Well Construction 101

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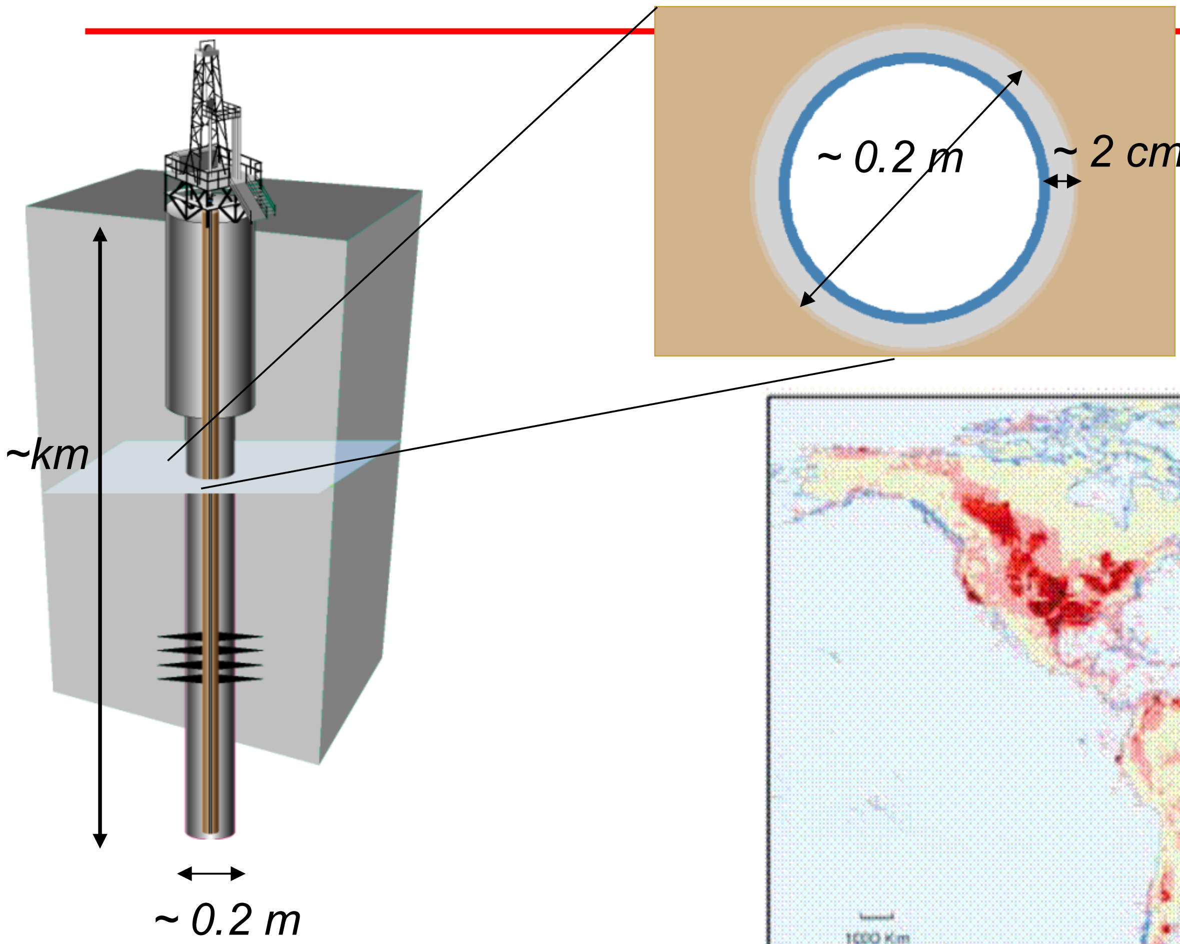
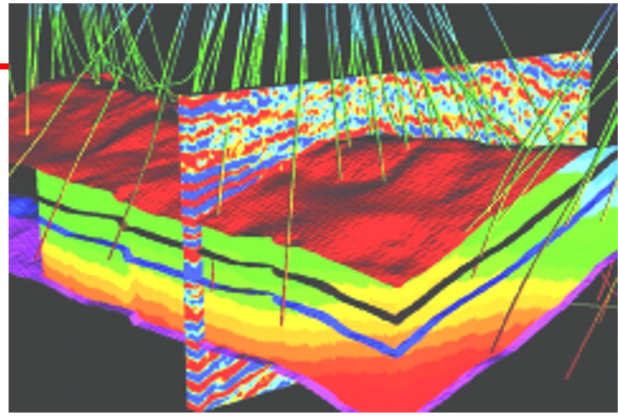
Outline

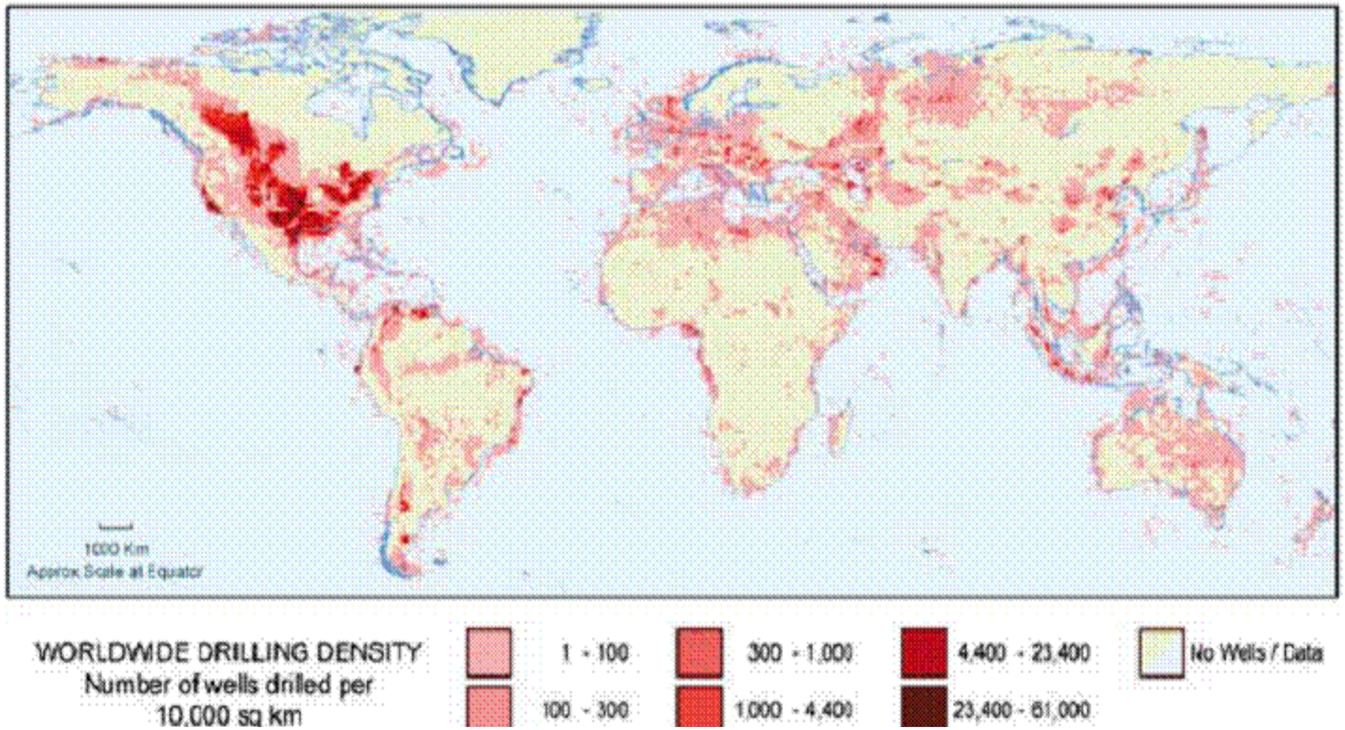
1. Well architecture
2. Drilling
   - Rig components
   - Rotary drilling
   - Mud circulation
   - (Directional drilling)
   - (Measurements While Drilling)
3. Cementing
   - (Cement placement)
4. (Introduction to wellbore stability)

() means ”will not be covered here due to time limitations”

