SKM 3413 - DRILLING ENGINEERING

Chapter 4 - Drilling Problems

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Contents

1. Stuck pipe/pipe sticking
2. Lost circulation
3. Shale problem/borehole instability
4. Mobile formations
5. Undergauge hole
6. Kick and blowout
7. Other problems
   - Shallow hydrocarbon zones
   - High bottomhole temperature
   - Corrosion

1. Stuck pipe/pipe sticking

- Definition: When part of the drill pipe or collars are stuck in the hole
- If pipe cannot be rotated or pulled and circulation is good, then pipe is probably wall stuck
- Causes of pipe sticking:
  a. Differential/wall sticking
  b. Mechanical sticking
  c. Key seating

a. Differential/wall sticking

- Definition: A pressure differential around the circumference of drill collars or pipe
- Wall sticking is caused by:
  - pipe is held by suction force resultant from overbalance hydrostatic pressure forcing filtrate into a permeable zone which leaves a thick mud cake on the wall of the hole
  - porous and permeable formation
  - motionless drill string

- To free wall-stuck pipe:
  - apply torque and tension to try to work the pipe loose
  - if possible, reduce the mud weight
  - determine the stuck point and spot a mixture of surfactant and oil

Prevention of wall sticking

- To minimize the possibility of wall sticking:
  - reduce the differential pressure
  - reduce the contact area: install stabilizers
  - use an oil-emulsion mud
  - use extreme-pressure lubricants
  - use low mud weights
  - use low solids content in the mud
  - stop circulation only when necessary
  - avoid long strings of large diameter drill collars
  - keep the hole as straight as possible
  - never stop drill collars adjacent to any permeable formation

b. Mechanical sticking

A drill pipe can be stuck mechanically when:

- Cuttings and sloughing formations pack off the annular space around the drill string (especially during a pump shutdown period)
- Drill through several layers of formation of different hardness
- Junk dropped from surface
- The drill string is run too fast until it hits a bridge, a tight spot or the hole bottom

To free mechanical sticking

- To work the drill string either by rotating and pulling it or by activating a drilling jar
- If this method fails, an organic fluid must be spotted and the above procedure has to be repeated
- The use of back-off operation is the final solution

c. Key seating

- Definition: a phenomenon happens at the dogleg where a new hole is created by drill string until the drill pipe is stuck to the wall
- When it passes through a dogleg, it tries to straighten and thus, creating a lateral force which causes the drill pipe joint to dig into the formation at the dogleg bow
- A key-seat can only be formed if the formation is really soft and the hanging weight below the dogleg is big enough to create a substantial lateral force
- This problem can be identified when the drill string can be moved downwards but not upwards

- To prevent key seating
  - drill straight holes or avoid sudden changes in hole inclination and direction in deviated wells
- To remove a key-seat:
  - the hole should be reamed
  - organic fluids can be spotted to reduce friction round the key-seat in order to facilitate the working of the pipe

2. Lost Circulation

- One of the major problems in drilling operation
- Occurred in almost every formation and at virtually all depths
- Occurs when hydrostatic pressure of mud exceeds the breaking strength of the formation
- <u>Definition</u>: Partial or complete loss of drilling fluid during drilling, circulating or running casing

