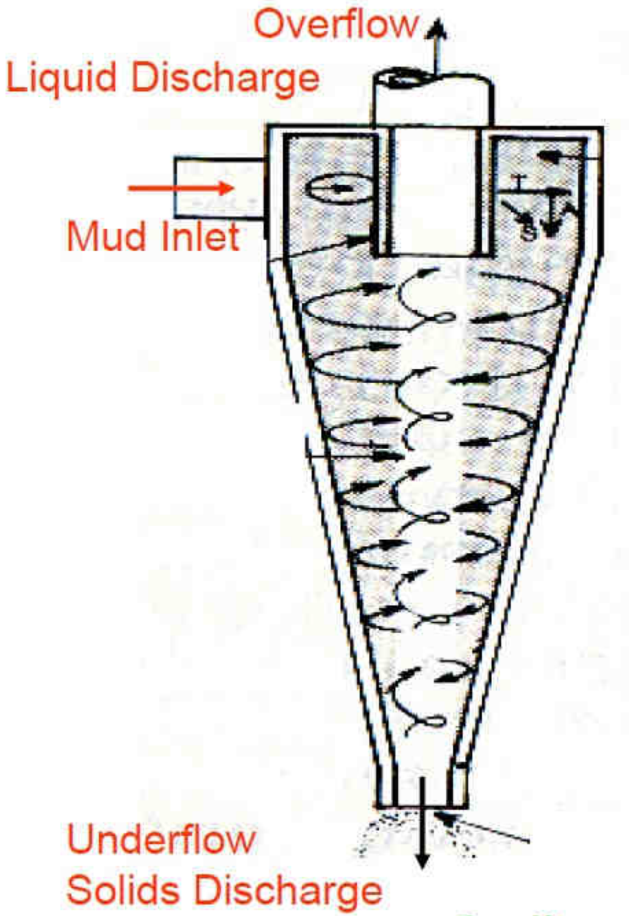
Mud Circulation System and Solids Control Equipment

