

# Drilling and Well Fluid Rheology

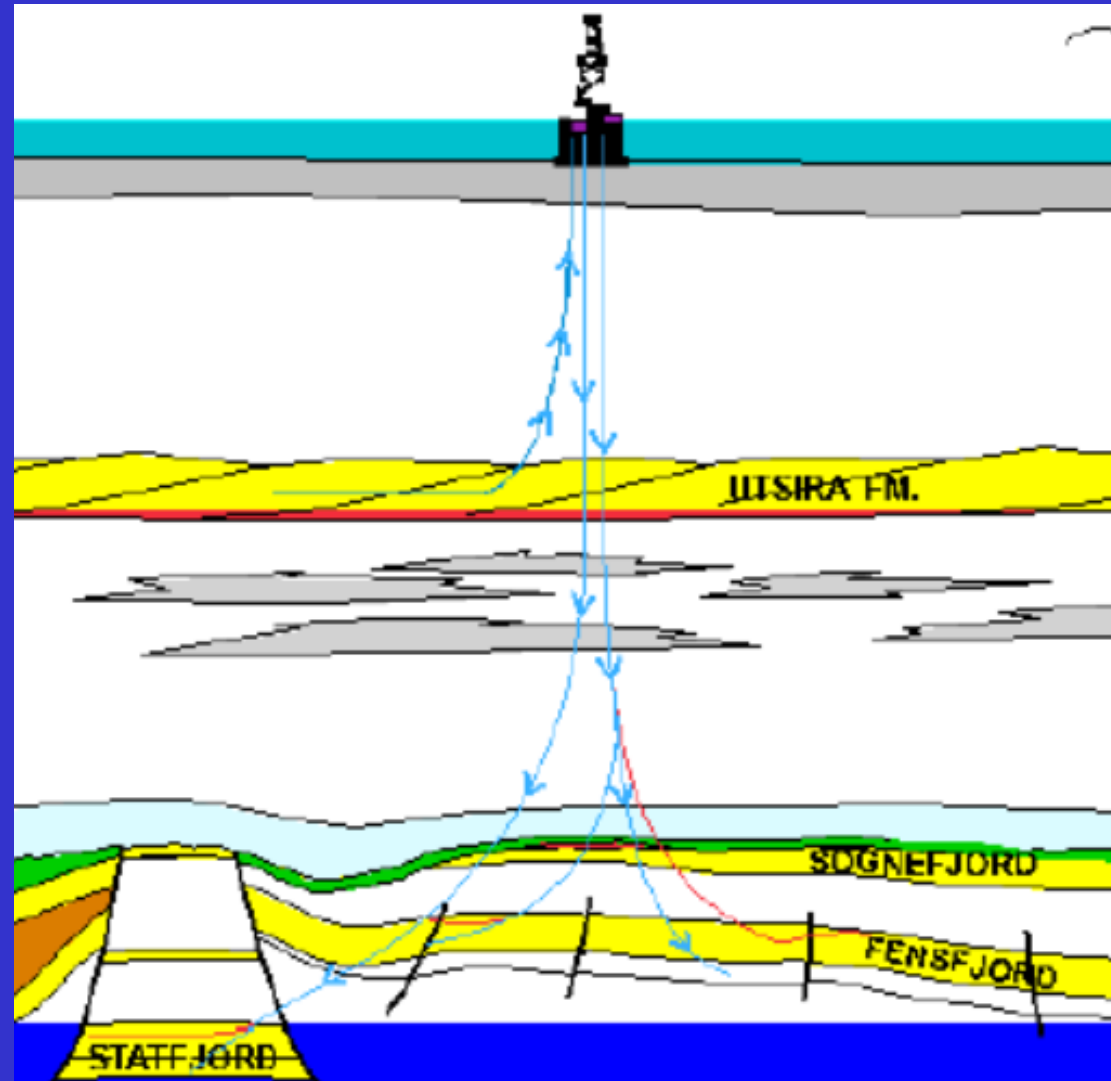
by

Arild Saasen

Statoil ASA

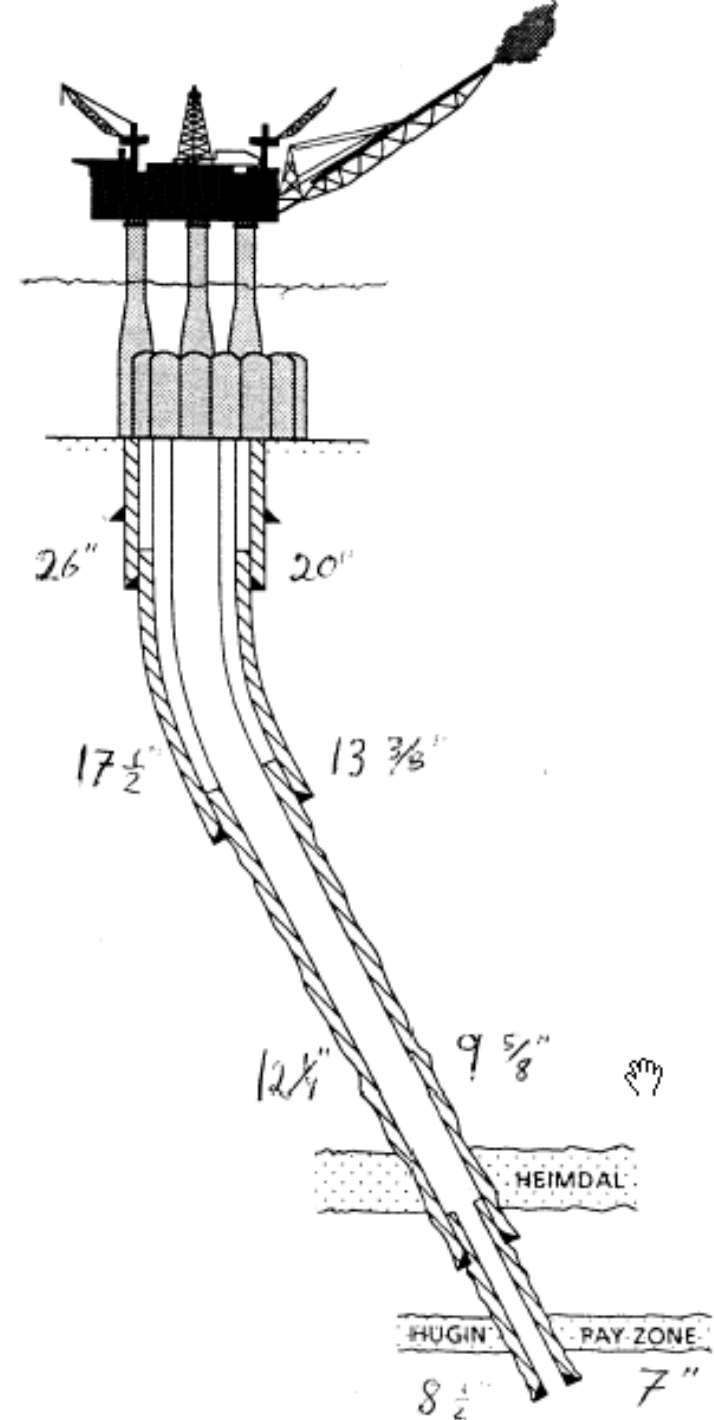
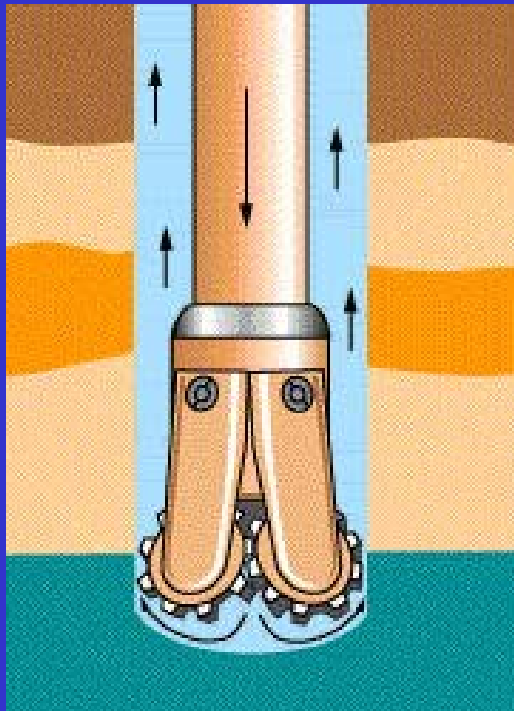
# Scope of Offshore drilling