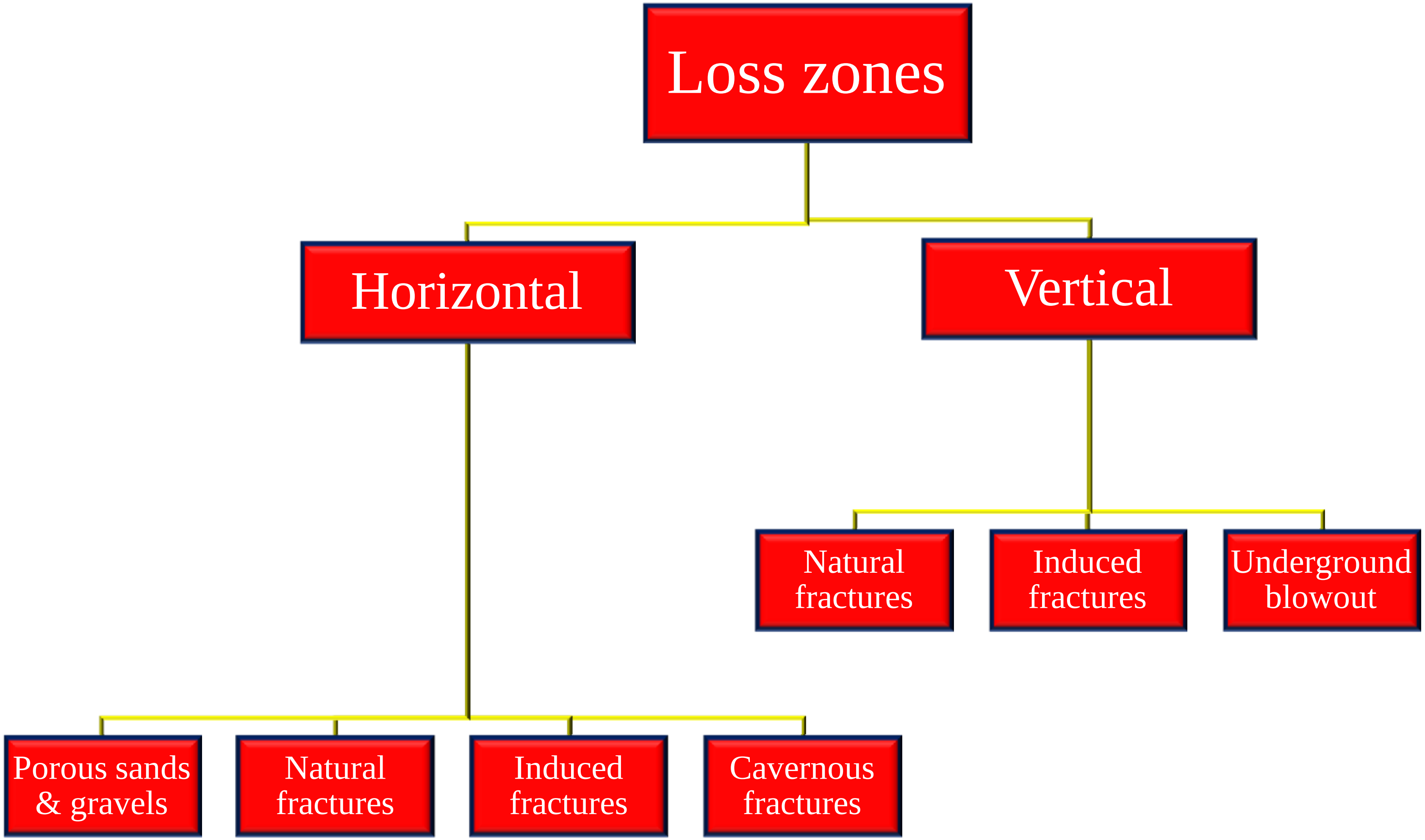
Type of Lost Circulation

- Those types inherent in the formation:
  - porous, permeable, and unconsolidated formations
  - cavernous or irregular formations
  - natural fractures in formations (faults, joints, fissures)
- Those openings caused by poor drilling practices:
  - induced fractures caused by high mud weights or pressure surges

Causes of Lost Circulation

- Rapid running of pipe i.e. generating surge pressures (tripping in or out)
- Spudding the bit or core barrel on the bottom of the hole
- Raising mud weight too quickly
- Improper balanced column of mud ($P_{hyd} > P_f$)
- Increasing pump pressure too quickly
- Whipping pipe
- High gel strength
- Sloughing shales (closed annular space)

Types of loss zones



Identifying features of horizontal loss zones

- Porous sands and gravels
  - gradual lowering of mud levels in pits
  - losses may become complete if drilling is continued
- Induced fractures
  - marked increase in pump pressure
  - drilling becomes tight
- Natural Fractures
  - may occur in any types rock
  - gradual lowering of the mud in pits.
  - Fracture must have a finite supported width to take mud
- Cavernous zones
  - normally confined to limestone
  - loss of returns may be sudden and complete
  - drilling may be rough before loss