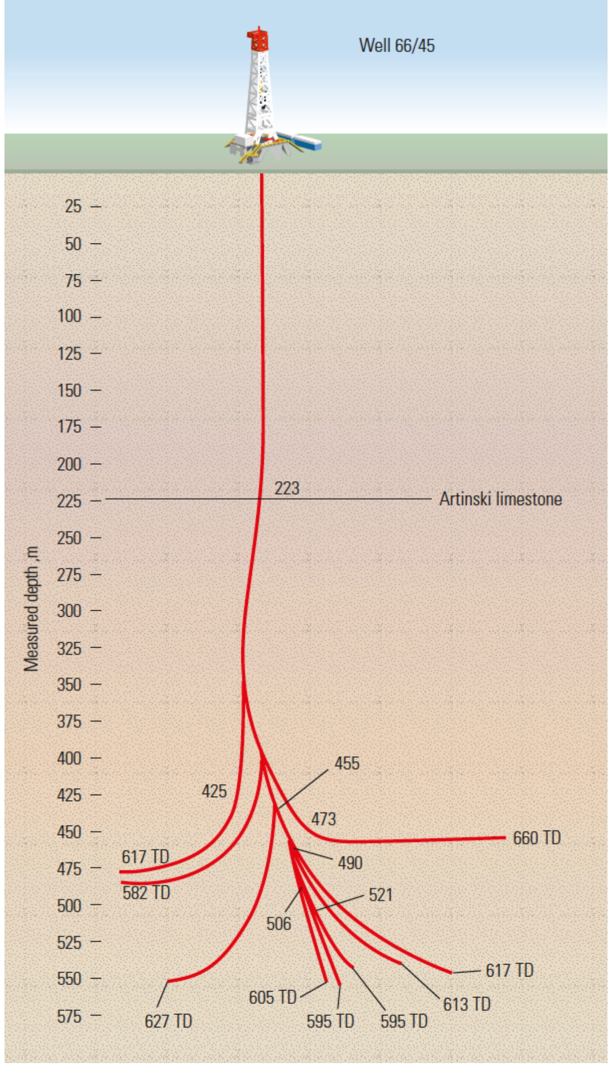
Wells - thinner than a hair

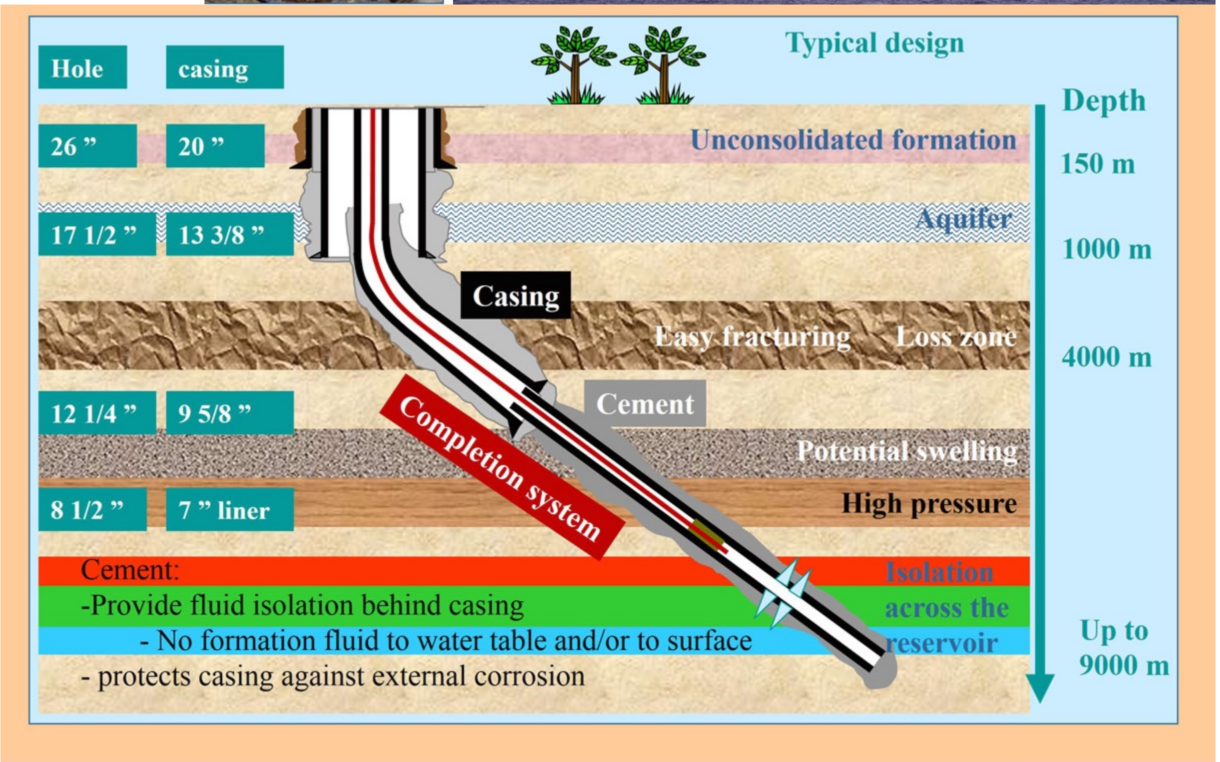






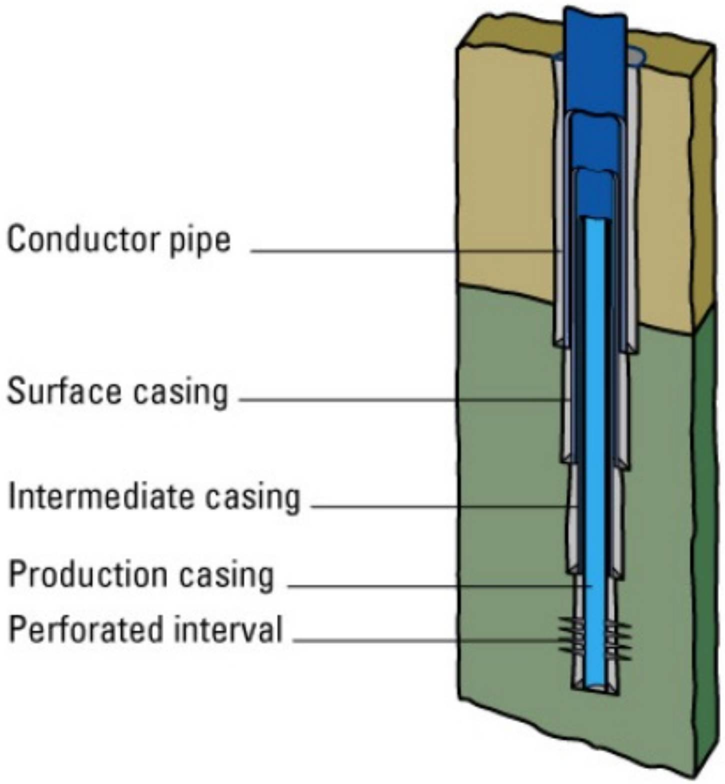
Well Construction





WELL ARCHITECTURE

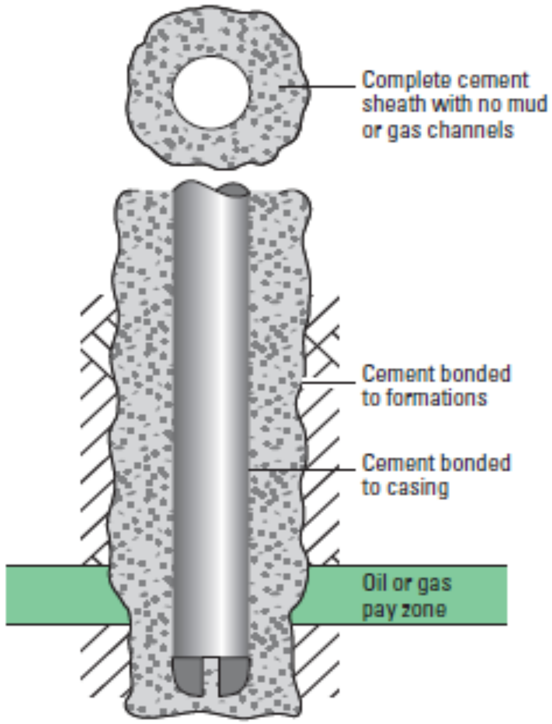
Diagram of a Wellbore



Primary Cementing

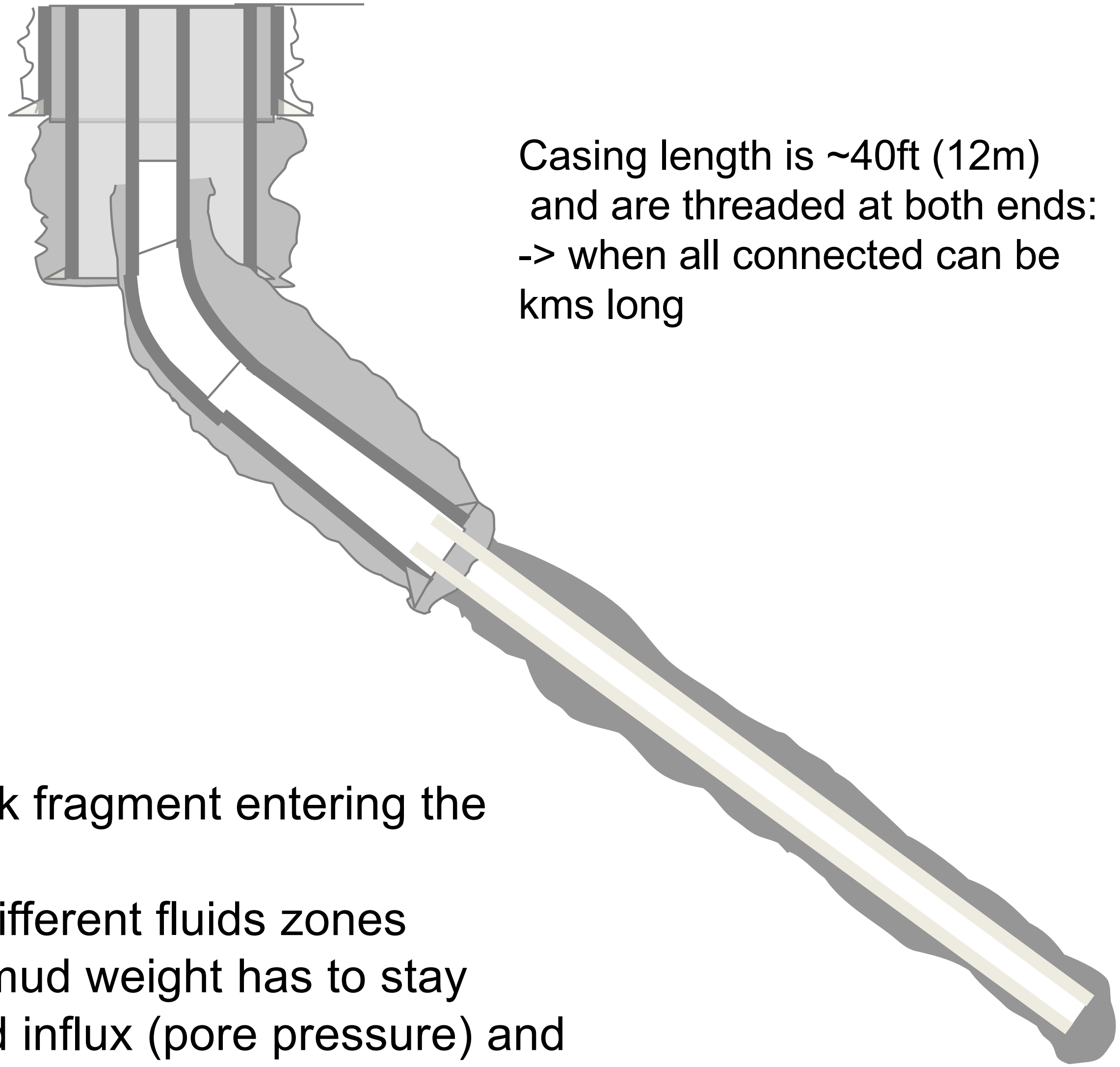
The introduction of a **cementitious material** **(via cement slurries)** into the annulus between casing and open hole or previous casing or both to:

- Provide zonal isolation
- Protect the casing string against corrosion
- Support axial load of casing strings and strings to be run later
- Support the borehole
- Meet government regulations



Types of Casings

- Conductor
- Surface
- Intermediate
- Production casing
- Liners and Tie-Backs



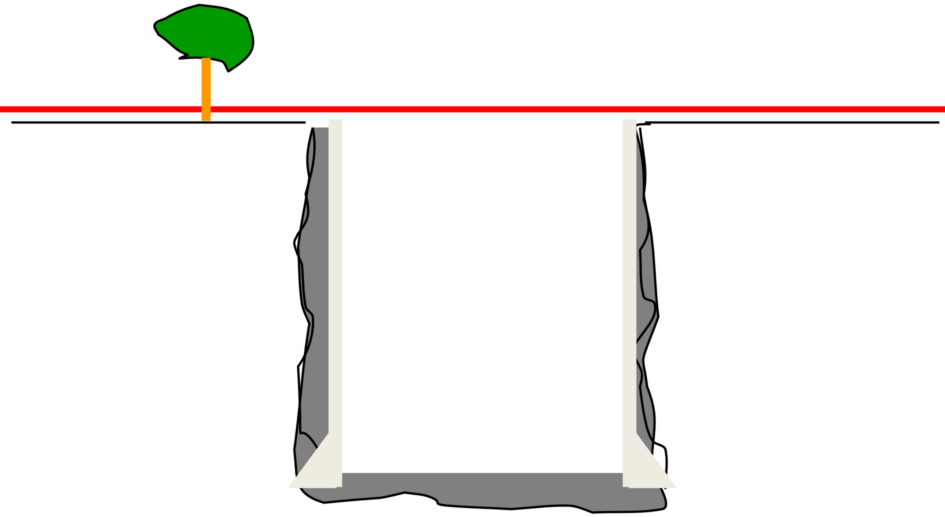
Casing length is ~40ft (12m) and are threaded at both ends: -> when all connected can be kms long

Casing is run to:

- Ensure long term stability (avoid rock fragment entering the well)
- Protect fresh water zones / isolate different fluids zones
- Make subsequent drilling possible: mud weight has to stay within a given window to control fluid influx (pore pressure) and avoid fracturing / fluid loss.

Conductor

- *Purpose:*
  - Prevents washing out under the rig
  - Provides elevation for flow nipple
  - Protects shallow sands from contamination
- *Challenges:*
  - Possible occurrence of shallow water flows
  - Low temperatures (offshore)
  - Drilling through gas hydrates under deep water conditions (offshore)
- Not viewed as a pressure seal



30 ‘’ casing in 36’’ hole

or

20 ‘’ casing in 26’’ hole

@

30 ft - 200 ft

Surface

Purpose:

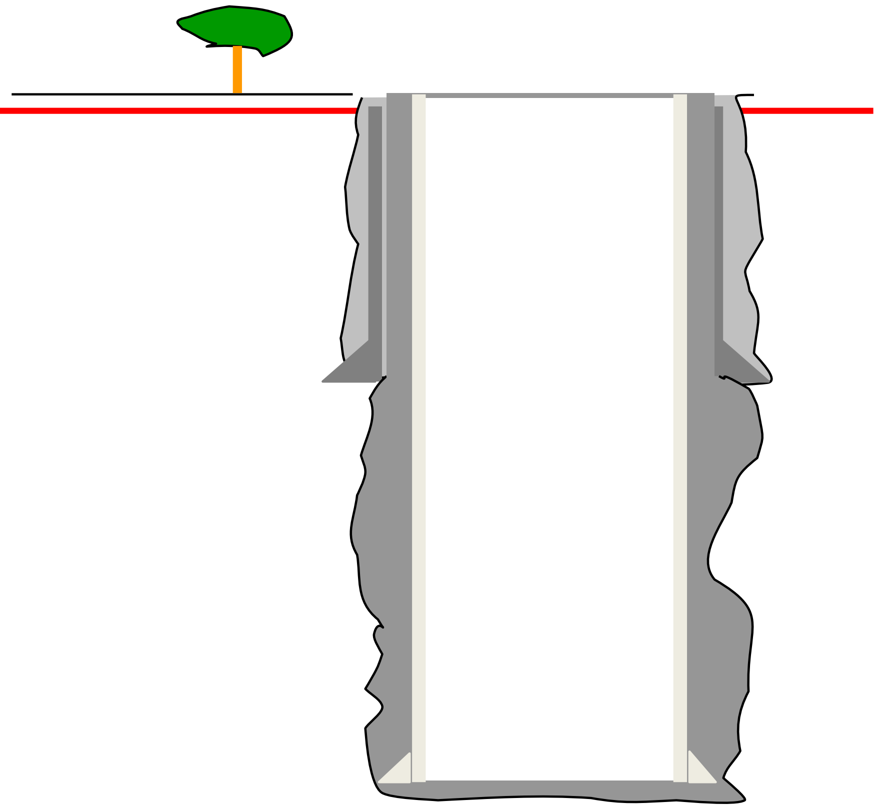
- Protect surface fresh water formation
- Case off unconsolidated or loss areas
- Provide a competent mechanical base for subsequent operations (BOP, casings, etc.)