To drill a well into the formation to be able to produce oil and gas



# Scope of Offshore drilling

The well must be drilled and cemented before completion



# Drilling on the Faroese shelf

Statoil's first well



# Drilling Fluid Objective

Hole cleaning

Well control

Cooling the bit

Avoiding damaging the formation

# Drilling Fluids

## Water based drilling fluids (WBM)

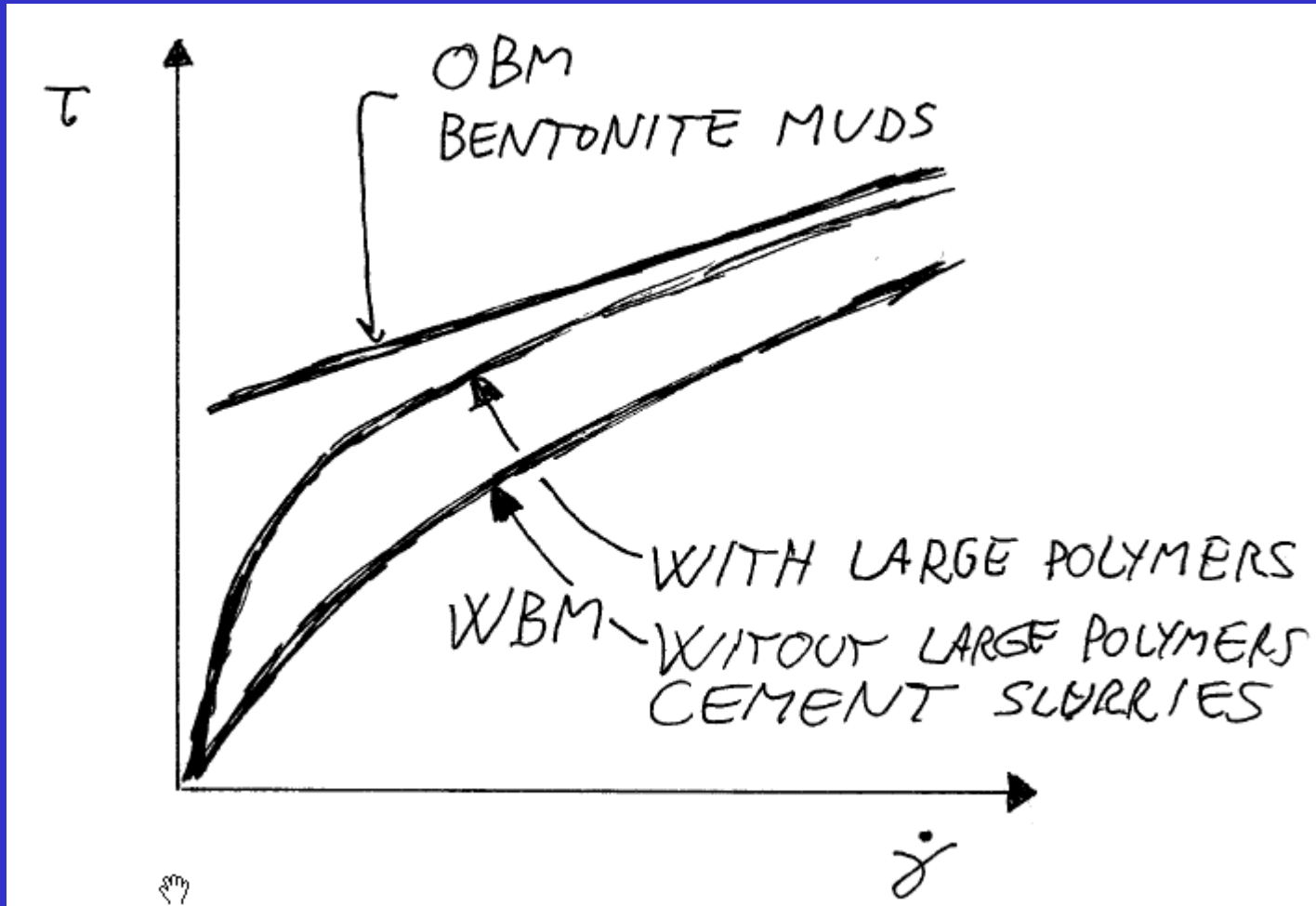
- Brine (Seawater, Freshwater, KCl, NaCl)
- Polymers (Xanthan, CMC, PAC)
- Weight materials (Barite, Ilmenite....)
- Bentonite

## Oil based drilling fluids (OBM)

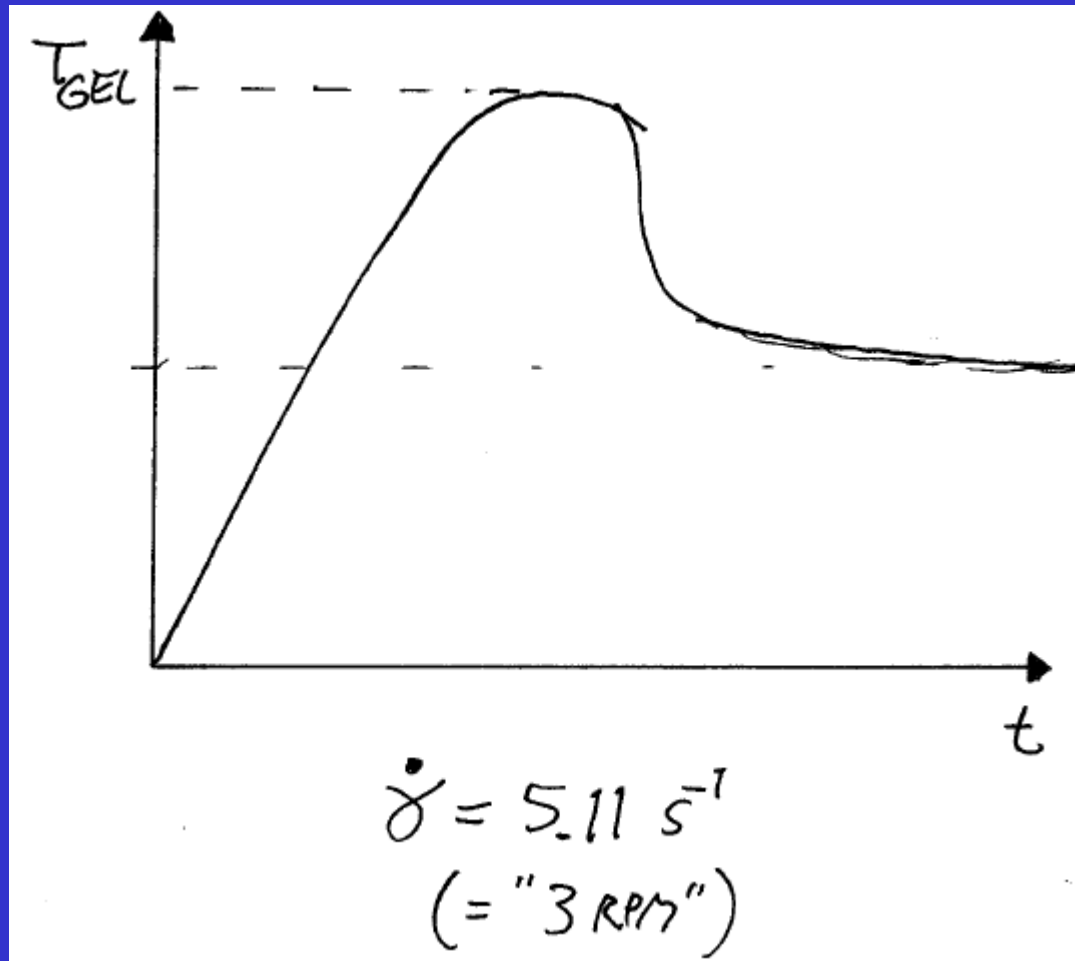
- Base oil
- Brine
- Organophilic clay
- Emulsifiers
- Weight materials (Barite, Ilmenite....)