Identifying features of vertical loss zones

- Natural fractures
  - may occur in any type rock
  - loss will go from partial to complete as more formation is drilled, particularly if drilling is accompanied by an increase in mud weight
- Induced fractures
  - may occur in any type rock
  - Sudden loss, complete loss of returns
  - when loss of circulation occurs and adjacent wells have not experienced loss

- Underground blowout
  - fluids flow from a lower active zone to an upper induced vertical fracture
  - Unstable pressure readings, change in pressures and mud volumes

Natural causes

- Unconsolidated shallow formations
- Porous and permeable formations
- Natural Fractures and voids
- Easily Fractured Formations

Unconsolidated shallow formations

- This formation may be highly fractured shale, sandstone and limestone.
- Sands and gravel ranging in size from fine to boulders also commonly occur.
- It usually occurs near the surface and the fractured formations at deeper depths.

Porous and permeable formation

- Porous, permeable sands occur at any depth.
- Porosity and permeability generally decrease with depth
- The lost circulation rate usually controlled by the permeability of the sand, the viscosity of the mud, and the differential pressure between the pores and the mud column.
- The lost-circulation rate is relatively constant and often decreases with time, as the filter cake is built up on the borehole wall and some distance into sand.

Natural fractures and voids

- Natural fractures and voids can occur at all depths in all formation
- The frequency of occurrence increases in the older, harder, more consolidated formation that usually found deeper and also been subjected to tectonic forces and stresses
- Once the fracture has been opened by an imposed pressure, mud lost to the fracture at a rapid rate can widen the fracture. Even though the pressure is later reduced, the opening may not close completely and the loss of circulation will continue

Easily fractured formations

- If the formation is weak, fractures may be created cause by the induced pressure, and the mud pumped away

Induced lost circulation

- Definition
  - Mud loss caused by operator’s action during the drilling operation
- Types
  - Overpressuring and fracturing the formation by initiating a fracture
  - Results of excess pressure
    - ✓ poor flow properties in mud system
    - ✓ pressure surges