Challenges:

- Possible occurrence of shallow water flows
- Low temperatures (offshore)
- Drilling through gas hydrates (offshore)

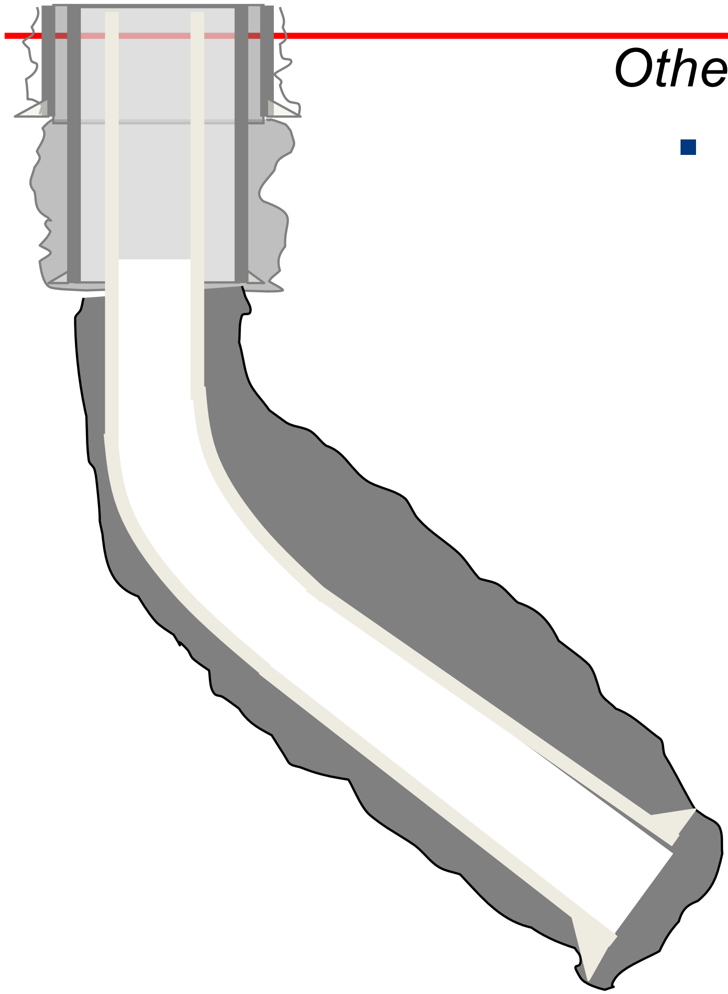
The blow out preventer (BOP) is typically mounted on it.

(more on BOP later)



16 " casing in 20 " hole
or
13 3/8" casing in 17 ½" hole
@
100 ft – 3000 ft

Intermediate Casing(s)

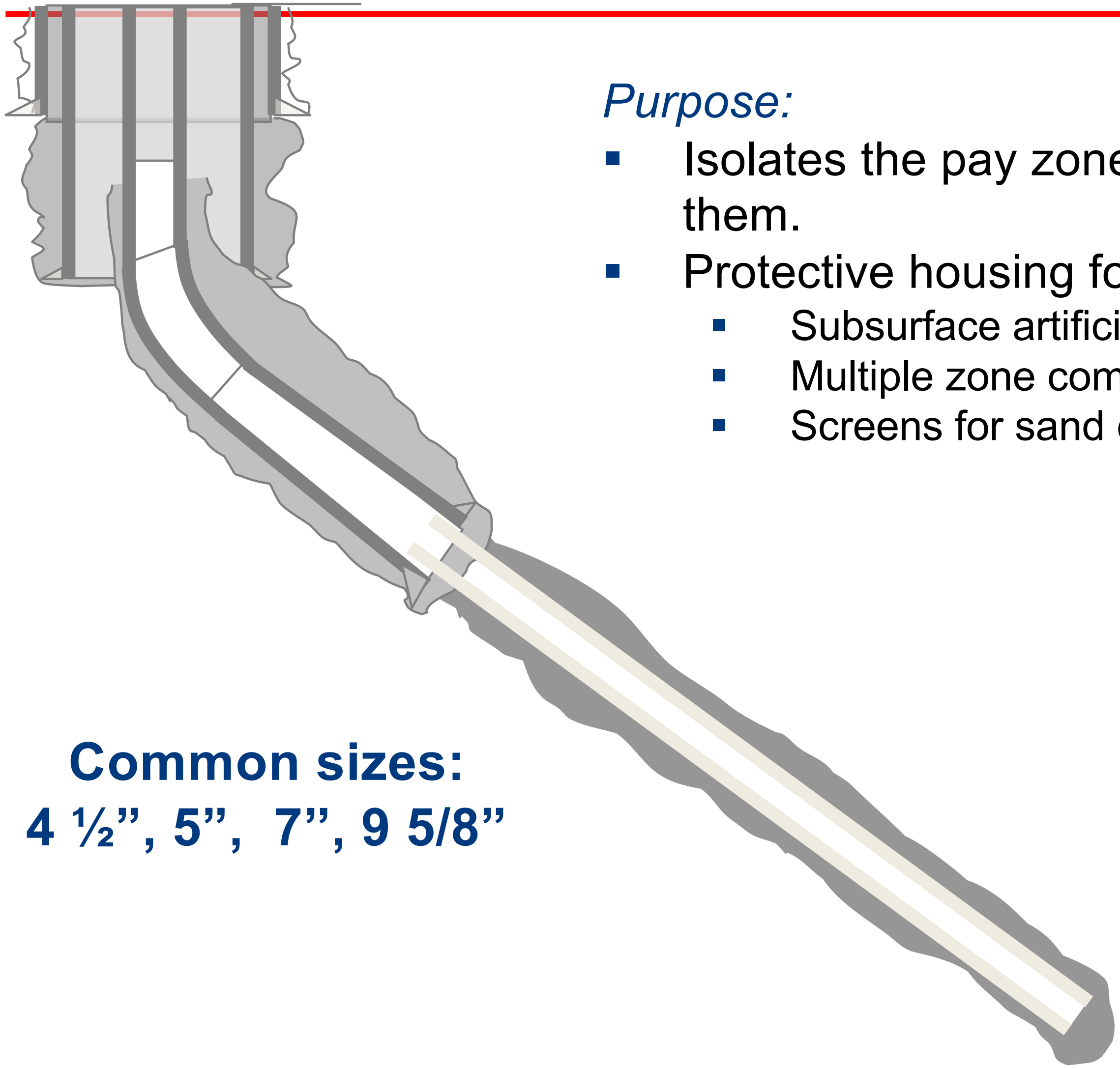


Others :

- Depending on geology / length of well etc.

13 3/8" casing in 17 ½" hole
or
9 5/8" casing in 12 ¼" hole
@
3000 to 10,000 ft (vertical or deviated)

Production Casing(s) or Liner(s)



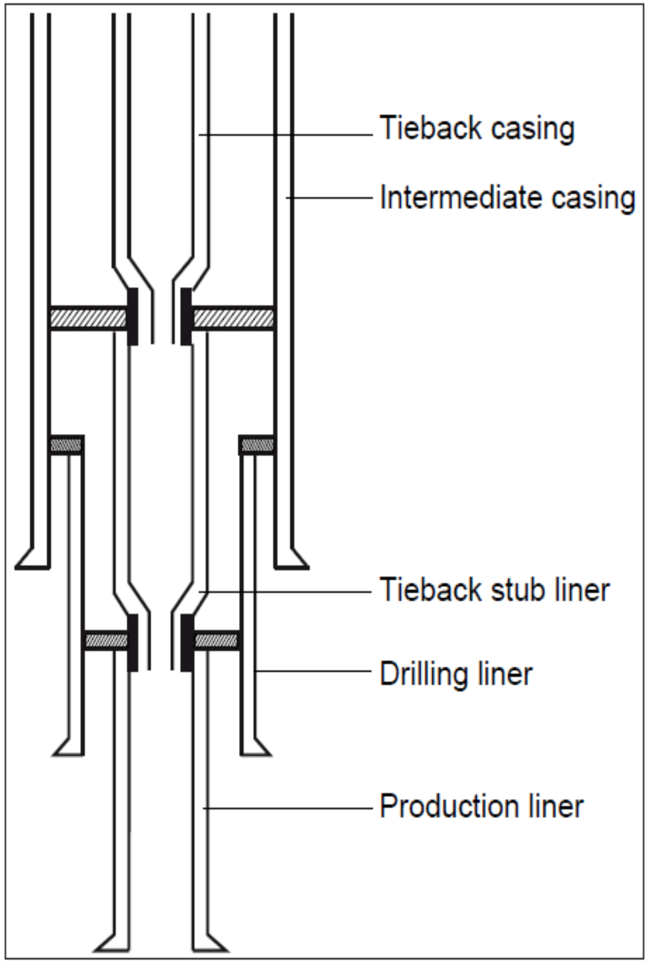
Purpose:

- Isolates the pay zone from other formations and the fluids in them.
- Protective housing for production equipment.
  - Subsurface artificial lift
  - Multiple zone completion
  - Screens for sand control

A liner is casing that does not go to the top of the well (savings in steel, lower friction pressure drop…)

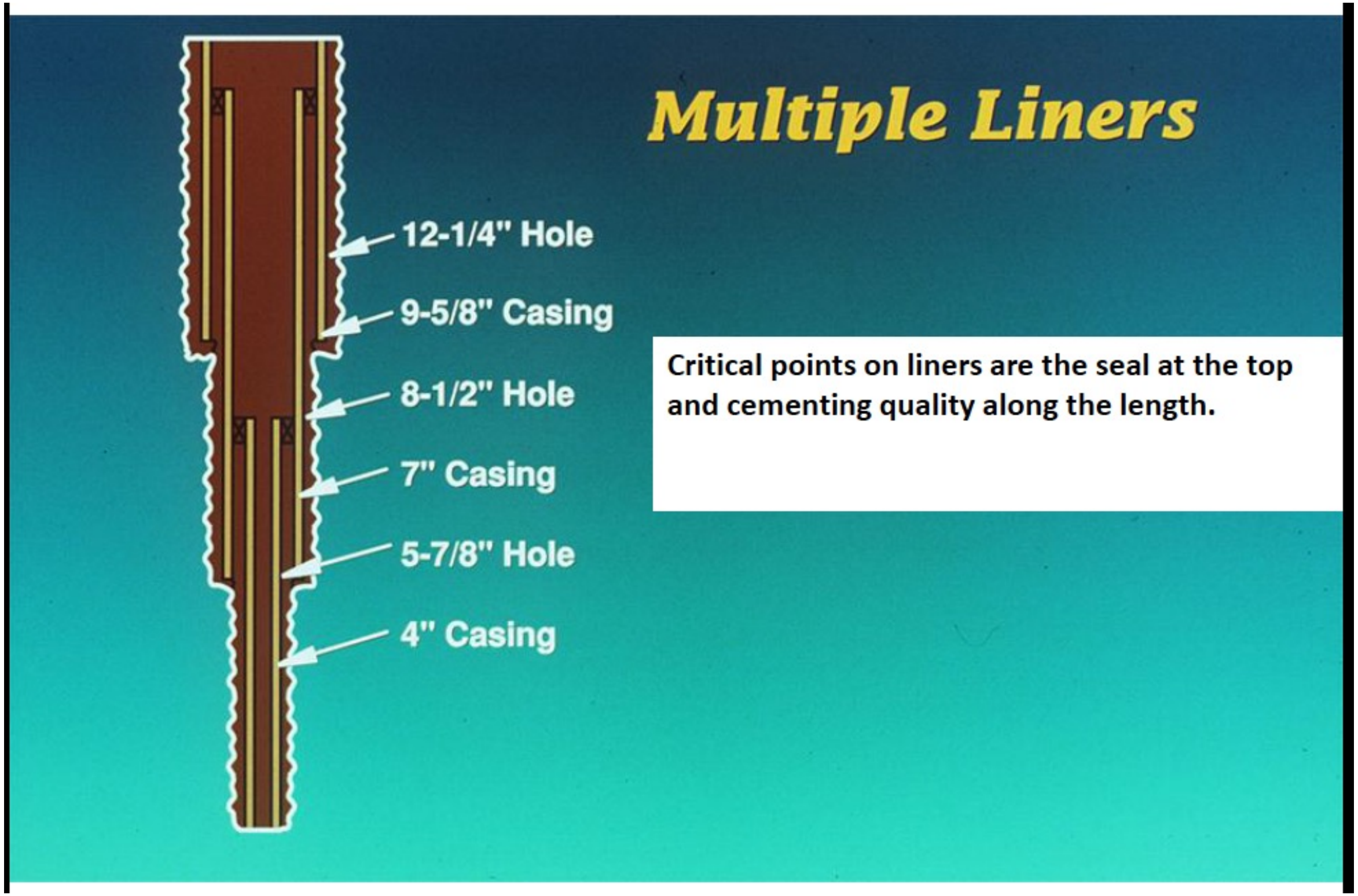
Common sizes:
4 ½", 5", 7", 9 5/8"

Tie-Back Casing



Purpose:

- Tie-back casing is normally used during production to repair damaged casing above a liner.
- Tie-back casing is also used for completions providing a housing to the completion equipment (upper/lower completion tie-backs, as in some Deepwater wells).