Clear brines (Formate brines.....)

# Drilling Fluids Viscosity Curves



# Drilling Fluids Gel Test

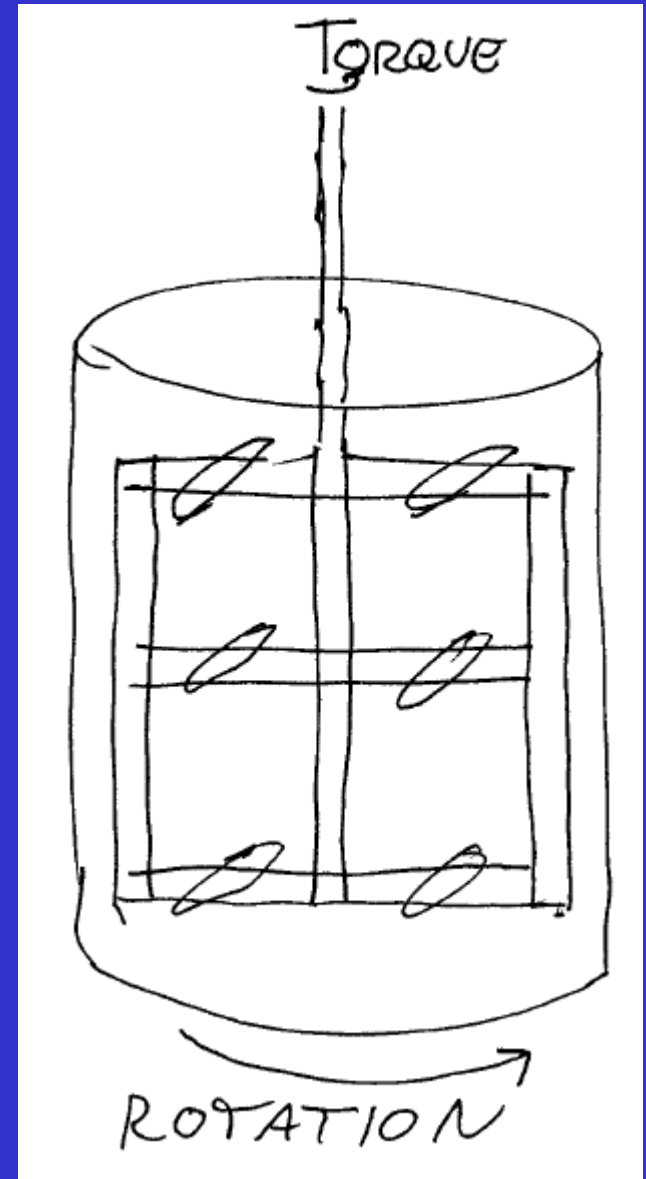


# Cement Slurry Evaluation

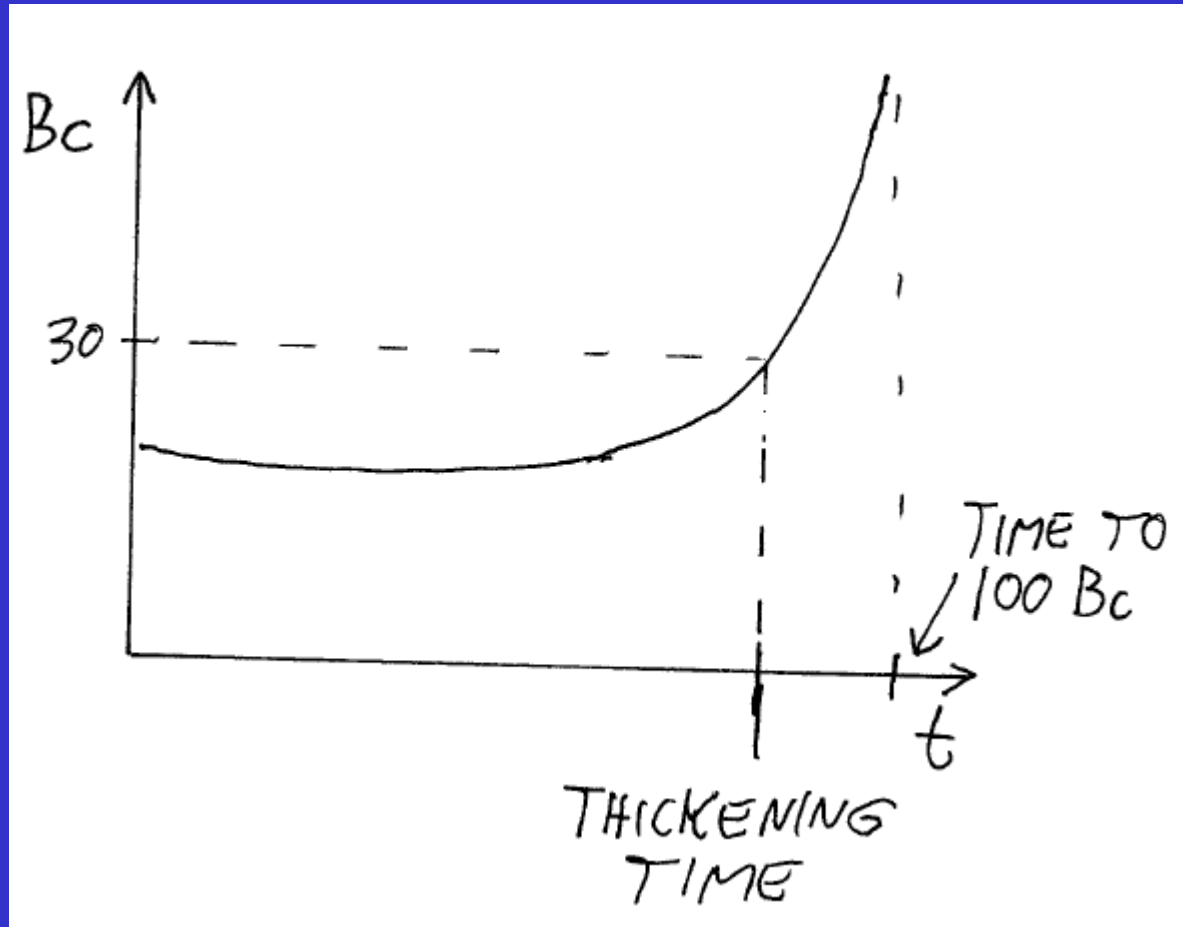
Measurement of viscosity

Thickening time evaluation

- Consistometer
- Bearden units of consistency – Bc
- At 30 Bc the slurry is no longer pumpable
- Toothpaste is 30-100 Bc