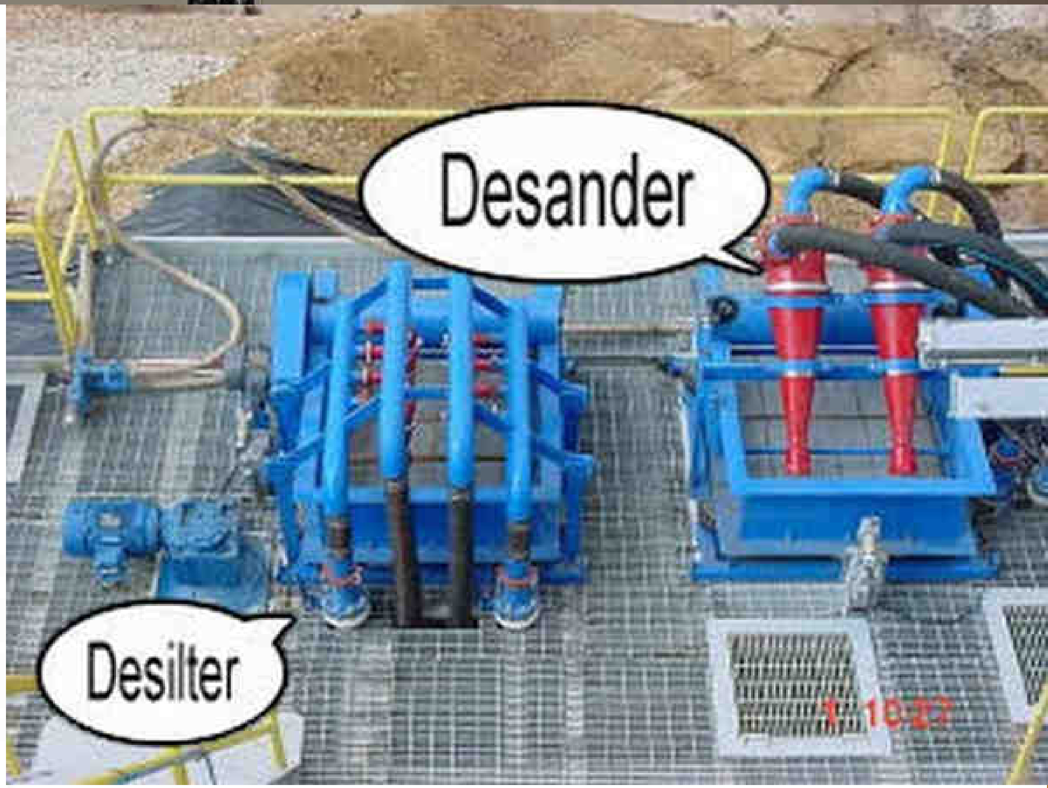


Mud Circulation System and Solids Control Equipment



Solids Removal by Hydrocyclones

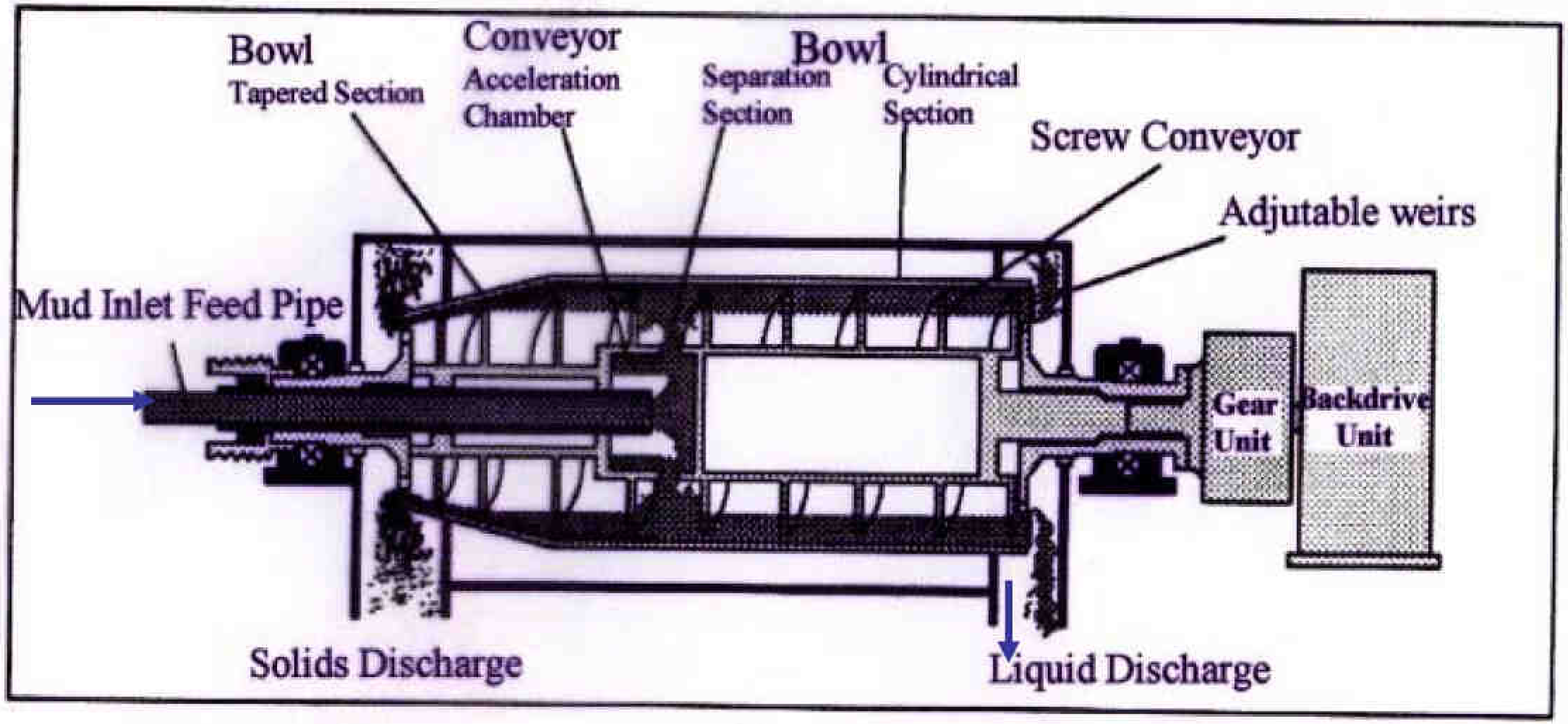




Desilter
12-20 Hydrocyclones Battery
Diameter: 2 – 6 inch
Cutting Size: 15 – 40 μ