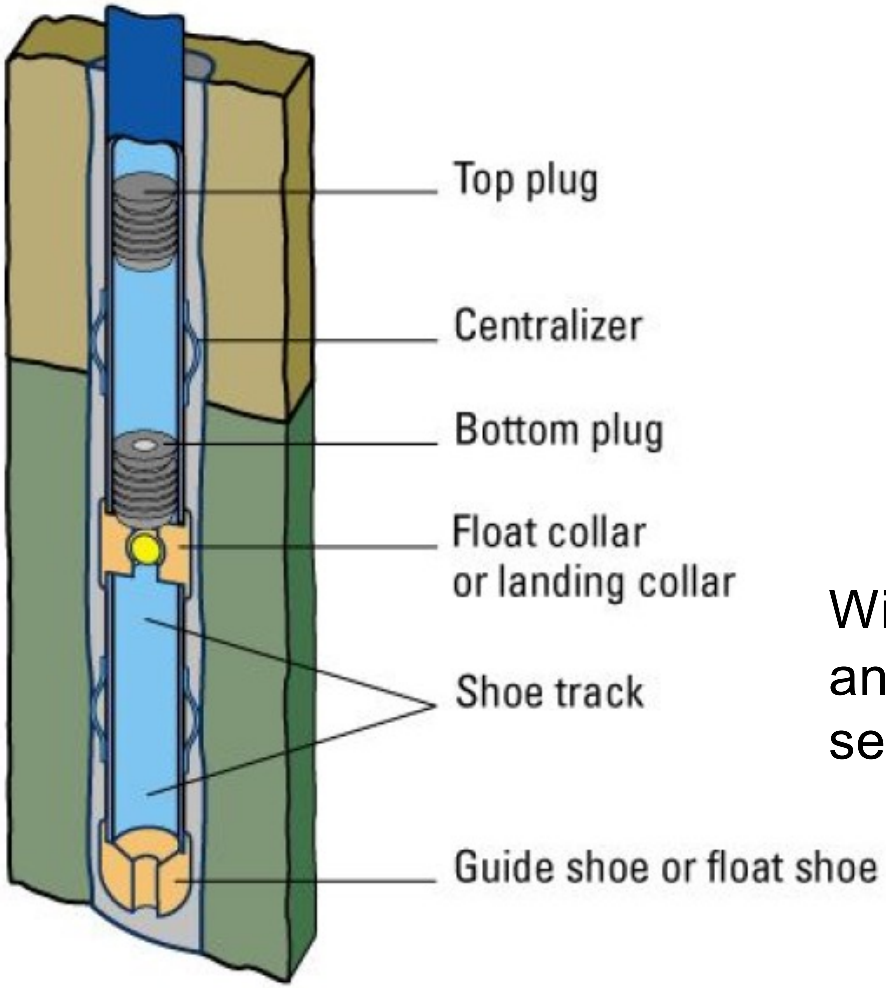


Critical points on liners are the seal at the top and cementing quality along the length.

Casing set points & design

- Casing are set almost always in shale formation in order to avoid fluid influx at the shoe during cement setting
- Overall architecture is made to ensure good zonal isolation & safe operation
- Casing are designed w.r. tension, burst, collapse, compression, corrosion, abrasion, acid resistance
- … loads vary during casing setting, drilling operations, well completion, production

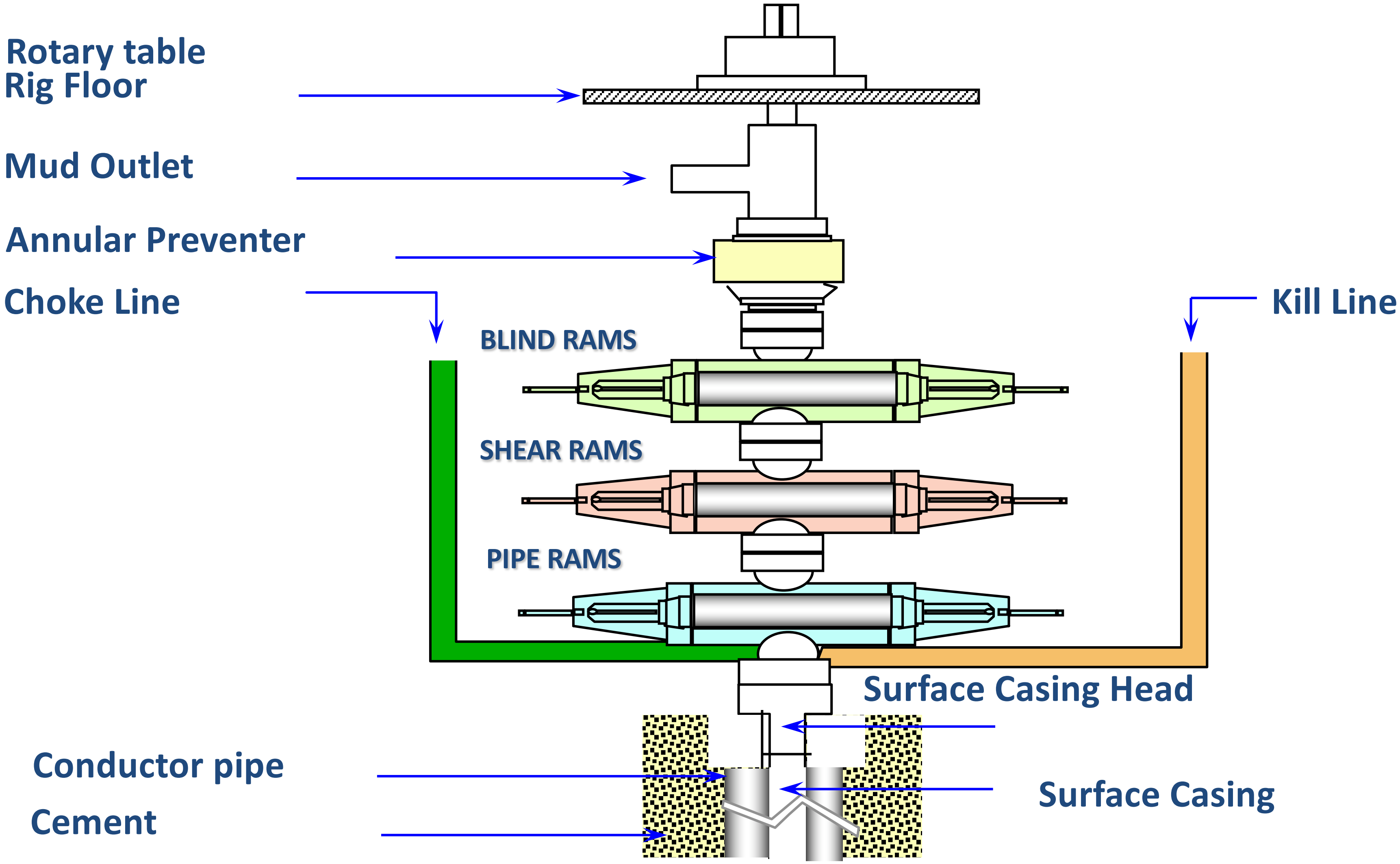
Casing shoe



Will be cemented inside (1 or more casing length) and then drilled if the well continues with another section

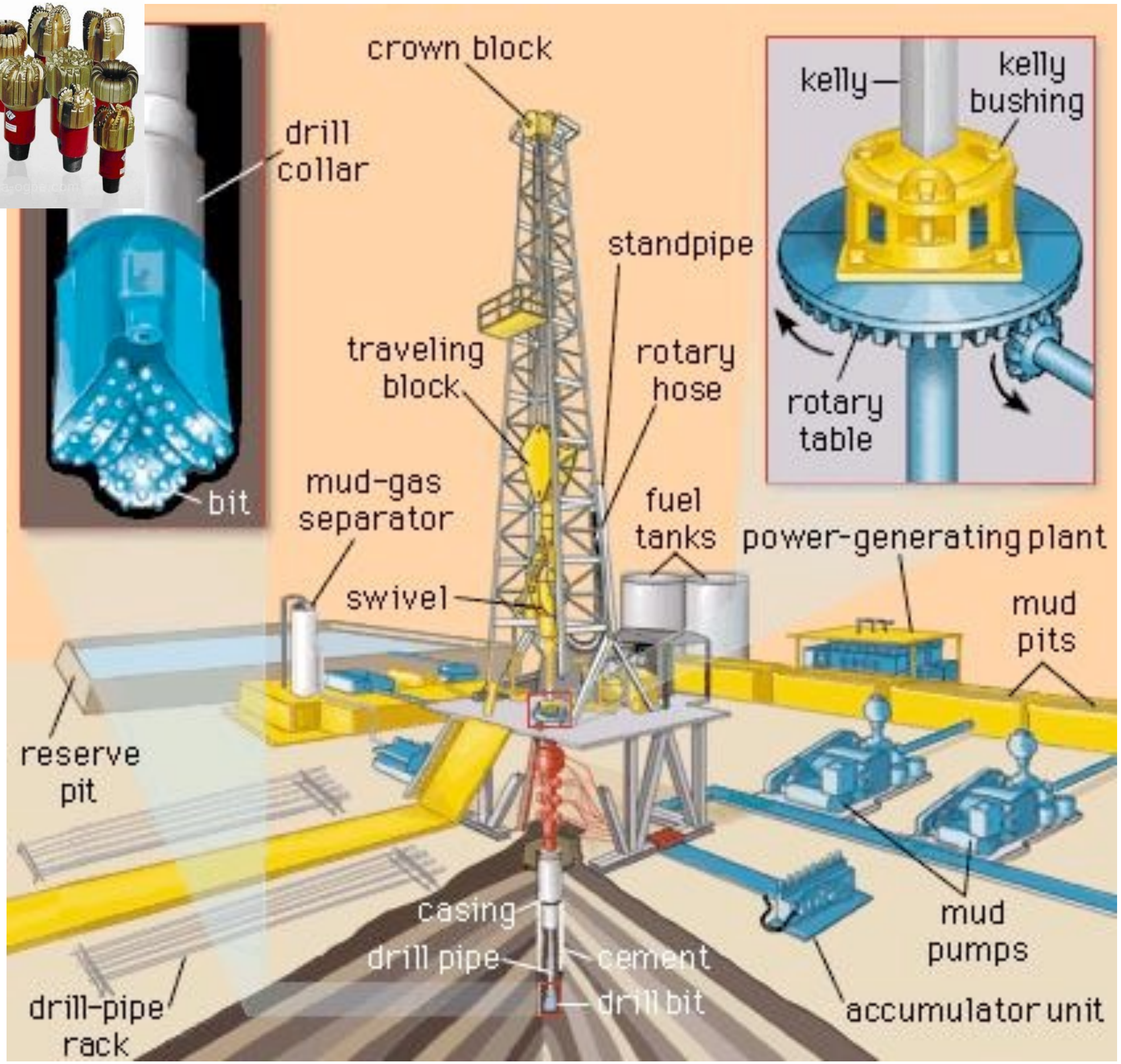
May have another float valve

The BOP Stack



DRILLING

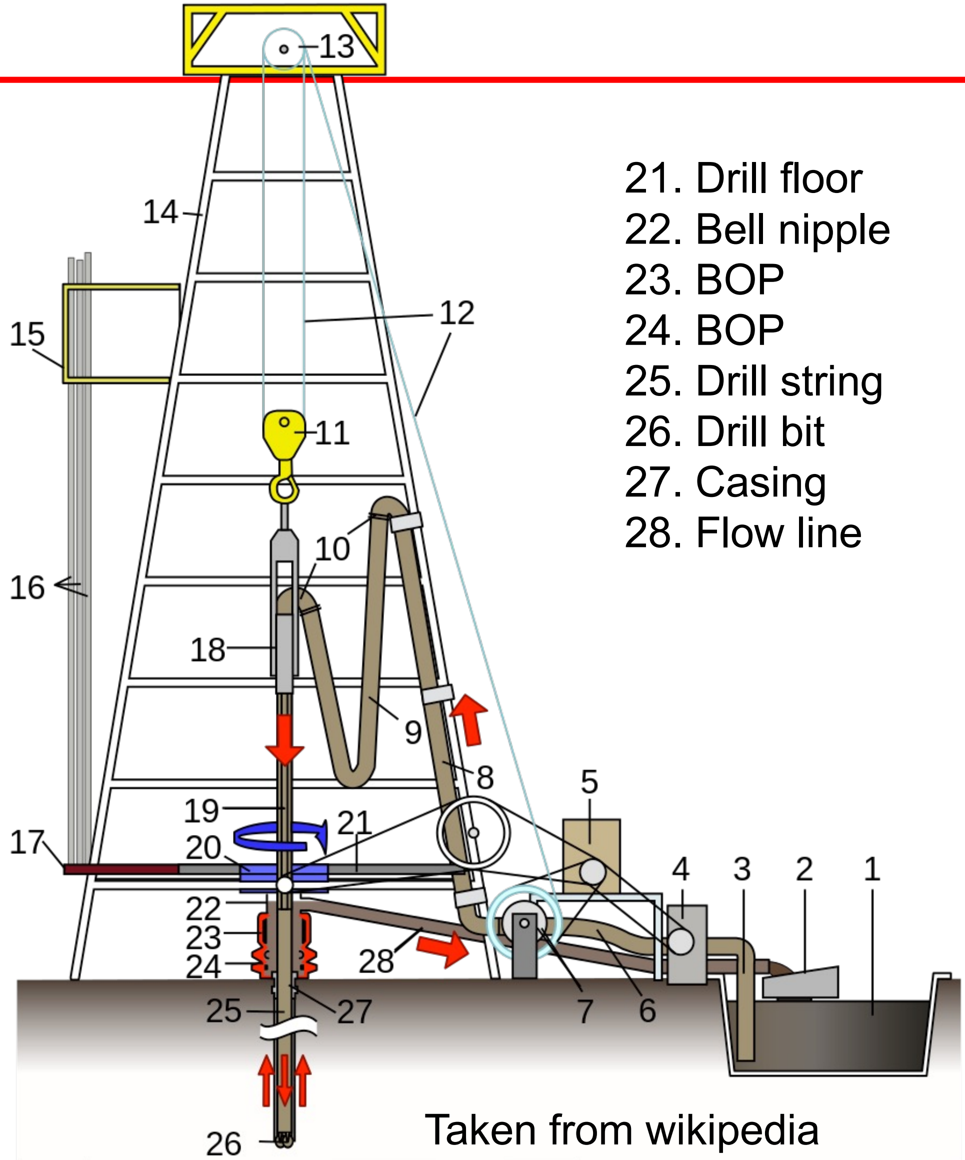
Rotary drilling



- Drilling by section(s)
  - Bit sizes
- Continuous mud circulation
  - To remove “cuttings”
  - To keep the well stable
- Strings connection
  - Every 30ft
  - 90ft with top drive
- Control
  - Weight on bit (hook)
  - Rotation
  - Mud type & ECD …

Rig components

1. Mud tank
2. Shale shaker
3. Suction line
4. Mud pump
5. Motor
6. Hose
7. Draw-works
8. Stand-pipe
9. Kelly hose
10. Goose neck
11. Travelling block
12. Drill line
13. Crown block
14. Derrick
15. Racking board (monkey board)
16. Stand of drill pipes
17. Setback floor
18. Swivel (top drive)
19. Kelly drive
20. Rotary table



21. Drill floor
22. Bell nipple
23. BOP
24. BOP
25. Drill string
26. Drill bit
27. Casing
28. Flow line

Kelly, kelly bushing & rotary table

- Kelly: square or hexagonal cross section, drilled inside to allow fluid to flow. Transmit rotary motion from the rotary table/kelly bushing while allowing the drill string to move vertically (it is screwed to the drill string).
- Kelly goes through the kelly bushing (serves to connect the kelly to the rotary table while allowing the kelly to move vertically).