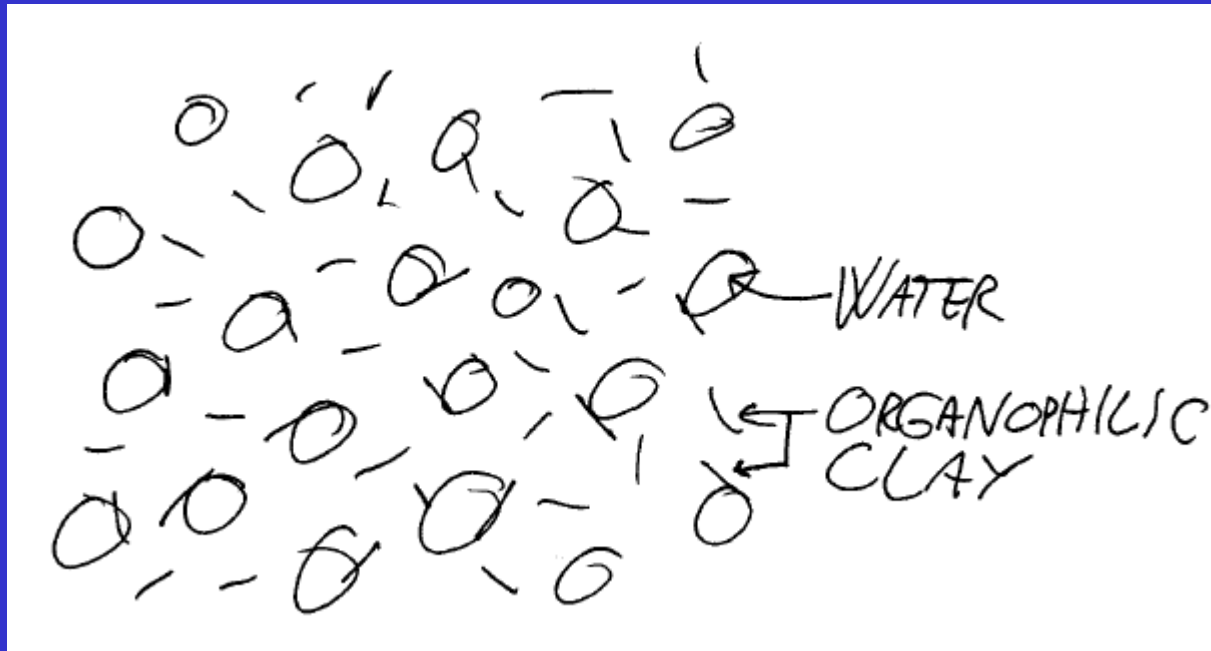


# Cement Slurry Evaluation



Roughly "constant" properties approximately 2/3 of the time prior to 30  $B_c$

# Oil Based Drilling Fluid



Water in oil emulsion

- Droplet size ~ 1-5 micron

# OBM viscosity curve

Drilling fluid viscosity depends on composition and base oil

$$\eta(\dot{\gamma}, T) = \frac{\mu_o(T)}{\mu_o(T_o)} \eta(\dot{\gamma}, T_o)$$

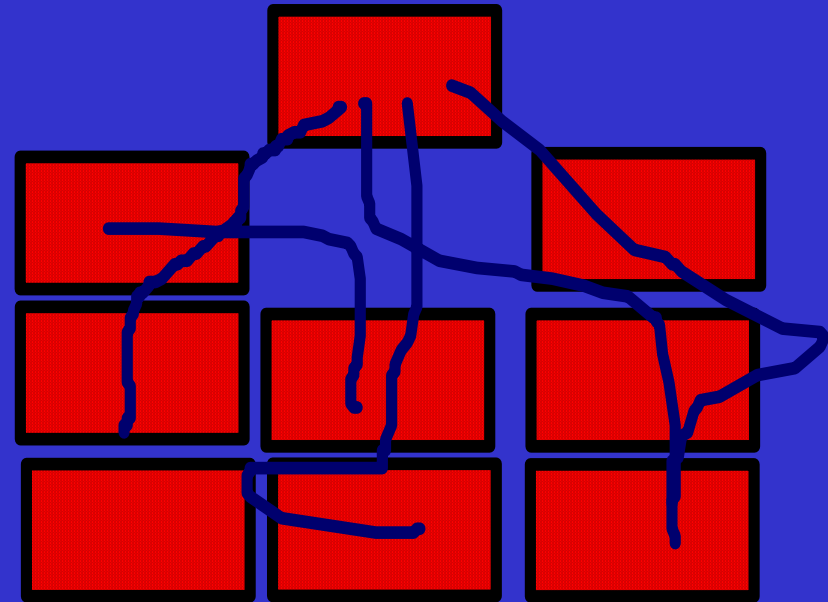
$\eta$  - OBM VISCOSITY

$\mu_o$  - BASE OIL VISCOSITY

n-Paraffin based OBMs do not obey this rule at low temperatures because of wax precipitation

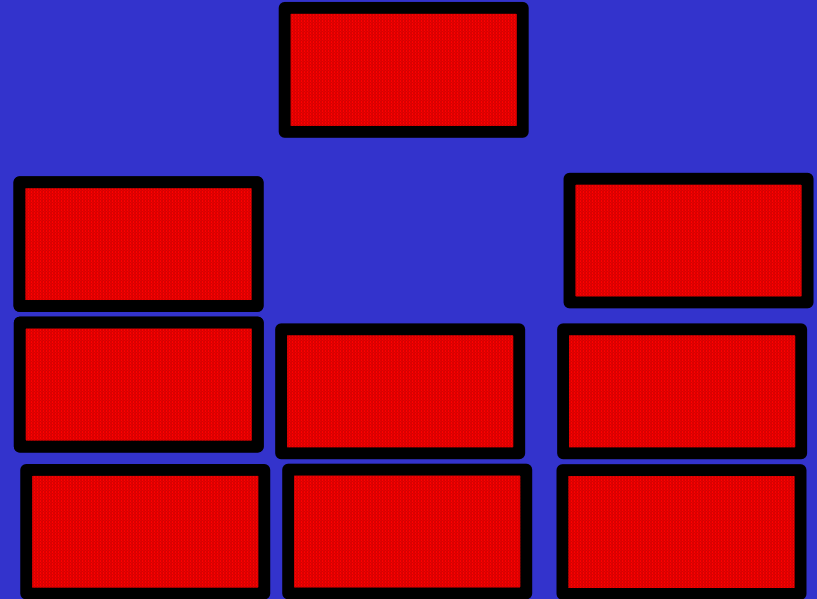
# Hole Cleaning in WBM

- Gel strengths detrimental for hole cleaning
- High molecular weight polymers detrimental for hole cleaning
- High pressure losses ideal for hole cleaning
- High flow rates ideal for hole cleaning