Desander
2-3 Hydrocyclones Battery
Diameter: 6 – 12 inch
Cutting Size: 40 – 74 μ

Solids Removal by Decanting Centrifuges

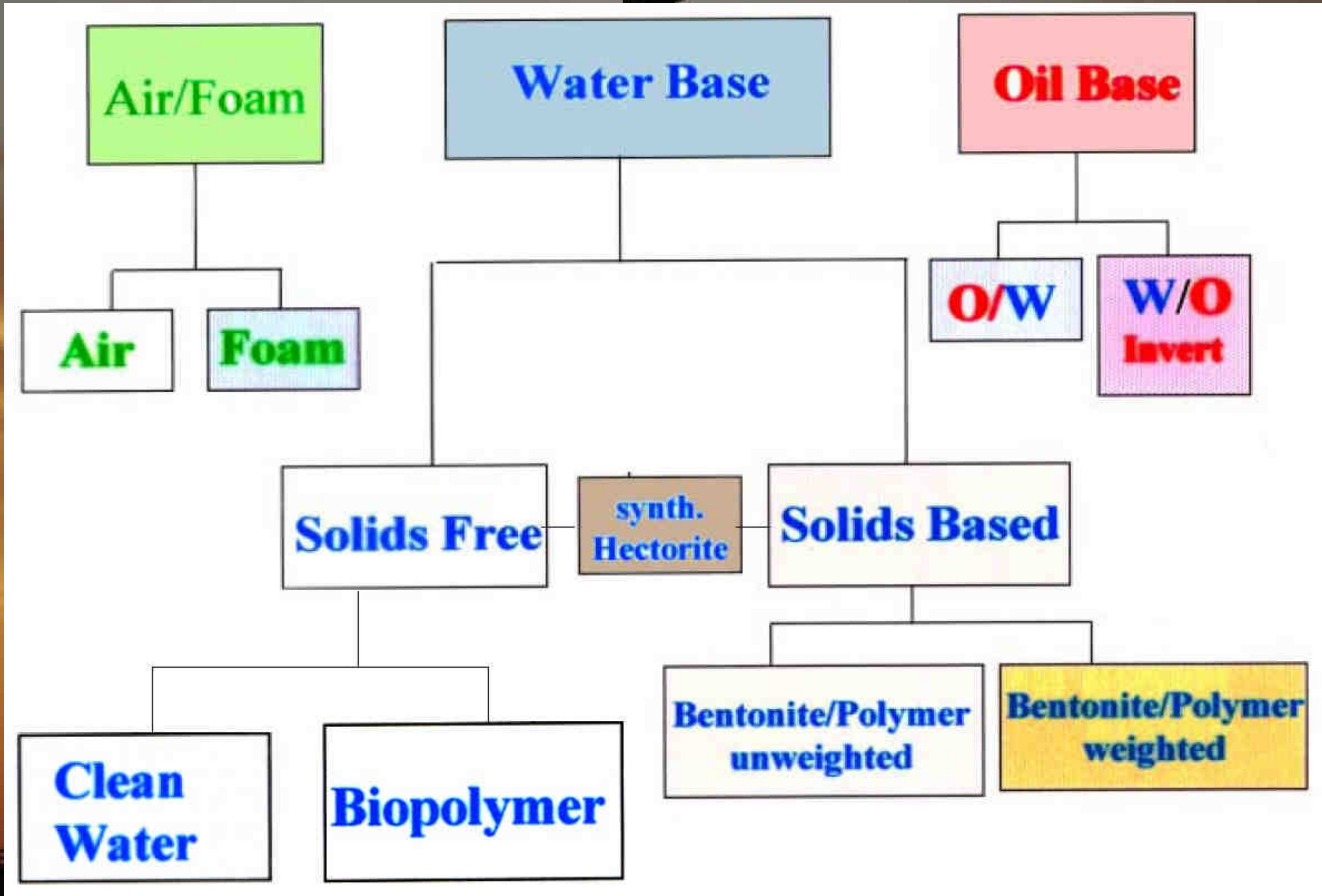


Application Areas and Operating Parameters

Removal of Ultrafine Solids
Particle Size: > 5 μ
RPM: 2500 – 3300
G-Force: 1200 – 2100