Connecting pipes / tripping pipes

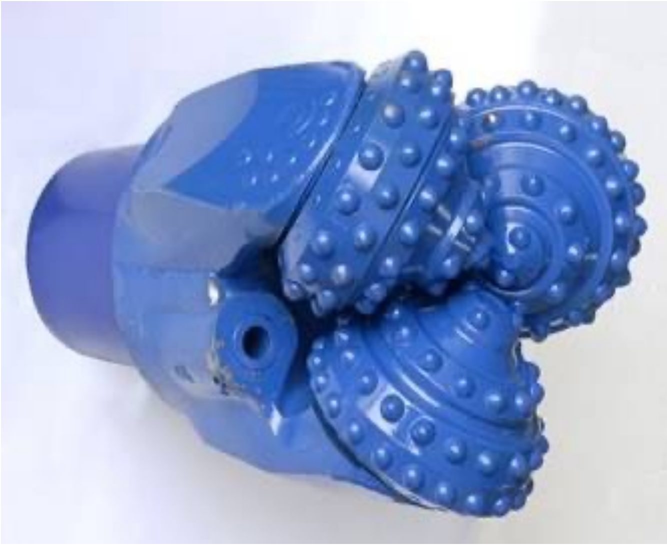
Easier to grasp with videos

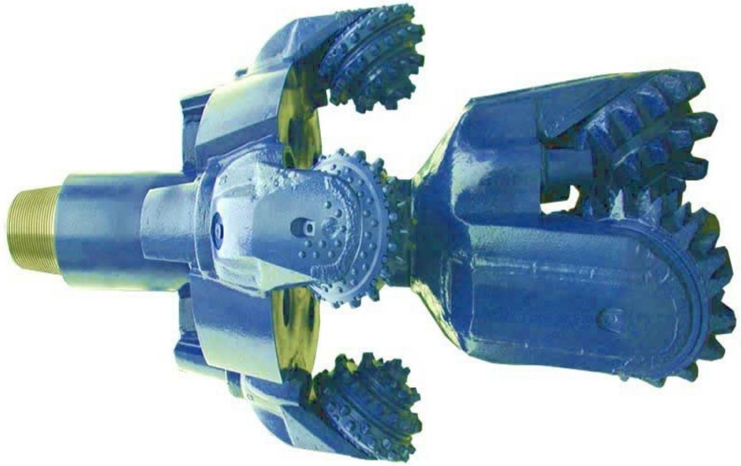
- Drill pipe connection: https://www.youtube.com/watch?v=KZxUiFFVEAQ
- Faster https://www.youtube.com/watch?v=aqLALzUft8Y
- Pipe tripping: https://www.youtube.com/watch?v=WqsGhbnR77I
- Pipe connection viewed from the top https://www.youtube.com/watch?v=1EHPfvxavtw

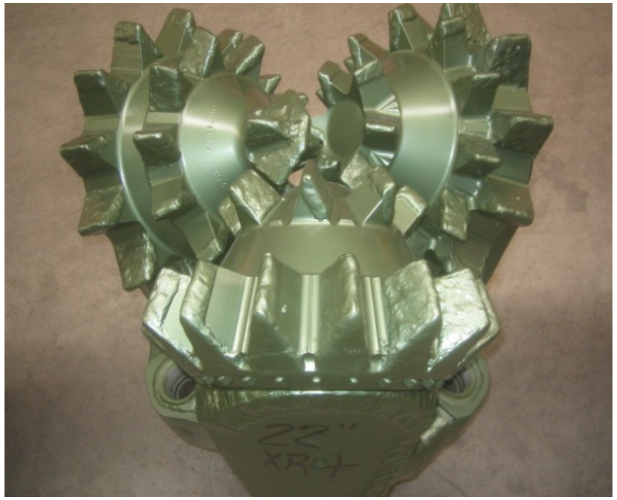
Top drive

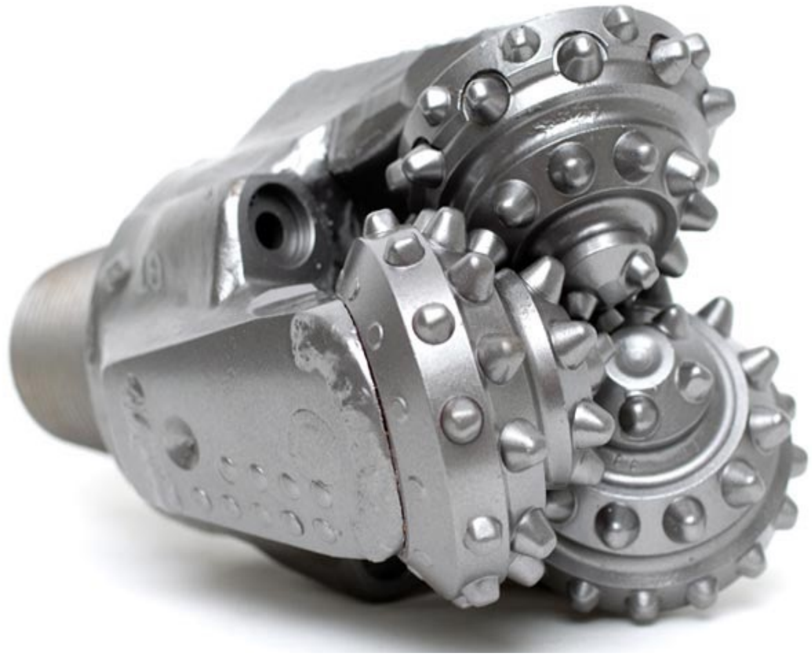
- Replacement of the rotary table
- Consists of 1 or more motor connected with appropriate gear to a short section of drill pipe.
- The top-drive is suspended from the hook such that the rotary mechanism is free to go up & down.
- Allow to minimize drill pipe connection and thus gain time (no kelly length)
- Allow rotation when tripping pipe (help avoiding stuck pipe)
- Most modern rigs are equipped with top drive

Tricone Drill Bits









PDC Drilling Bits

- Polycrystalline Diamond Compact

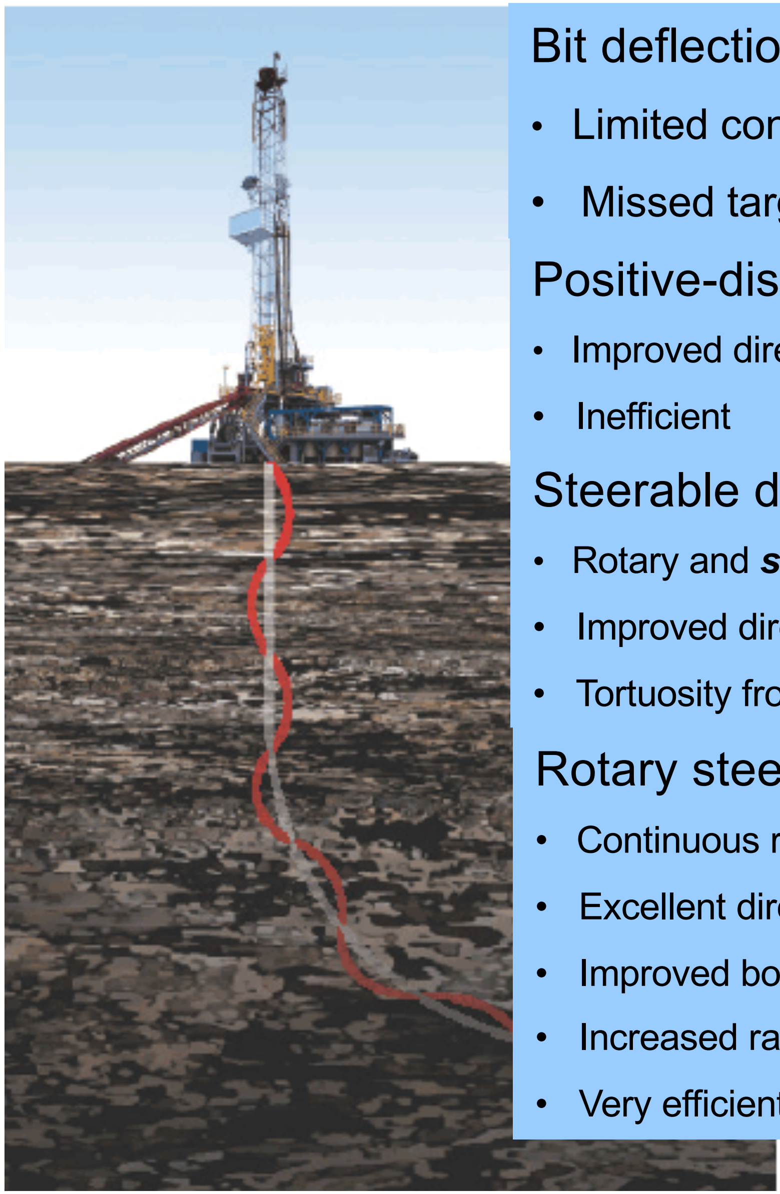
Sidetracks - whipstock

- Special gear (whipstock) allowing to sidetrack from an existing well
- Comes in all kind
- Was also used in the old days to 'deviate' a well

Directional drilling

- Need to survey the well trajectory
- Need to be able to mechanically steer the bit
- Need to “see” where we want to go (i.e. image bed boundaries etc.): Logging while drilling (geophysical measurements)

You did what??????



Bit deflection using **whipstocks**

- Limited control
- Missed targets

Positive-displacement motor **PDM**

- Improved directional control
- Inefficient

Steerable drilling motor (mud motor)

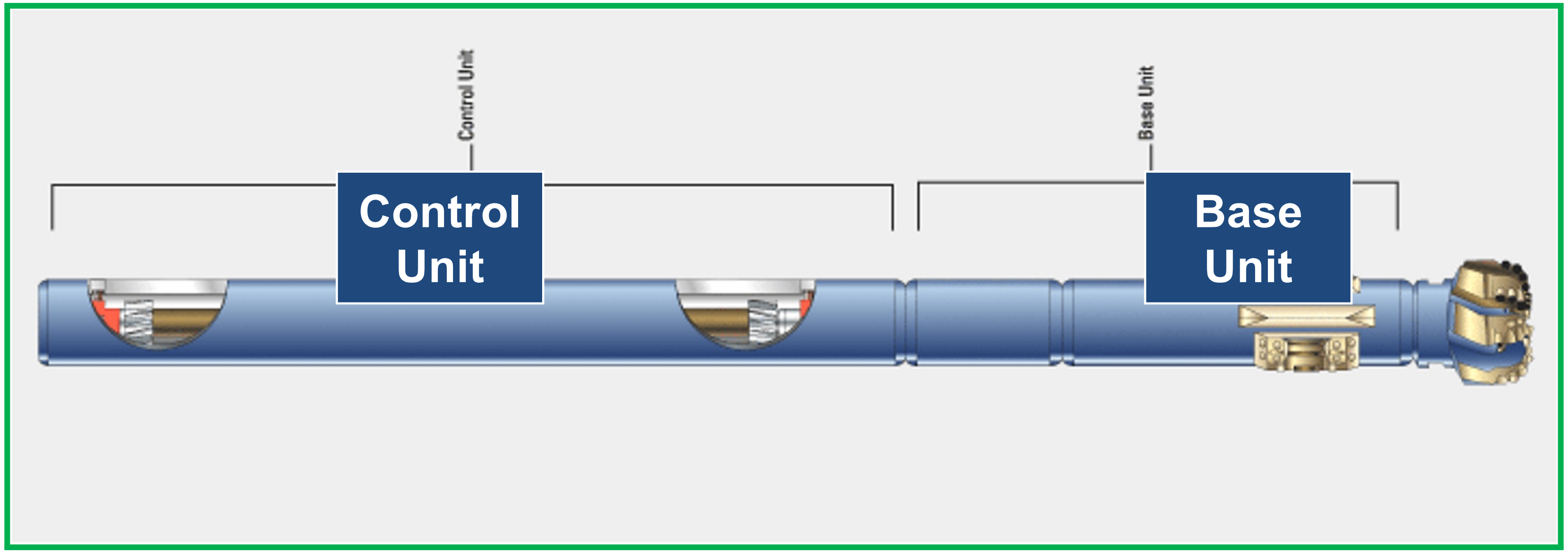
- Rotary and ***sliding*** modes controlled at surface
- Improved directional control
- Tortuosity from *slide* drilling limits horizontal reach