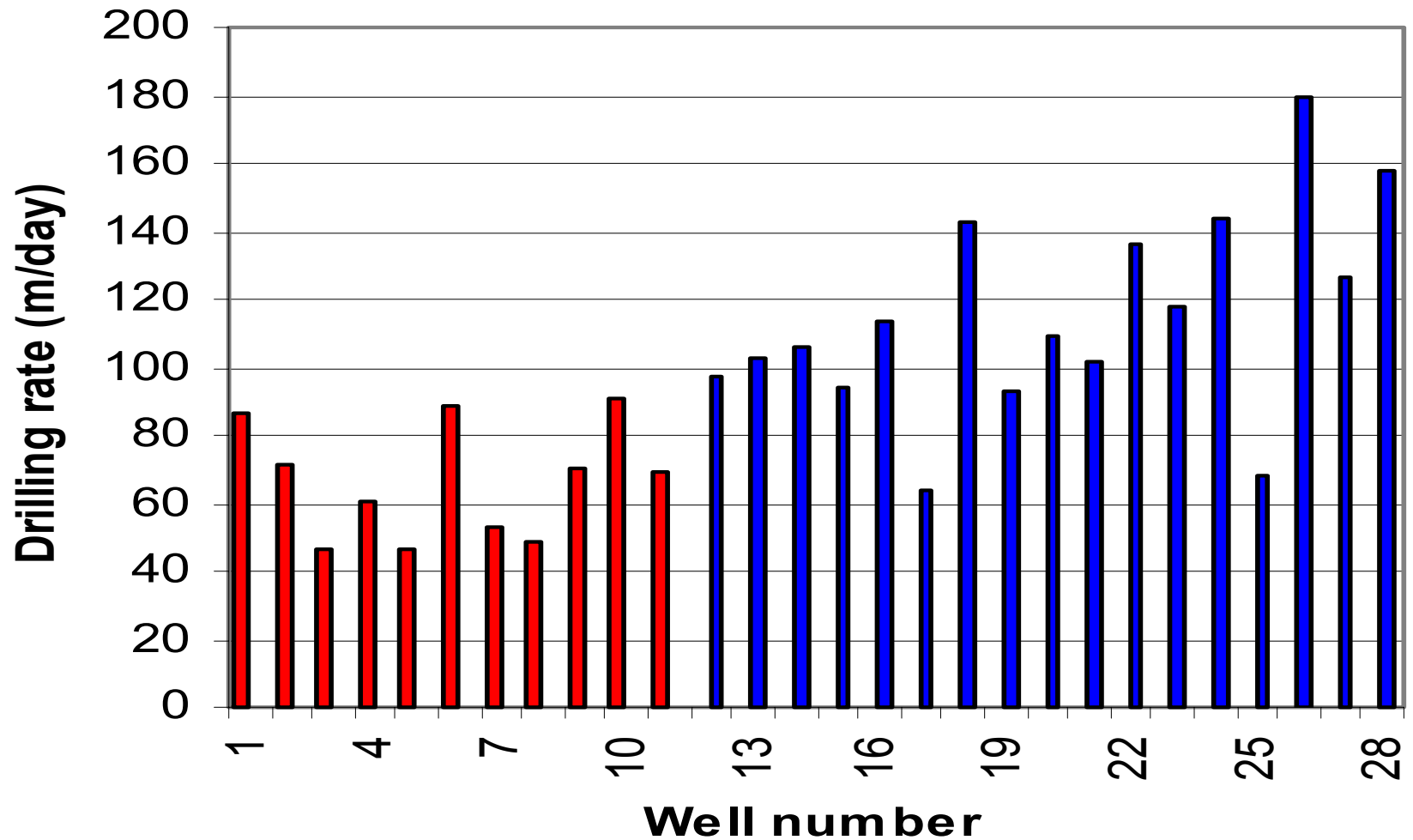


# Hole Cleaning in OBM

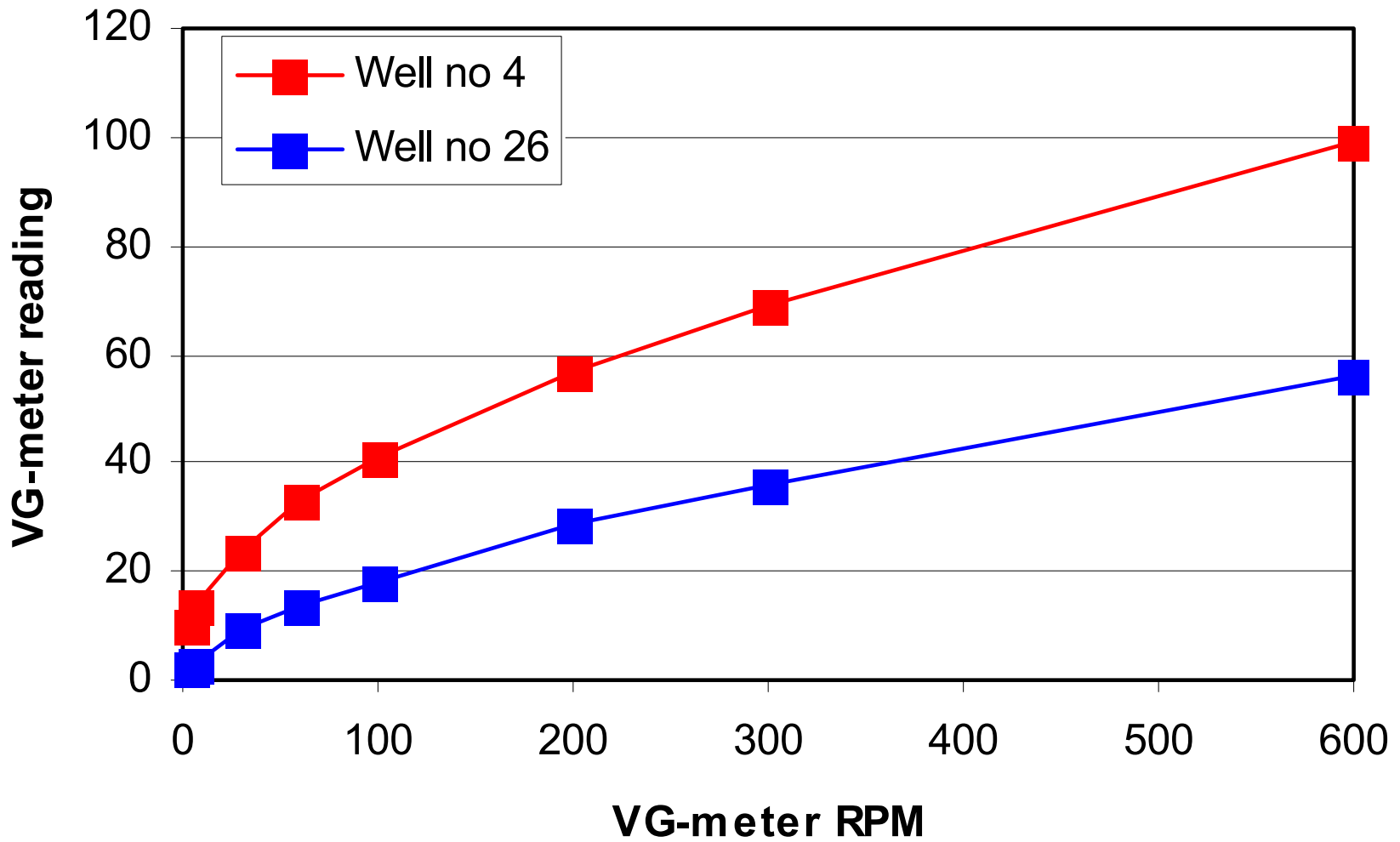
- Similar guidelines for OBM and WBM
- OBM and WBM cannot be directly compared
- Easier to remove cuttings in OBM