Barite Recovery in Weighted Muds
Particle Size: > 4 – 7 μ
RPM: 1600 – 1800
G-Force: 700 – 800

Classification of Mud Systems



Characterization of Mud Systems – Clean Water

Advantages

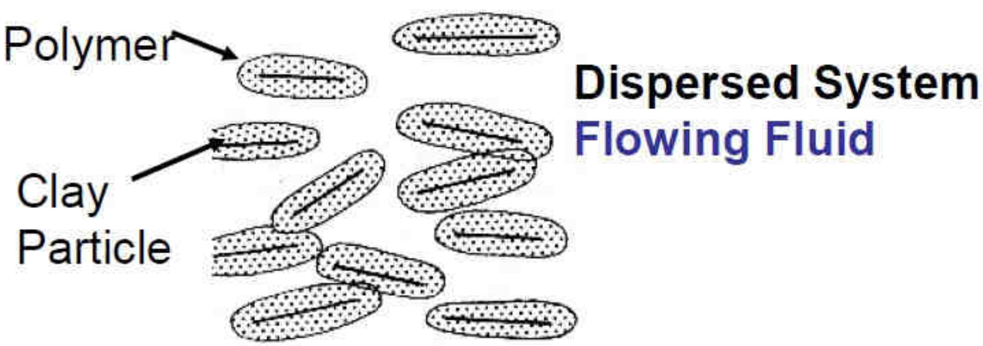
- Low Cost
- Good Penetration Rates
- Good Solids Removal
- Excellent Conditions for Geoscientific Investigations
  - -Cuttings Analysis
  - -Geochemical Mass Balance
  - -Detection of Formation Fluids And Gases
  - -Borehole Logging
  - -Hydraulic Testing

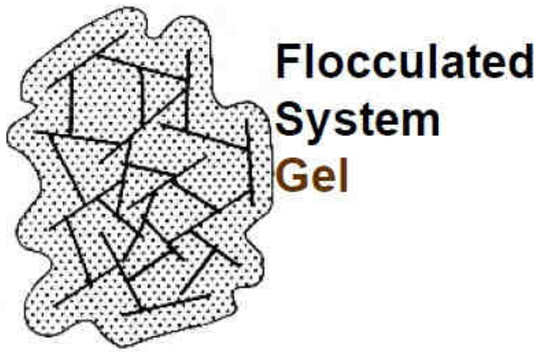
Disadvantages

- Poor Cuttings Transport Efficiency
- No Static Carrying Capacity
  - -Cuttings
  - -Weighting Material (Barite)
- Poor Lubricity Coefficient
- Uncontrolled Filtration
- Poor Borehole Wall Support
- Destabilisation of Formation Rocks

Characterization of Mud Systems – Bentonite/Polymer Muds

Bentonite/Polymer Muds are Complex Colloidal Systems





Advantages

- Control of Properties
- Good Cuttings Transport Efficiency
- Good Static Carrying Capacity
- Good Solids Removal
  - Cuttings
  - Weighting Material
- Good Filtration Properties
- Good Borehole Wall Support