Rotary steerable system

- Continuous rotation
- Excellent directional control
- Improved borehole quality
- Increased rate of penetration
- Very efficient (but costly)

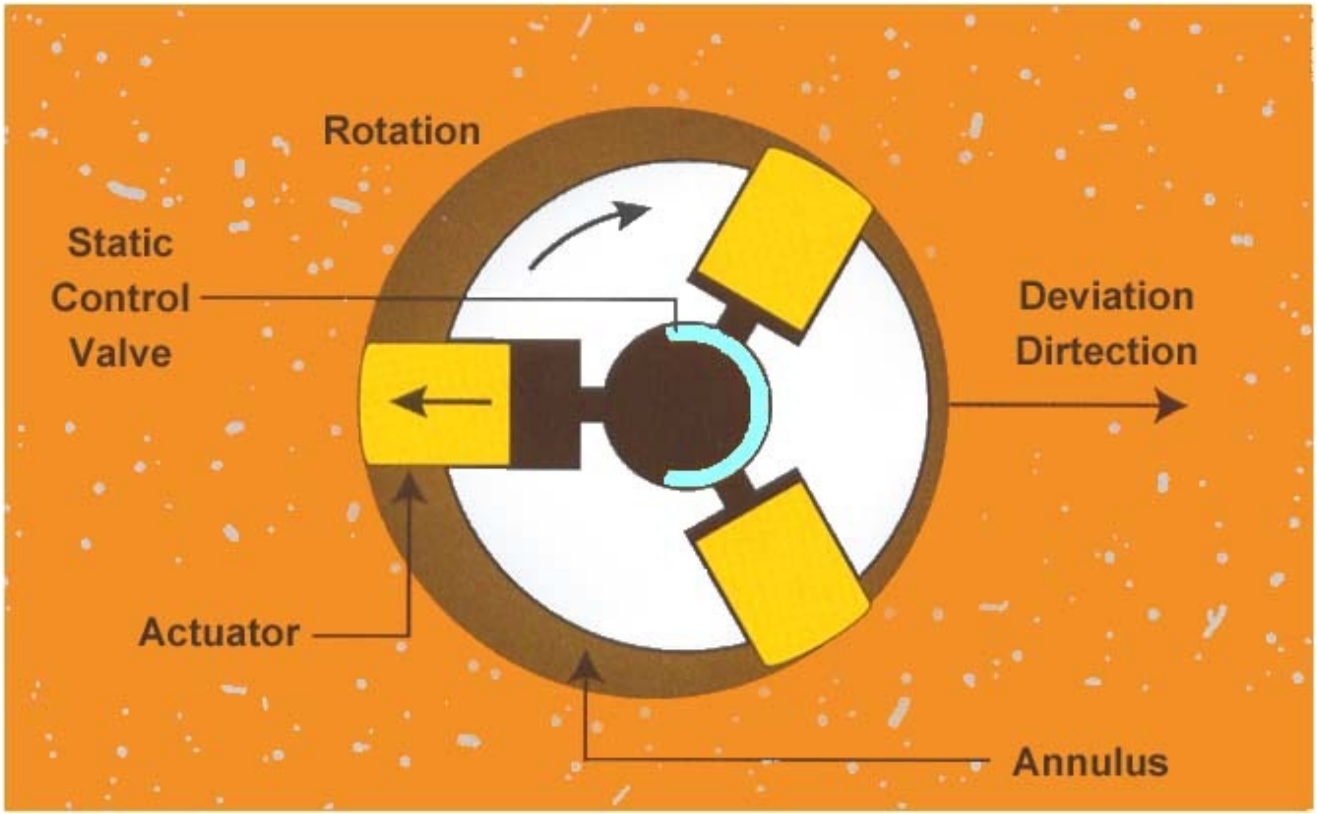
Methods of Deflection

Schlumberger Rotary Steerable Assembly

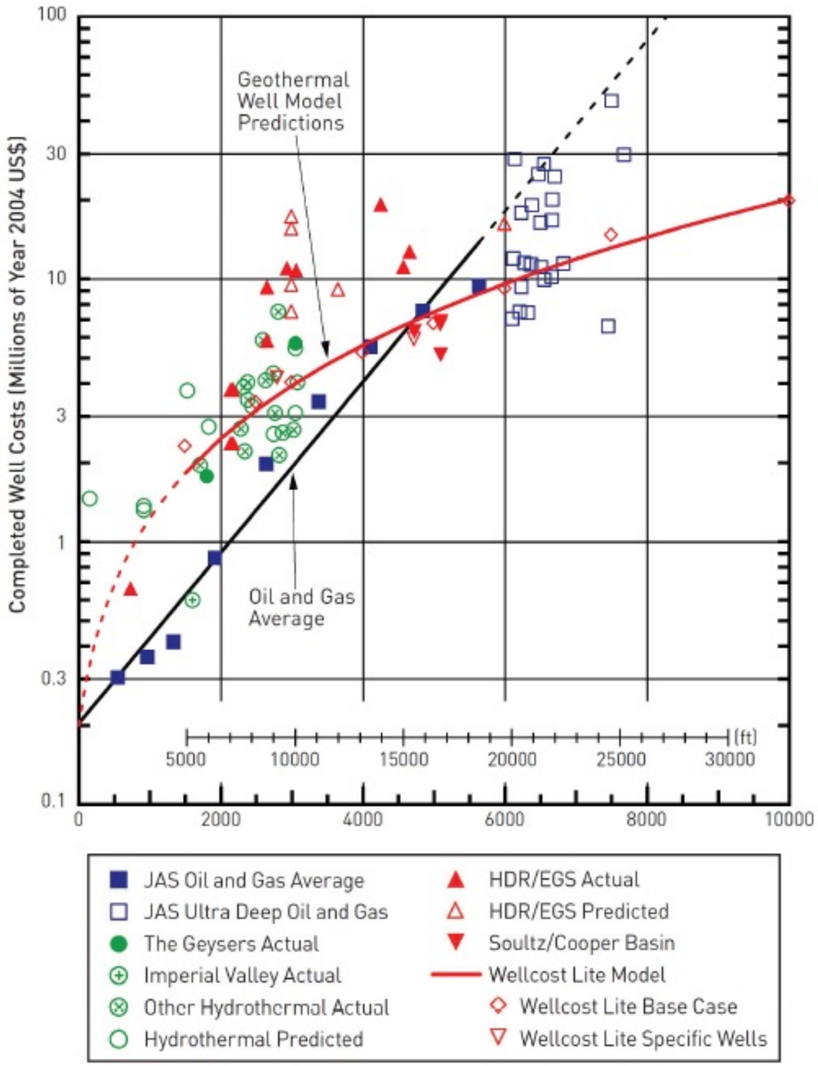


Methods of Deflection

Schlumberger rotary steerable system has pistons near the bit that push against the side of the hole



Drilling costs – onshore wells



[Tester 2007]

What is MWD?

Measurement While Drilling (MWD) systems measure formation properties (e.g. resistivity, natural gamma ray, porosity), wellbore geometry (inclination, azimuth), drilling system orientation (tool face), and mechanical properties of the drilling process.

MWD vs LWD

Logging while drilling (LWD) is closely related to **MWD**.

LWD provides formation measurements, while **MWD**

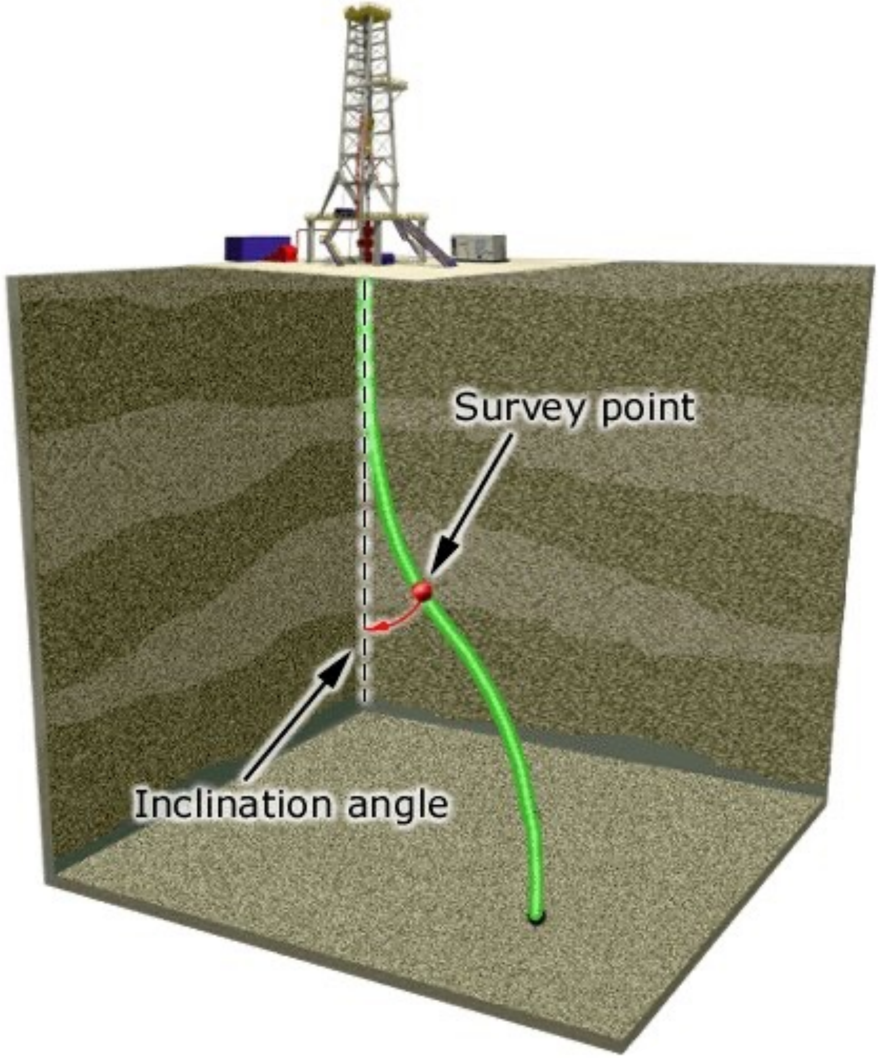
provides drilling mechanics and survey measurements.

MWD
- Inclination, azimuth, tool face
- Rotational speed of the drill string
- Smoothness of that rotation
- Type and severity of
  any vibration downhole
- Downhole temperature
- Torque and weight on bit
- Mud flow volume

LWD
- density
- porosity
- resistivity
- acoustic-caliper
- inclination at the drill bit (NBI)
- magnetic resonance
- formation pressure

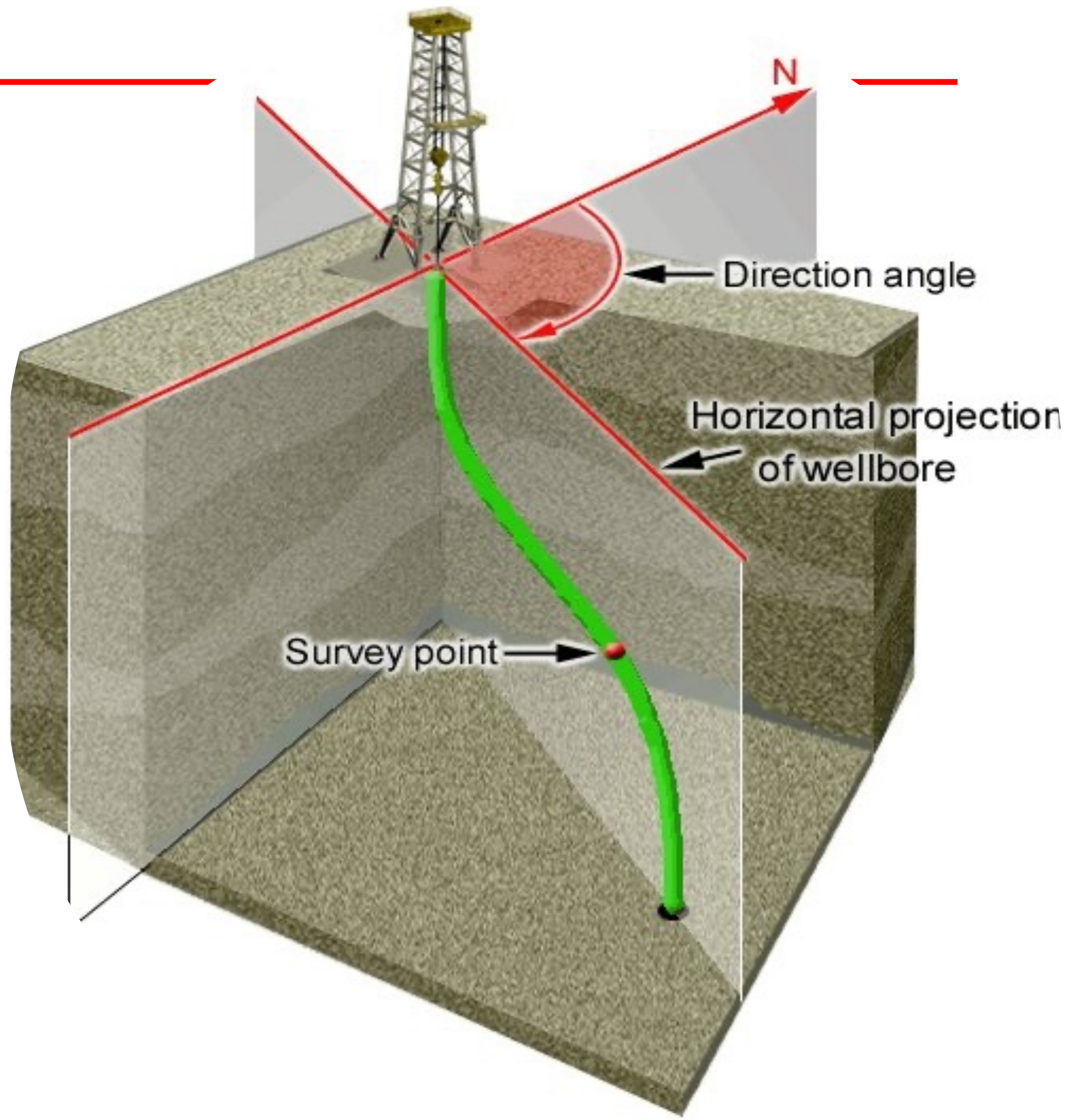
Inclination

- Inclination is the angle between a vertical line and the path of the well bore at that point.
- An inclination of 0° is a vertical hole.
- An inclination of 90° is a horizontal hole.