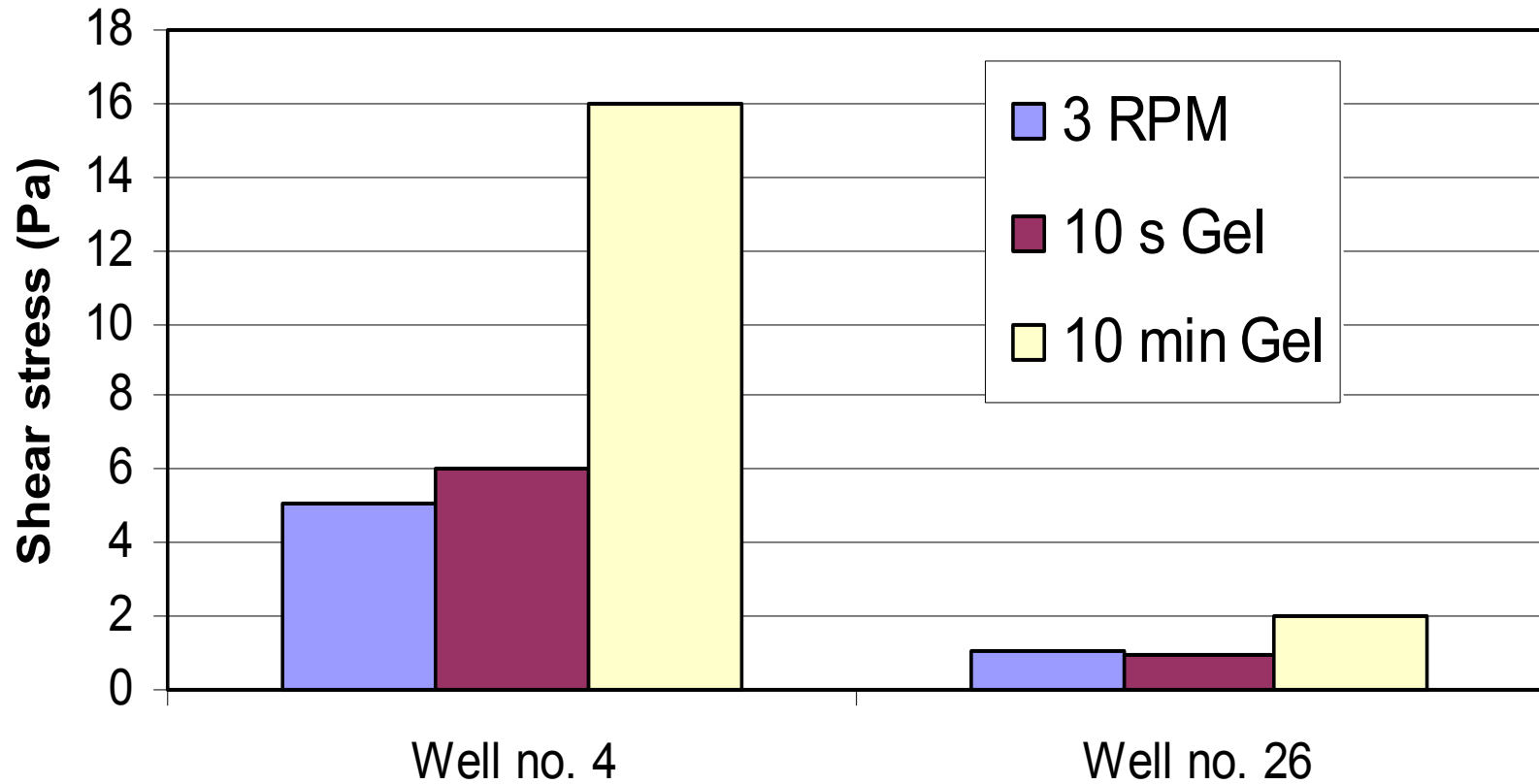
# Hole Cleaning in WBM



# Hole Cleaning in WBM



# Hole Cleaning in WBM



**Low shear values and gel formation**

# Filtration control

Seepage of fluid filtrate into the formation

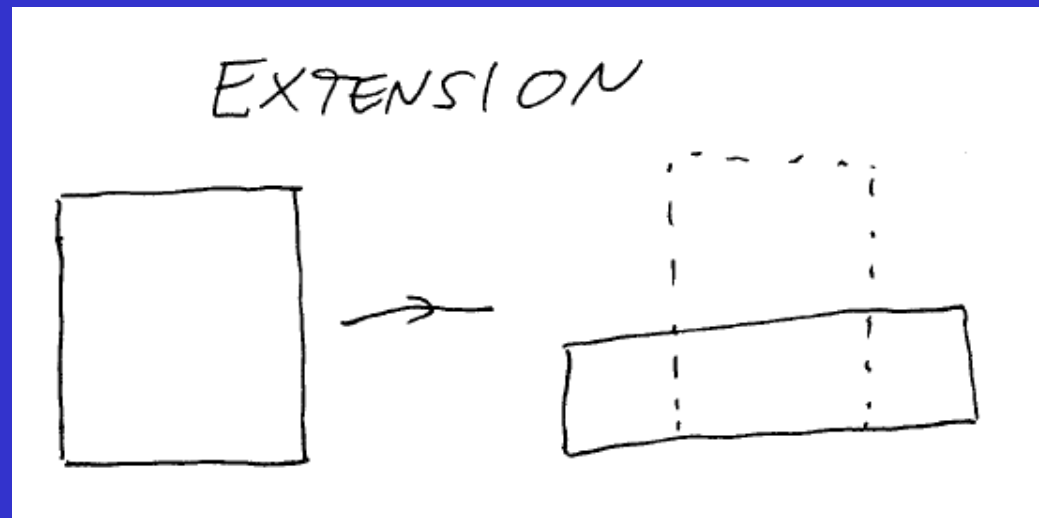
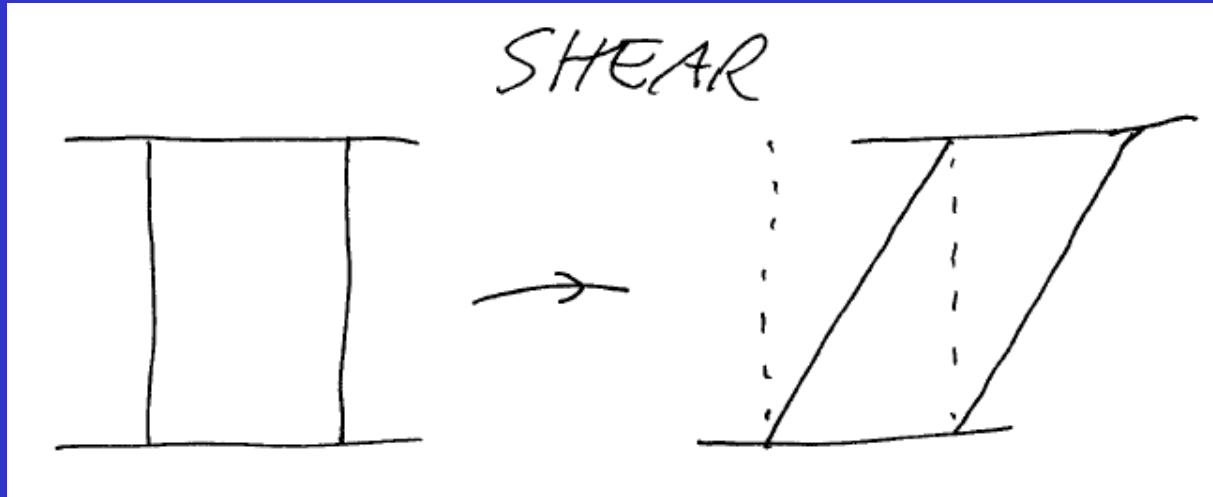
## OBM

- Water droplets and clay platelets block pore entrances

## WBM

- Solid particles block pore entrances
- Extensional viscosity of filtrate hinders flow