Disadvantages

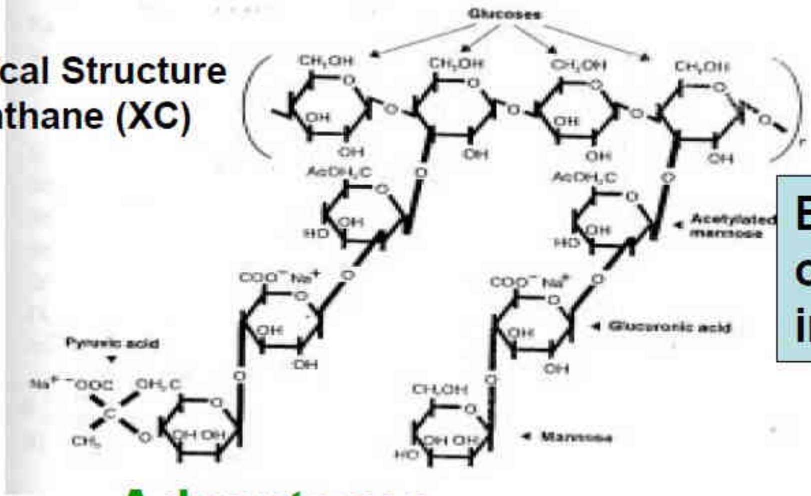
- Complex System
- High Solids Content
- Organic Additives
- Impairment of Geoscientific Investigations
  - Cuttings Analysis
  - Geochemical Mass Balance
  - Detection of Formation Fluids and Gases
  - Borehole Logging
  - Hydraulic Testing

Typical Composition of Bentonit / Polymer Muds

Components	Concentration (kg/m³)
➢Clay -Bentonite -Attapulgite -Sepiolite	60 – 70
➢Polymer (Protective Colloid) -CMC -PAC -Starch -PAA -VS/VA	10 - 20
➢Deflocculant/Dispersant -Lignosulfonate -SSMA Polymer	3 - 6
➢Sodium Hydroxide/Carbonate	pH: 9 - 10
➢Barite	Density: 1200 - 1600

Characterisation of Mud Systems – Biopolymer Mud

Chemical Structure
Of Xanthane (XC)



Biopolymer Muds are Solutions of High Molecular Biopolymers in Water

Advantages

- Solids Free
- Good Cuttings Transport Efficiency
- Excellent Shear Thinning
- Sufficient Static Carrying Capacity
- Good Lubricity Coefficient
- Efficient Solids Removal

Disadvantages

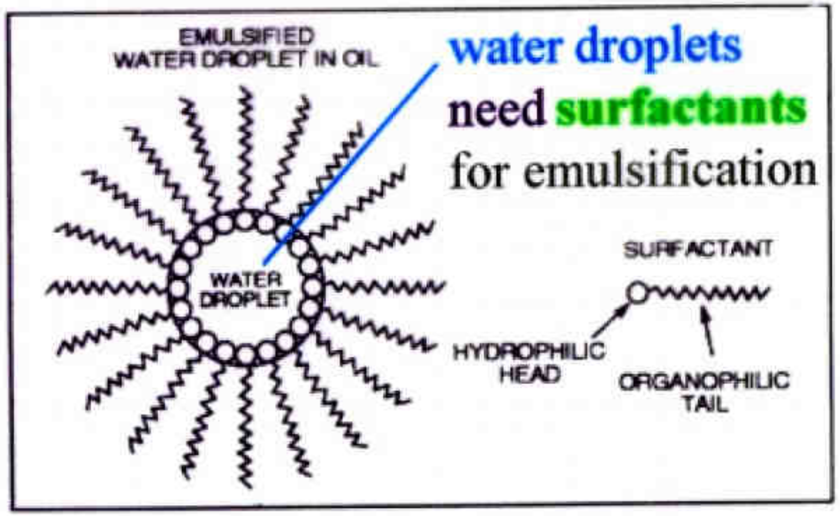
- Limited Temperature Stability (120°C)
- Bacterial Degradation
- Impairment of Geoscientific Evaluation
  - -Gas Analysis (artificial Methane Due to Polymer Degradation)
- No Filtration Control