Induced lost circulation

Types of loss zones

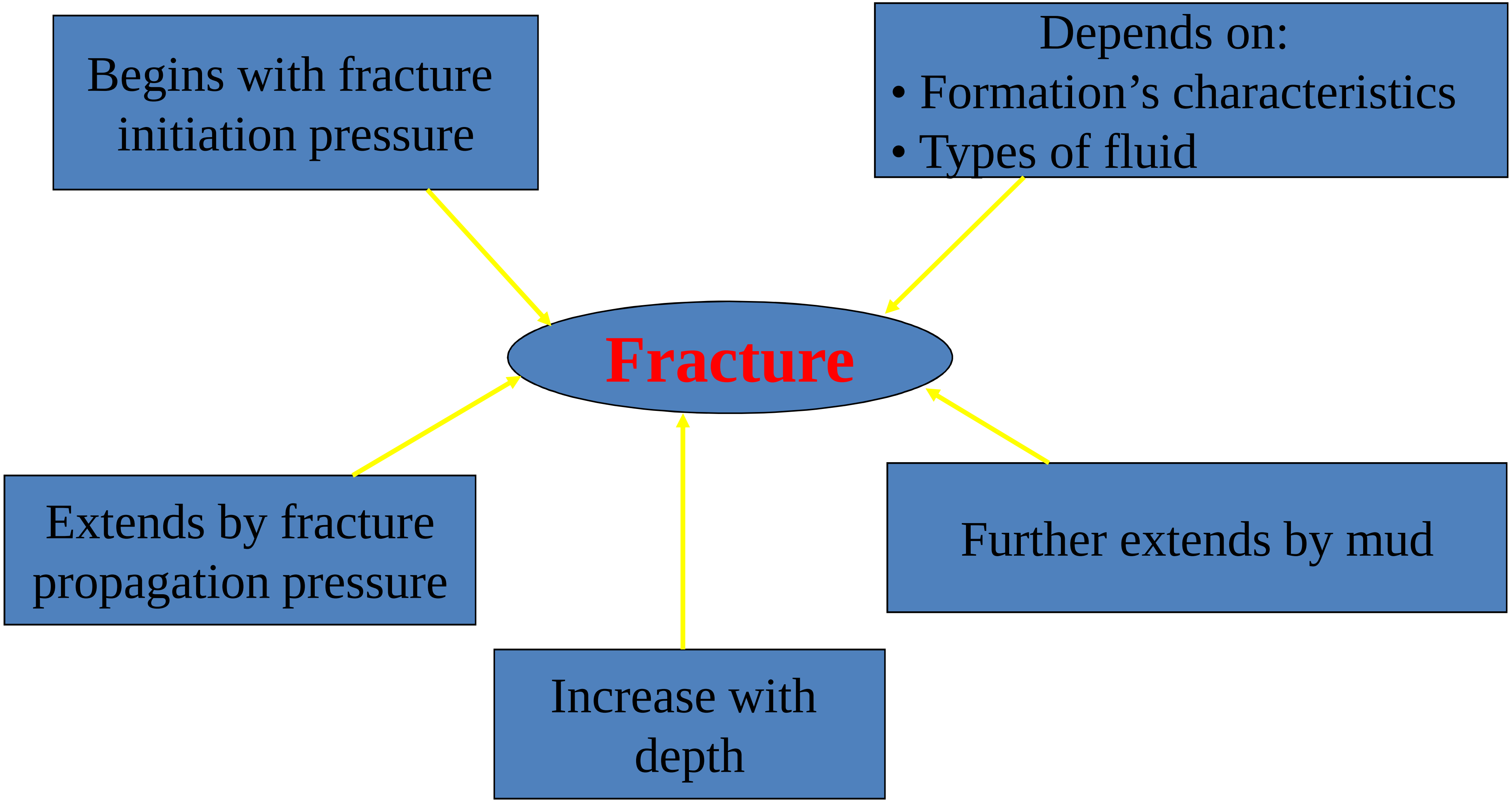
Horizontal induced fractures

(occur where fractures are horizontal in any formation under mud rungs)