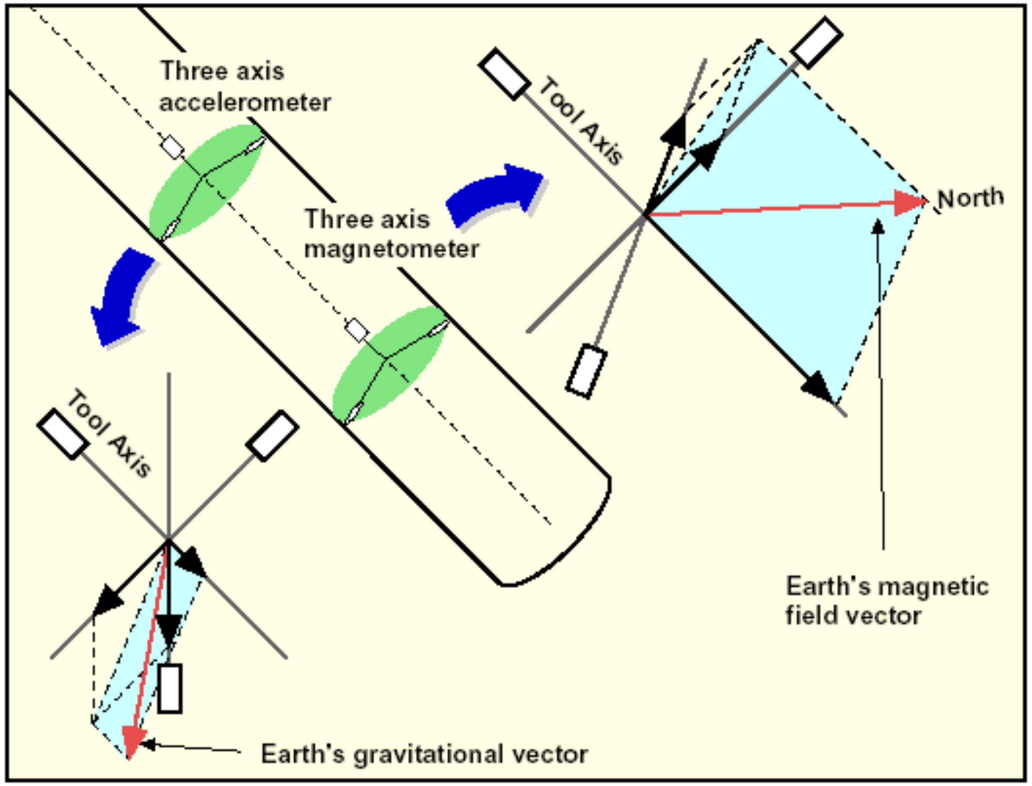


Azimuth

- Azimuth is the angle between North Reference and a horizontal projection of the current Survey position.
- A hole drilled due North has an azimuth of 0°.

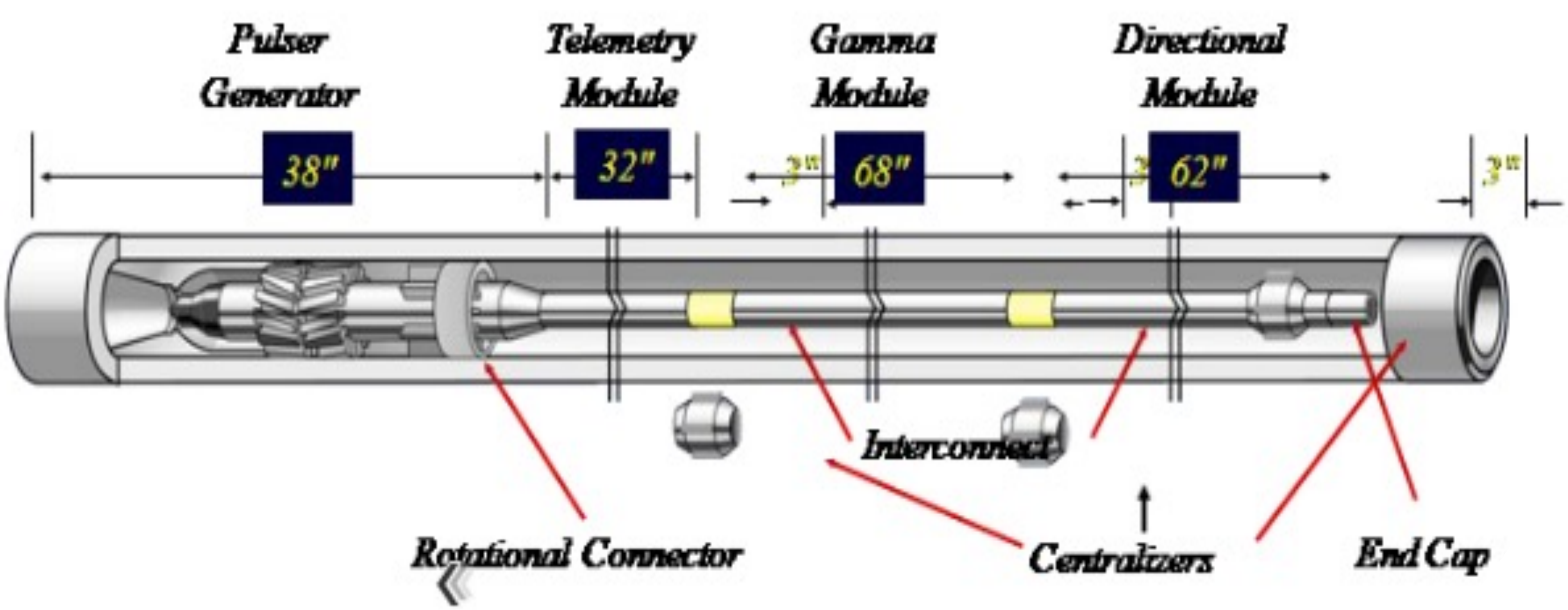


Directional Sensors



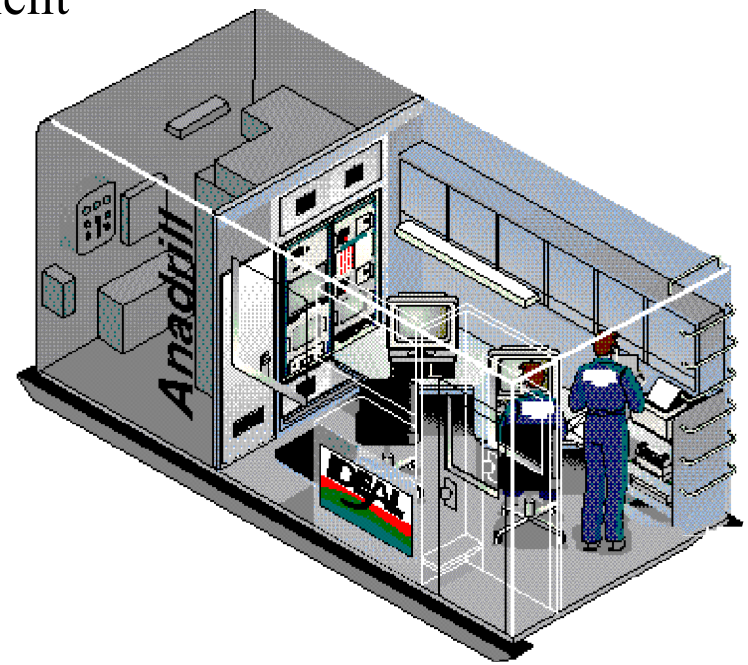
- The sensors used in steering tools and MWD/LWD tools are solid-state electronic devices known as magnetometers and accelerometers which respond to the earth's magnetic field and gravitational field respectively.

The MWD downhole tools



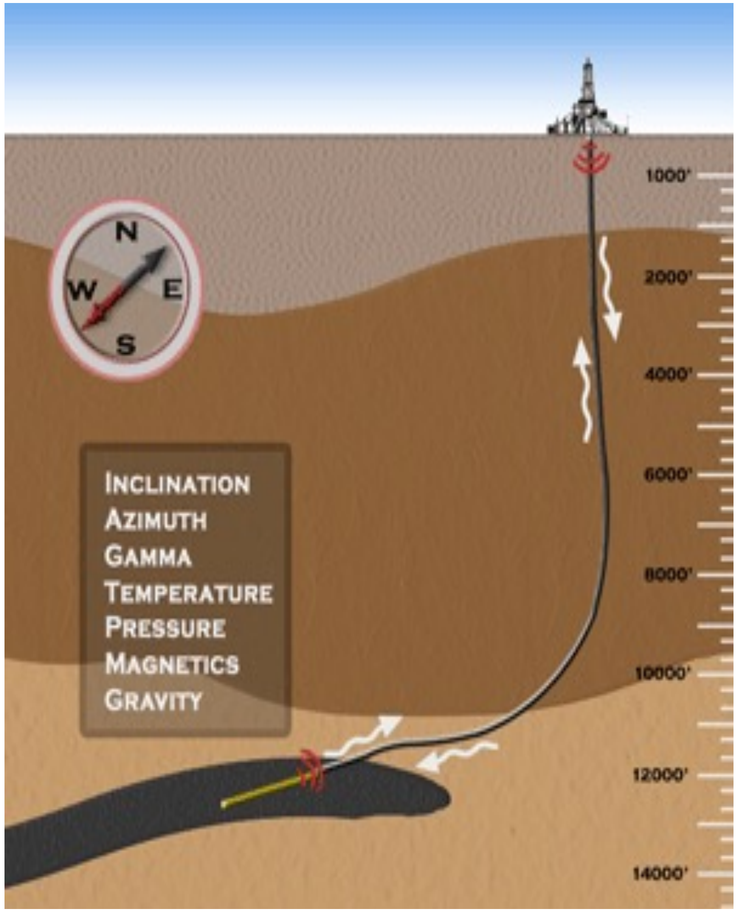
The MWD Surface System

- Surface sensors for measuring surface drilling parameters, as well as the well's depth.
- A transducer at the surface to receive the measurement signals from the MWD tool.
- A computer for decoding downhole data at the surface.
- A computer for processing, storing, and using all of the data.