# Extensional viscosity



# Extensional viscosity

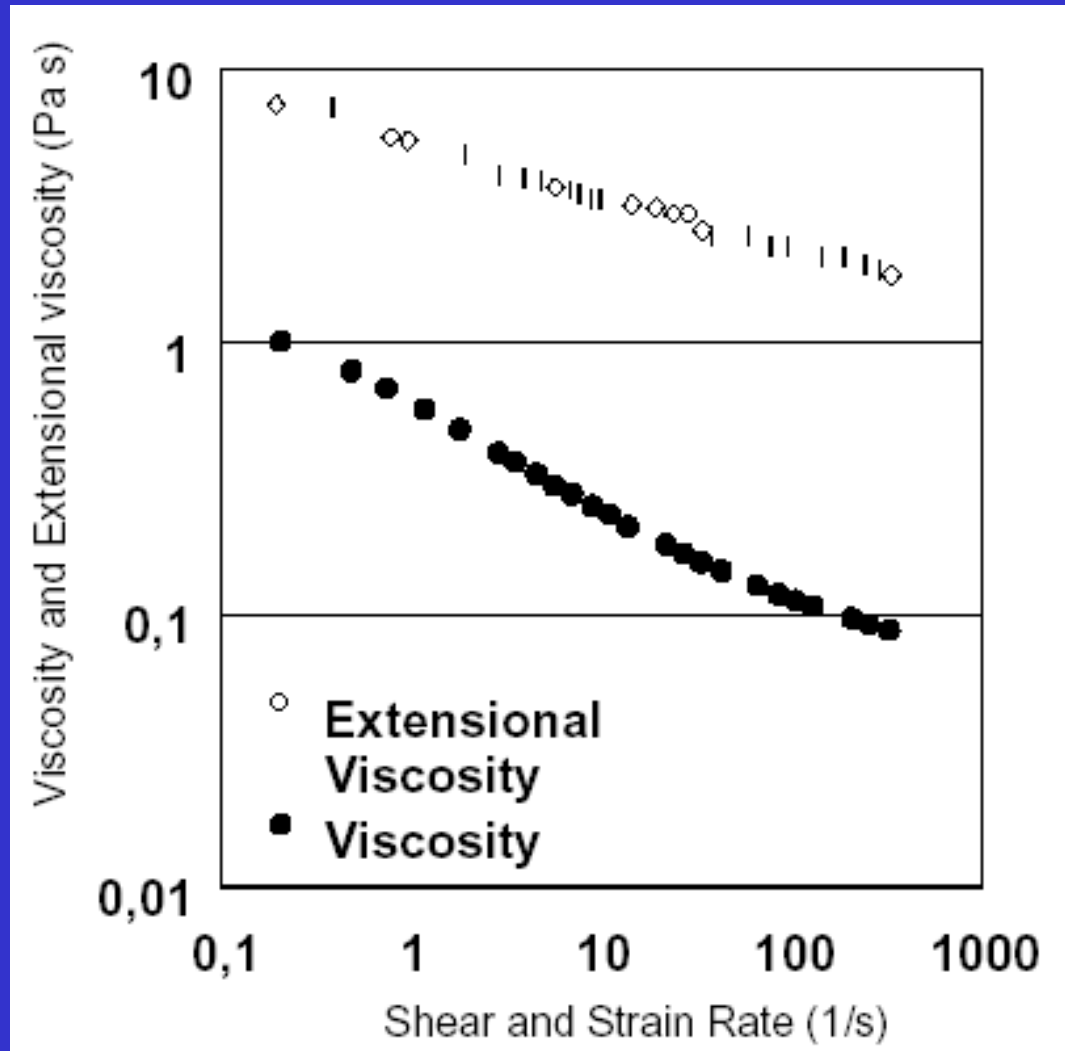
FOR NEWTONIAN FLOW

$$\bar{\mu} = 3\mu$$

TROUTON RATIO

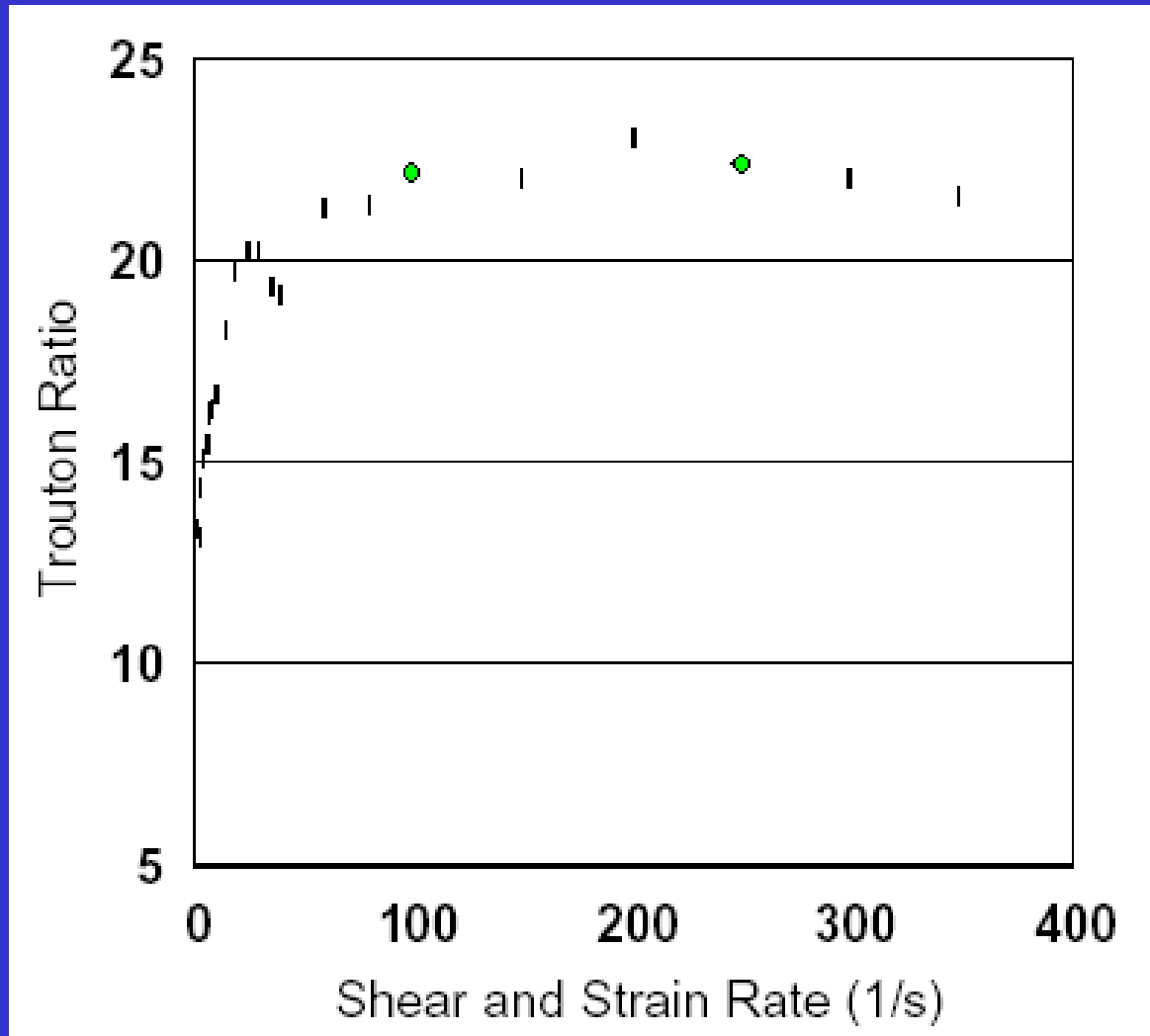
$$Tr = \frac{\bar{\eta}(\dot{\epsilon})}{\eta(\dot{\gamma})} \geq 3 \text{ FOR } \dot{\epsilon} = \dot{\gamma}$$