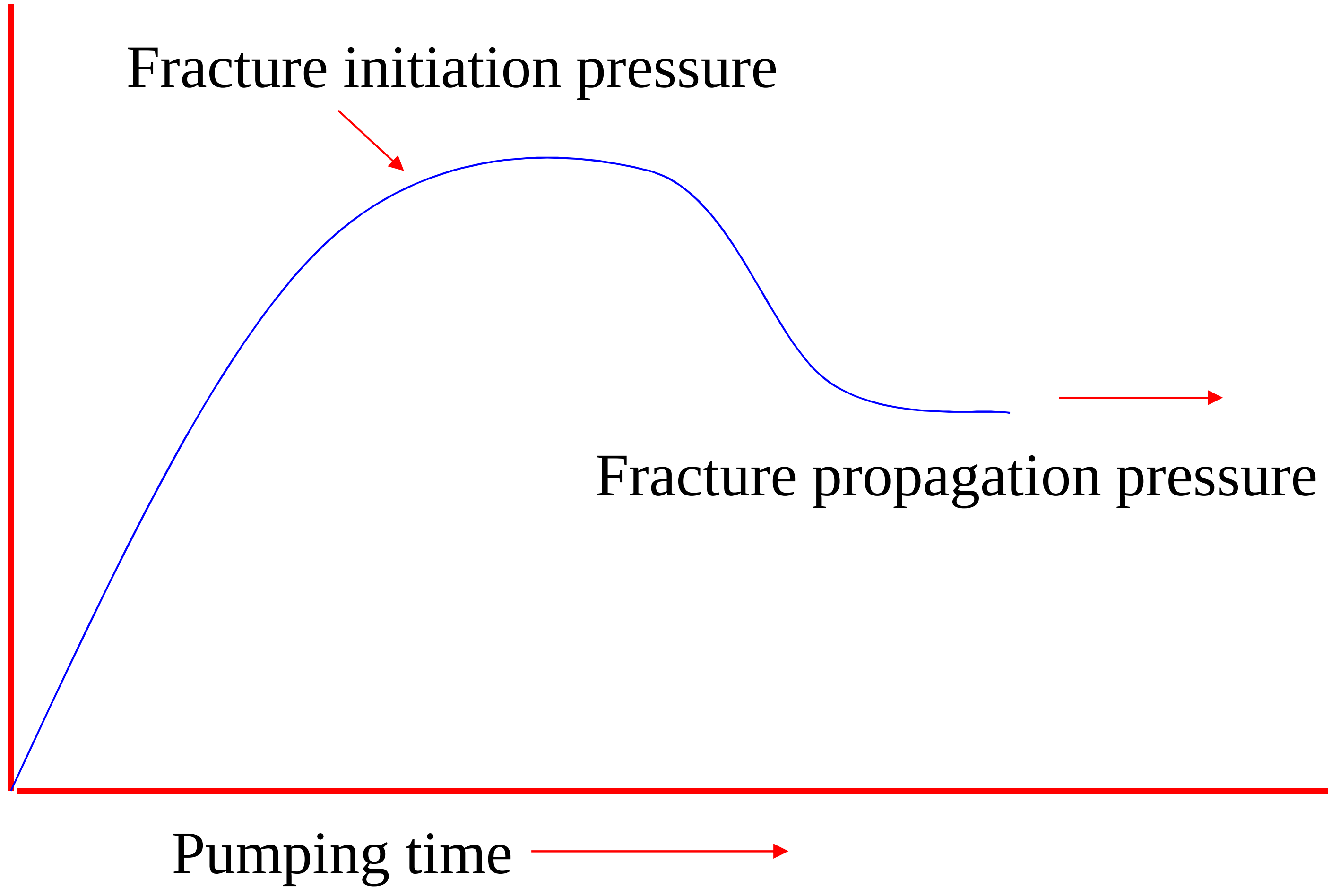
Vertical induced fractures

(occur in any type rock but would be expected below 2,500 ft.)

How fracture is formed?



How fracture is formed?



How fracture is formed?

Fracture initiation pressure → Fracture propagation pressure

↓

Magnitude difference (fluid, formation)
Fluid → penetrating
→ non- penetrating

← Easier to fracture using penetrating fluid

↓

Mud extends the process, propagation < initiation

Effects of Lost Circulation

- Loss of muds (high cost)
- Loss of drilling time (consequent cost increases)
- No information on the formation being drilled
- If the lost circulation zone is a potential pay zone, considerable productivity impairment may result
- The drop in annular mud level may cause a blowout
- Excessive caving of formation

Treatment

- Identify the source of mud loss
- Determine the appropriate treatment

Criticality of Loss Circulation

- The severity of the loss (the rate) will dictate the criticallity of the situation and the emergency of the action to be taken

Type	Amount loss (% of the circulating rate)	Action/Remarks
Seepage loss	< 10%	Usually treated as a routine problem without interfering with any part of the operation
Slight loss	10 - 25%	Treated immediately but the current operation may continue if geopressured zones are not present in the well
Hazadous	25 - 50%	Stop all operations (excluding well control) until remedial action has resolved the problem
Severe	> 50%	

Loss Severity	Loss Rate (bbl/hr)	Typical Formation	LCM Type/Treatment
Seepage	1 to 10	Porous and permeable	Fine - medium granular Fine - medium fibre
Partial	10 to 50	Unconsolidated sands and gravels; Small open fractures	Fine - coarse granular Fine - coarse fibre Fine - coarse flake
Severe	50 to 100	Long sections of unconsolidated sands etc Fractures	Medium - coarse granular Medium - coarse fibre Medium - coarse flake
Total	>500	Cavernous Large fractures	Sodium silicate and cement Gunk treatments