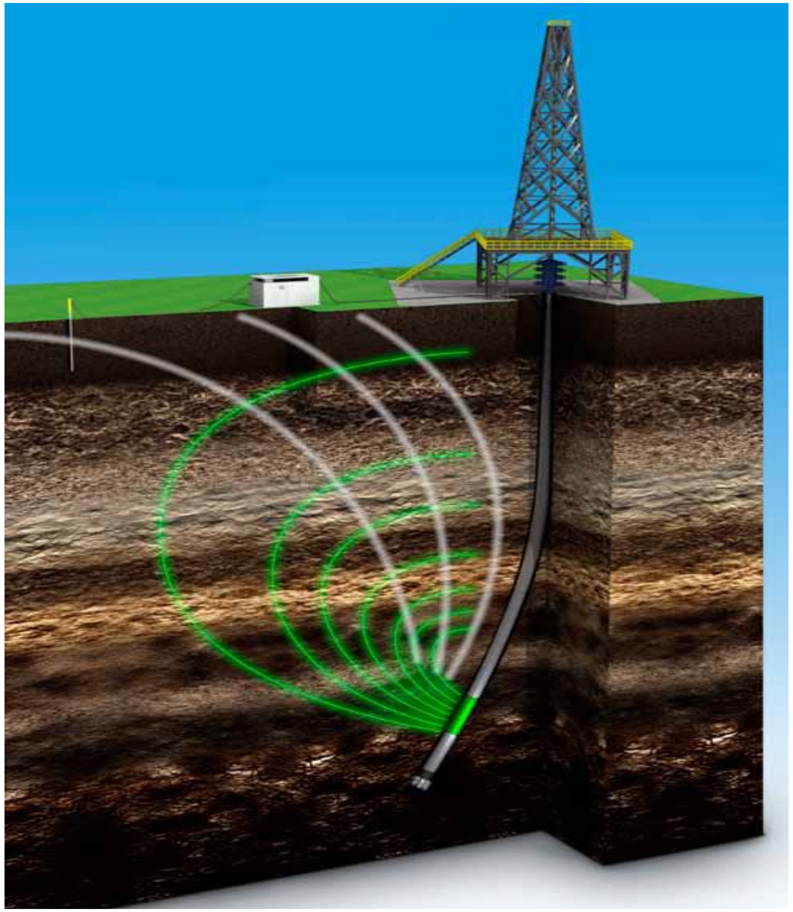


How the Data is Transferred

Mud Pulse Telemetry



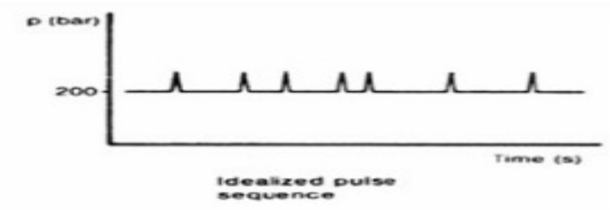
Electromagnetic Telemetry



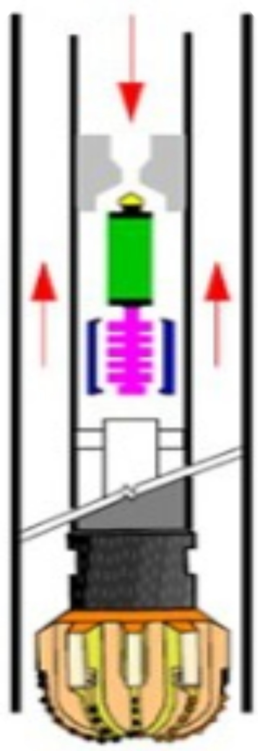
Mud Pulse Telemetry

Positive Mud Pulse Telemetry

- Positive mud pulse telemetry (MPT) uses hydraulic poppet valve to momentarily restrict mud flow through an orifice to generate increase in the pressure in form of positive pulse which travel back to the surface to be detected .



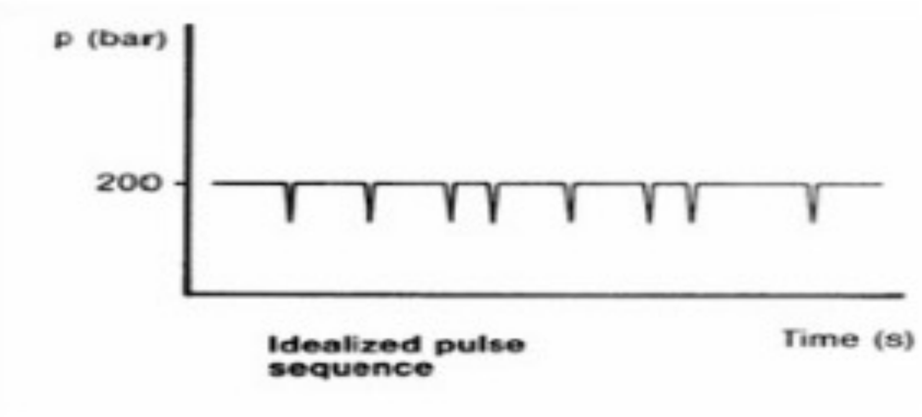
30bit/s !



Mud Pulse Telemetry

Negative Mud Pulse Telemetry

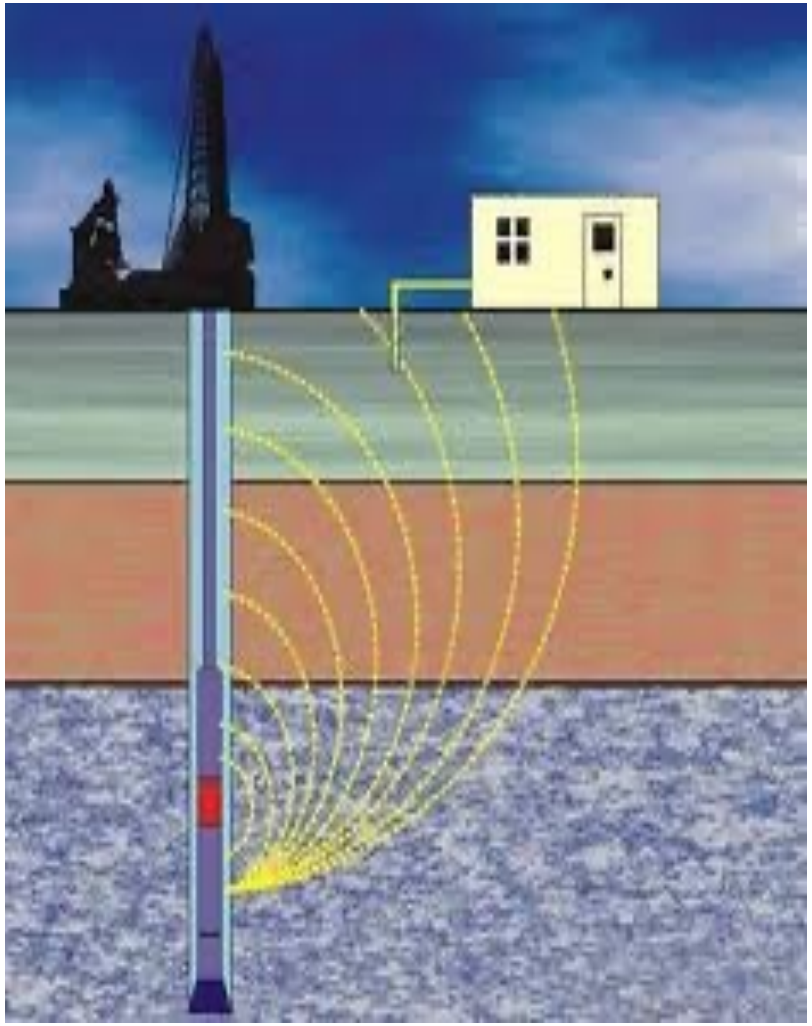
- Negative MPT uses a controlled valve to vent mud momentarily from the interior of the tool into the annulus .
- This process generates a decrease in the pressure in the form of a negative pulse which travels back to the surface .



30bit/s !

Electromagnetic Telemetry

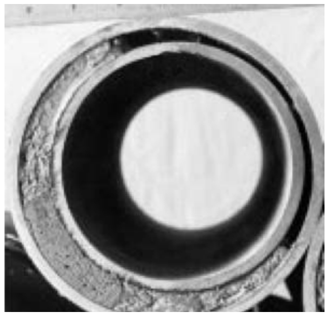
- The EM does not use the drilling mud to send pressure waves.
- The tool sends either a magnetic pulse or electrical current through the ground to the surface.
- On the surface the data is received through ground antennas and the data is processed.
- EM systems are significantly faster (10x) than conventional mud pulse
- Depth limitations (which are a function of how much power can be supplied by batteries for the duration of the drilling interval), + usual EM interferences

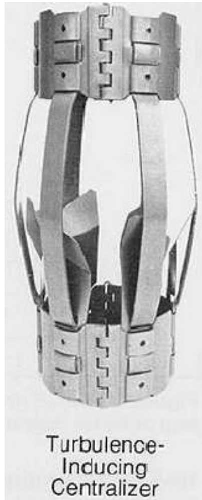


CEMENTING

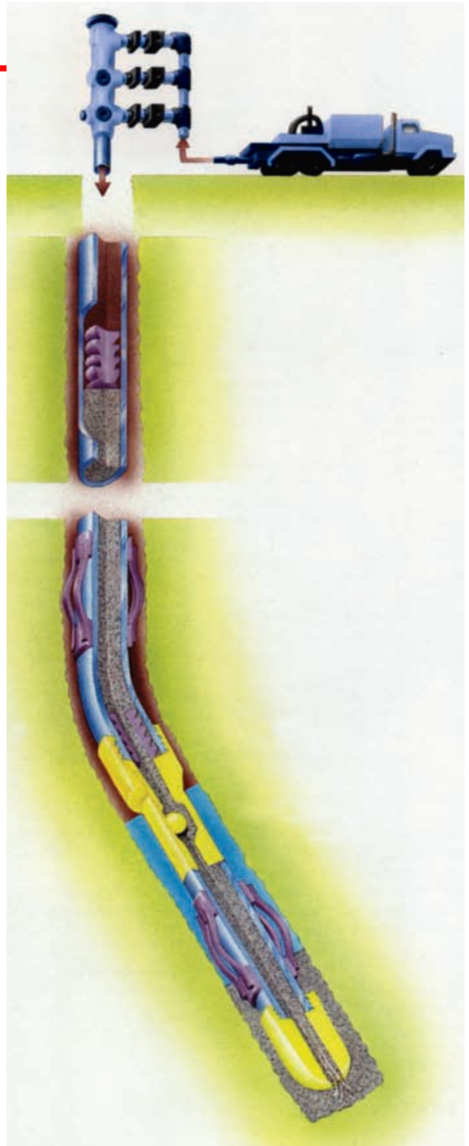
Cementing

- Crucial to ensure
  - zonal isolation between geological layers & avoid ‘pollution’
  - Control over-pressurized zones
- U-tube cementing
  - Lower & centralize casings
  - Pump: washer, spacer, cement slurries
  - Design: volume, chemistry etc.





Basic Cementing Process



Most primary cement jobs the basic process for accomplishing a primary cementing job consist of:

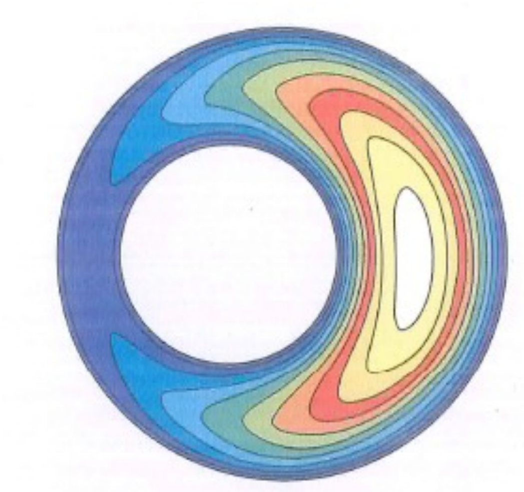
- Use the two-plugs method for pumping and displacement cement slurry down through the casing and up the annulus.
- Process is completed when a pressure increase at the surface and displacement is terminated.
- Leave the well shut in for a time to allow the cement to harden before completion work or drilling out.

Data Required for Initial Design

- Casing (size, type, depth, hardware, previous casing)
- Lithology, depths, problem zones (losses, washouts, water flow, gas migration, salt formation, etc.)
- Open hole geometry (caliper, excess, depths, etc.)
- Survey (Kick Off Point, bearing, azimuth)
- Pore and fracture pressure
- Temperature
- Mud properties (density, type, etc.)

  and samples
- Require fill – TOC (Top of cement).

Importance of casing centralization



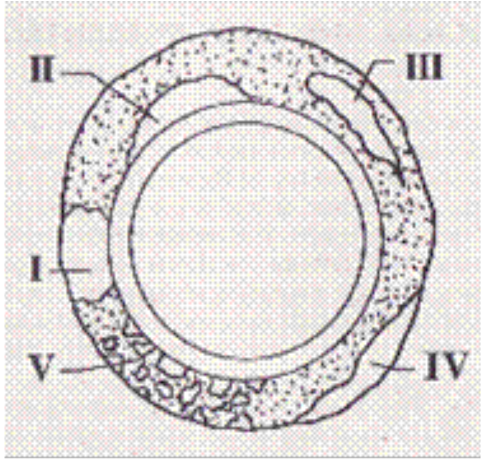
- Lack of casing centralization has a direct impact on cement placement
- It results in poor mud removal / poor cementing
- Casing rotation during cement placement & early setting -> helps mud removal & uniformity of placement

Required cement properties

- Pumpability
  - Viscosity
  - Density (w/c, hollow spheres, foam etc.)
- Stability / sedimentation / dehydration
- Setting / thickening time
  - Accelerators (Calcium chloride, Sodium chloride …)
  - Retarders (lignins, sugars…)
- Mechanical properties
  - Elastic, failure (w/c, Solid particles etc.)

Cement failure modes

- Cement placement
  - Fluid-fluid displacement (fluid dynamics)
  - "Mud Channels" are long, connected pocket of a fluid bypassed and left behind (I on drawing) [Mud channels minimized in new wells]
  - Scant evidence of "mud on the wall" at cement-formation interface (IV)
- Cement curing
  - Gas (and brine) migration → "chimneys" (**II**, I, III, IV)
- Thermal and mechanical stresses
  - Solid and fracture mechanics
  - "Microannuli" at casing-cement and cement-formation interfaces (II, IV)
  - Vertical (radial) cracks



J. Smolen, "Cased Hole and Production Log Evaluation" Penn Well 2004