# Extensional viscosity



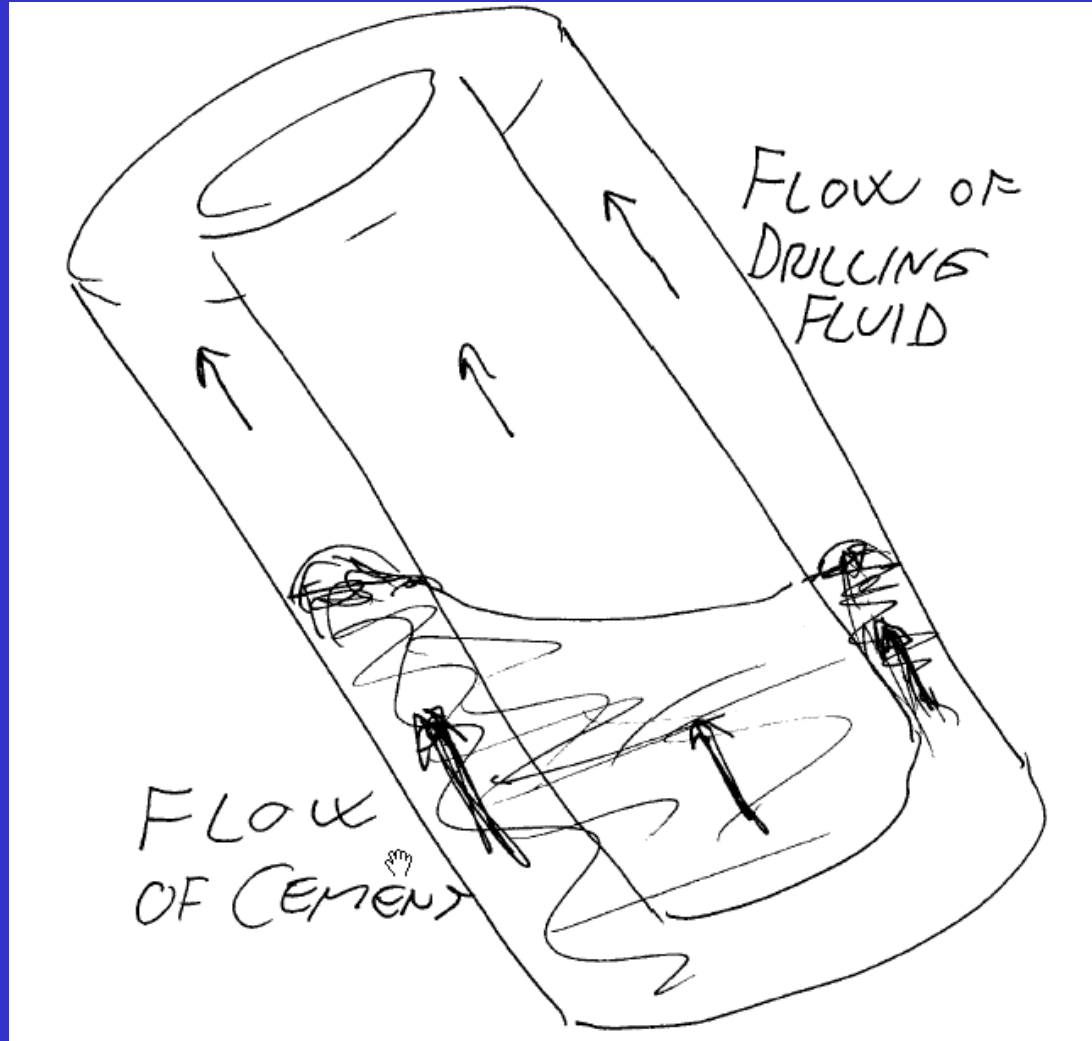
Gullfaks A-19A

# Extensional viscosity



Gullfaks A-19A

# Cement Displacement



# Cement Displacement

STABLE DISPLACEMENT

$$\Delta P_{\text{FRICTION}_{\text{CEMENT}}} > \Delta P_{\text{FRICTION}_{\text{DRILLING FLUID}}}$$

$T_{\text{GEL}_{\text{DRILLING FLUID}}}$  LOW

SHEAR THINNING INDEX  $n'$ :

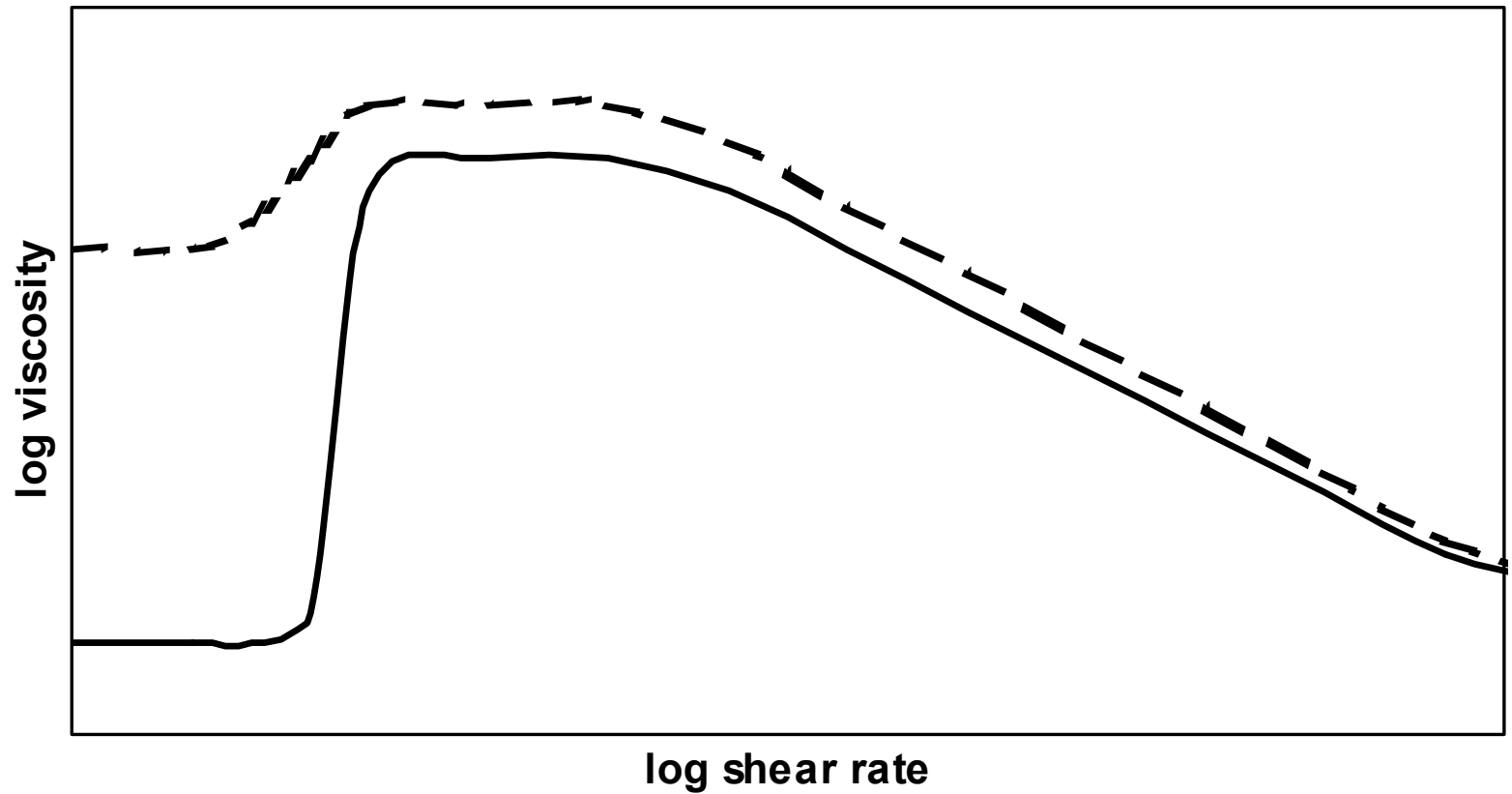
$n'_{\text{CEMENT}}$  AS LARGE AS POSSIBLE

# Barite sag

- *Necessary gel formation to hinder sagging of average barite particle*
  - *0.13 Pa*
  - *0.26 dial reading*
- *Average barite particle*
  - *25 micron*
- *Average ilmenite particle as accepted by Statoil*
  - *10 micron*

$$\tau_g \geq \frac{\Delta\rho}{6} gD$$

# Barite sag



# Drilling Fluid Rheology Summary

Hole cleaning

- No High Molecular Weight Polymers

Well control

- Barite Sag

Cooling the bit

- Flow

Avoiding damaging the formation

- Extensional viscosity