To Combat LC

- Raised the bit into the cased part of the hole & wait
- Reduce mud weight
- Spot LCM of proper size

Prevention of LC

- Control downhole pressure
  - minimize hydrostatic pressure
  - maintain minimum annular velocity
  - avoid restriction in the annulus
- Setting the intermediate casing into the transition zone
- Raised weight of mud gradually when combating high pressure zones
- Start pumps only after rotating pipe
- Run & pull drill pipe in the hole slowly
- Never spud pipe
- In areas of known LC pretreat with LCM

Prevention of LC (ctd)

- Break circulation slowly
  - circulate at a slow rate and low pressure until good returns are obtained without loss of mud, then increase the circulation rate
- Selecting a mud system
  - maintain a minimum mud viscosity and gel strength to prevent setting of the weighing material
  - mud system should be able to resist contamination
  - maintain minimum mud density
  - use filler materials (loss circulation materials) to prevent severe loss of mud to the formation to restore circulation

Prevention of LC (ctd)

- Use a simple drilling programme and have a good drilling practice
  - drill the lost-circulation zone with a maximum-clearance drilling assembly
  - lower the drill pipe slowly
- Observation of well hole and precautionary steps
  - extra mud-storage capacity
  - make sure supply of mud-mixing and lost circulation material is ample
  - observe the mud level

Remedial actions

- Reduction of mud weight
- Correction of lost returns by “waiting periods”
- Placement of soft plugs - LCM
- Placement of mud containing a high concentration of bridging particles
- Adoption of special drilling methods such as “blind drilling”, drilling under pressure, drilling with air, or aerated mud
- Drill ahead-cuttings circulating in the mud system can act as lost-circulation material
- Pull the bit up at least 50 ft from the bottom
- Dry drill - minimize the effects of lost circulation or regaining circulation in minimal time

LCM

- Fibrous material - sawdust, cotton seed hulls, hay, leather, bark
- Lamellated (flat, flacky) material - mica, cellophane
- Granular material - nut shell, perlite, volcanic ash
- Combination of two or more of the above materials

3. Shale problem/borehole instability

- Shale:
  - sedimentary rock form by deposition and compaction of sediments
  - contain clays, silt water, quartz, feldspar
  - compact or unconsolidated rock depend on water content
- Definition of shale problem/borehole instability:
  - a condition where the shale section containing bentonite or other hydratable clays which continually absorb water from the mud, expands, swell & slough into the hole
  - hole instability resulting from drilling shale sections
- Other terms: sloughing shale, heaving shale, running shale

Problems due to Sloughing Shale

- Ineffective hole cleaning
- Stuck pipe & its recovery
- Bridges & filled up
- Increased mud volume & treating costs
- Poor cement jobs & increase cement requirements
- Difficult logging
- Poor sidewall recovery
- Wellbore enlargement
- Excessive solid build up in the mud

- A sloughing hole can jam the drill string and block circulation
- Severity depend on:
  - percentage content of montmorillonite (higher montmorillonite, higher shale dispersion)
  - the age of the rock (older shale, lower dispersion)