Characterisation of Mud Systems – Oil Base Muds

Oil Base Muds are Emulsion Systems

Oil in Water

Water in Oil
Invert Emulsion



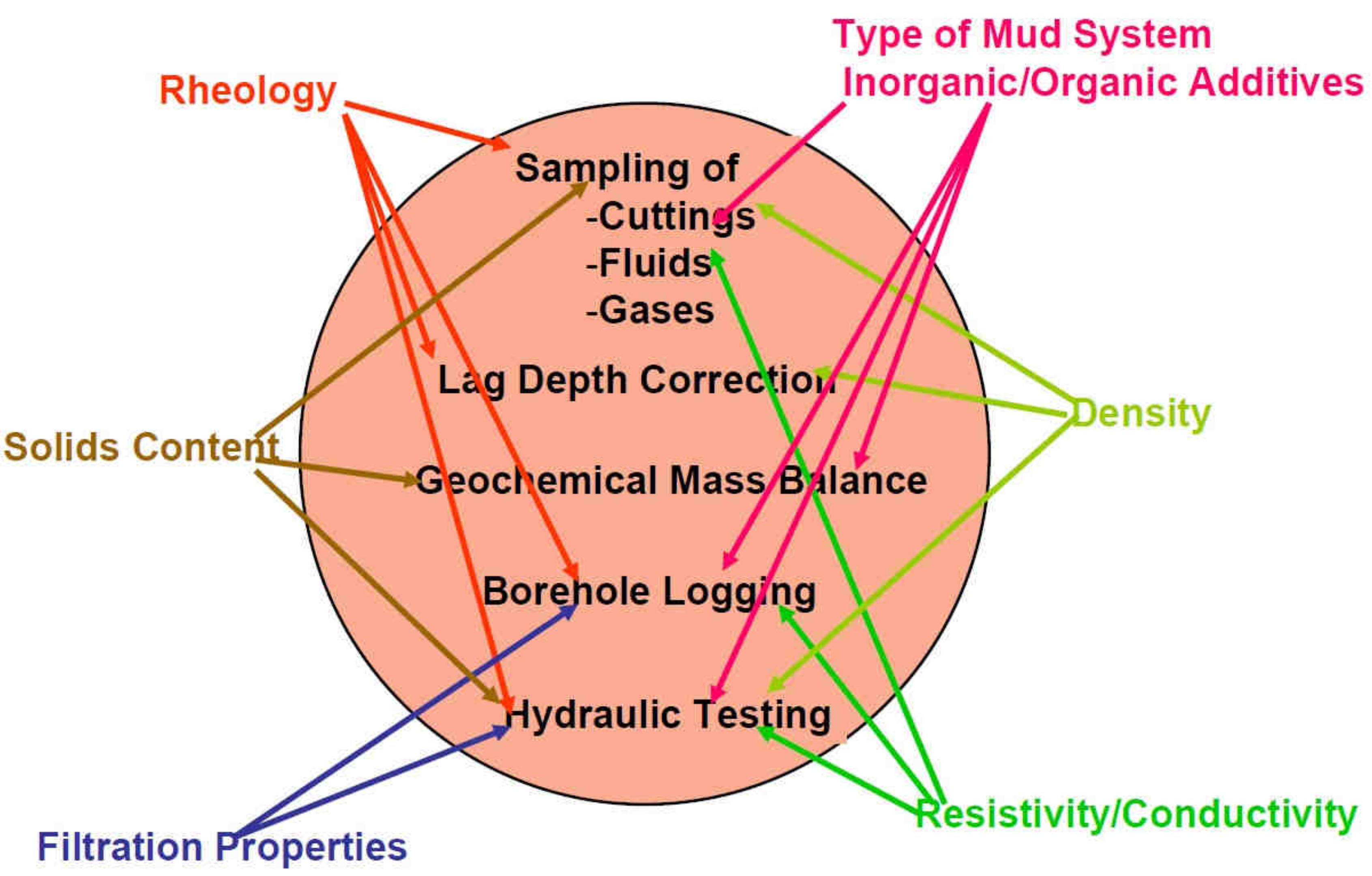
Advantages

- Excellent Lubrication
- Favourable to Borehole Stability
- No Corrosion
- Good Temperature Stability
- Deviated Wells/Extended Reach Well

Disadvantages

- Complex System
- Impairment of Geoscientific Investigations
  - -Borehole Logging (No Electrical Conductivity)
  - -Detection of Formation Fluids and Gases
- High Cost
- Environmental Problems

Geoscientific Objectives Influenced by Mud Properties



THE END!!!


Sleep
Life's cheapest Luxury
A "Sleep-well" Mattress will give you at least ten years of luxurious, healthful sleep.
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THE SLEEP-WELL MATTRESS
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