Causes of Sloughing Shale

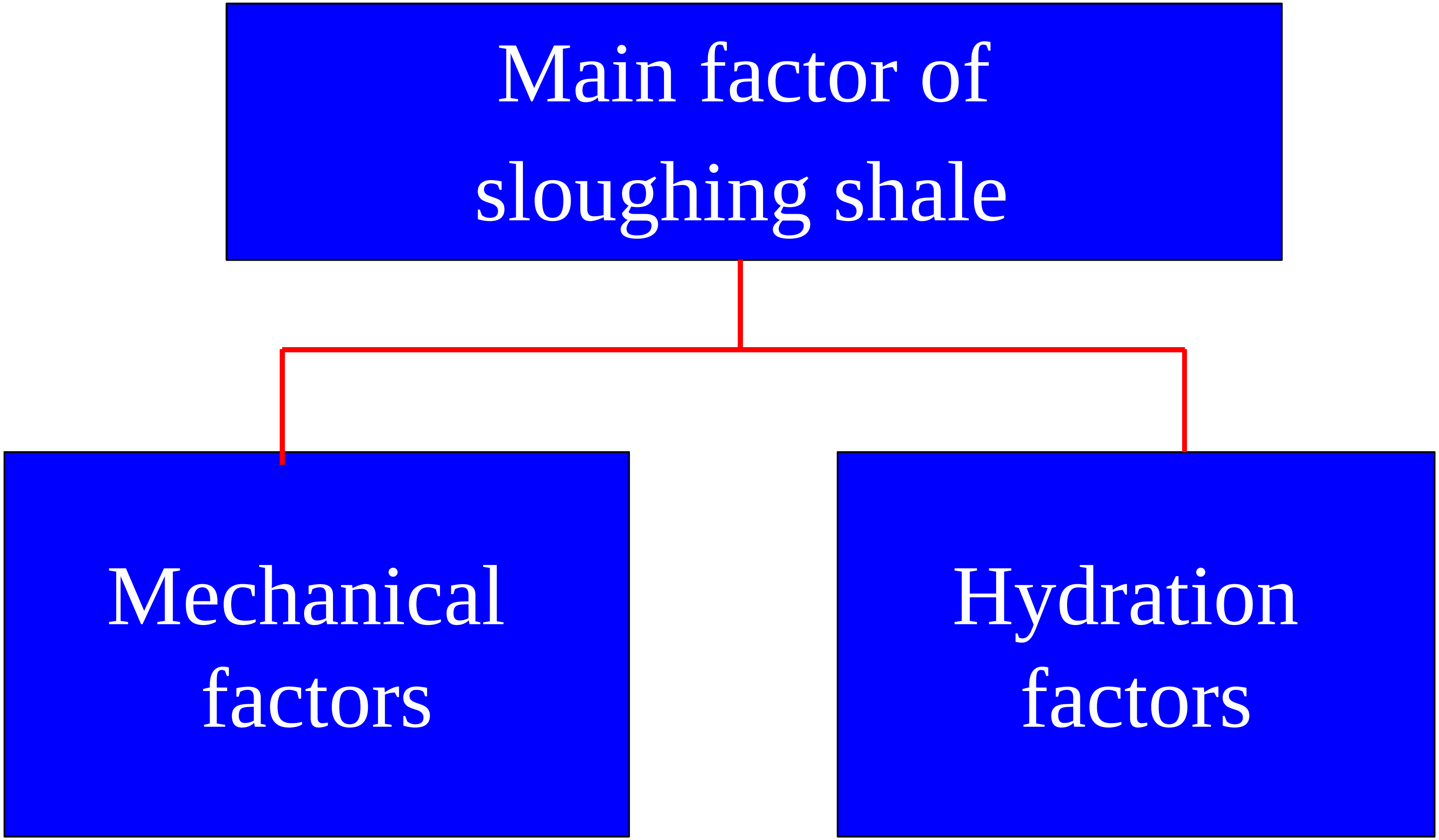
- Hydration of shale
- Mechanical fissuring of shale sections due to pressure surges
- Restricted hole gauge (balling, etc.)

Borehole instability

- An unstable borehole poses several problems for the drilling operation:
  – fill on trips increasing the drilling time & decreasing bit life
  – hole washout
  – swelling formations producing tight hole

Causes of shale instability

- Overburden pressure
- Pore pressure
- Tectonic forces
- Water adsorption
  - Dispersion
  - Swelling


Main factor of sloughing shale
Mechanical factors
Hydration factors

Mechanical factors

- Erosion effect
  - annular flow of mud
  - depend on degree of turbulence in the annulus and mud viscosity
- Impaction by drill string cause the breakage of shale
- Caving due to horizontal movement of the shale section

Hydration factors

- Shale hydration force
  - the drilling of shale section relieves the compaction force on the borehole
- Osmotic hydration
  - the difference in salinity between the mud and formation water of the shale
  - adsorption force when formation water of the shale is more saline than the mud
  - desorption force when the mud is more saline than the formation water

Other factors

- Dipping shale
  - shale expansion in a direction perpendicular to its bedding planes
  - more shale heaving when the section is highly dipping
- Abnormal pressured shale
  - water content of the rock is much higher compared to the normal pressure shale
  - plasticity of the shale is high due to the overburden load
  - shale will be squeezed into the hole because the difference between formation pore pressure and mud hydrostatic pressure

Planning...

- Examine the geology of the area for the presence of water sensitive clays
- Check the past case histories of geopressure formation

Prevention of sloughing shale

- Use suitable mud system to inhibit hydration (high Ca & K content, OBM, oil-emulsion, ...) to decrease the tendency of mud to hydrate water sensitive clays
- Increase circulation rate for more rapid removal of particles
- Increase mud density for greater wall support ($P_{hyd} > P_f$)
- Decrease water loss of mud
- Avoid fast trips or swabbing of the hole
- Keep flow properties & annular velocity at such a level as to insure good hole cleaning

4. Mobile formations

- A salt or shale can squeeze into the well bore because it is being compressed by the overburden forces
- The deformation results in a decrease in the well bore size, causing problems running BHA's, logging tools and casing and stuck pipe
- A deformation occurs because the mud weight is not sufficient to prevent the formation squeezing into the well bore
- Once broken, the hole will become enlarge

Warning Signs

- Increase in mud chlorides
- Large overpulls at connections
- Pump pressure increase

Rig site identification

- Stuck shortly after pumps are turned off
- Rotation may be possible but with high torque
- Overpull when moving up, takes weight when running in
- Sticking occurs with BHA at mobile formation depth
- Restricted circulation with BHA at mobile formation depth

Preventive Actions

- Identify salt dome
- Monitor mud chlorides and mud resistivity
- Maintain sufficient mud weight
- Select an appropriate mud system that will not aggravate the mobile formation
- Plan frequent reaming/wiper trips particularly for this section of the hole
- Slow trip speed before BHA enters the suspected area
- Minimize the open hole exposure time of these formations
- With mobile salts, consider using a slightly under-saturated mud system to allow a controlled washout

5. Undergauge hole

- Drilling hard abrasive rock wears the bit and the stabiliser gauge and results in a smaller than gauge hole
- When a subsequent in-gauge bit is run, it encounters resistance due to the undergauge section of hole
- If the string is run into the hole quickly without reaming, the bit can jam in the undergauge hole section
- This mechanism normally occurs:
  - After running a new bit
  - After coring
  - When a PDC bit is run after a roller cone bit
  - When drilling abrasive formations

Rig site identification

- Pulled bit or stabilisers are undergauge
- Occurs only when RIH
- Sudden setdown weight
- Circulation is unrestricted or slightly restricted
- Bit stuck near the bottom of the hole or at the top of a cored section

Preventative Action

- Use suitably gauge-protected bits and stabilisers
- Consider the use of roller reamers
- Always gauge all BHA components both when running in and pulling out of the hole
- Ream suspected undergauge sections
- Slow the trip speed down before the BHA enters an undergauge zone

6. Kick and blowout

- Kick: An entry of formation fluids (gas, oil or water) into the wellbore during drilling
- Blowout: Uncontrolled flow of formation fluids (gas, oil or water) from the wellbore
- Kick and blowout can occur when hydrostatic pressure of mud is lower than the formation pressure

Causes of Kick/Blowout

- Drilling into high pressure zones (abnormal pressure)
- Swabbing when coming out of the hole
- Improper hole fill-up on trips
- Lost circulation during drilling or cementing

Detection of Kick/Blowout

- Rise in pit level
- Hole fails to take right amount of fluid after trips
- Gas cutting or decrease in mud weight
- Increase in pump speed or decrease in pump pressure

Prevention of Kick/Blowout

- Use high mud weight
- Use right type of mud and keep in good condition
- Check mud weight frequently
- Check fluid level frequently
- Add weight material evenly
- Do not add excessive weight reducing materials such as oil or water
- Trip slowly
- Keep hole clean to prevent swabbing
- Observe surface gas