Fundamentals of Onshore Drilling

Introduction to Onshore Drilling

presentation No. 1

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.
- ***World Oil´s Handbook of Horizontal Drilling and Completion Technology***. Gulf Publishing Company, Houston, Texas 1991, ISBN: 0-87201-361-8.
- ***A Primer of Oilwell Drilling***. Petroleum Extension Service, Houston, Texas 2001, ISBN: 0-88698-194-8.
- Robello, R. G.: ***Downhole Drilling Tools***. Gulf Publishing Company, Houston, Texas 2007, ISBN: 978-1-933762-13-5.

Fundamentals of Drilling

drilling means to make a hole in order to get access to the earth´s subsurface

Objectives may be

- gaining information about the subsurface from sampling/testing/logging
  => hole discarded
- production/injection of fluids/gases (oil/gas/water)
  => hole completed into well
- monitoring of subsurface properties (aquifer preassure, stress state, etc.)
  => hole completed into well

objectives define hole/well construction

Fields of Drilling Applications

Exploration/Production of Natural Resources

- Oil and Gas
- Water
- Geothermal Energy

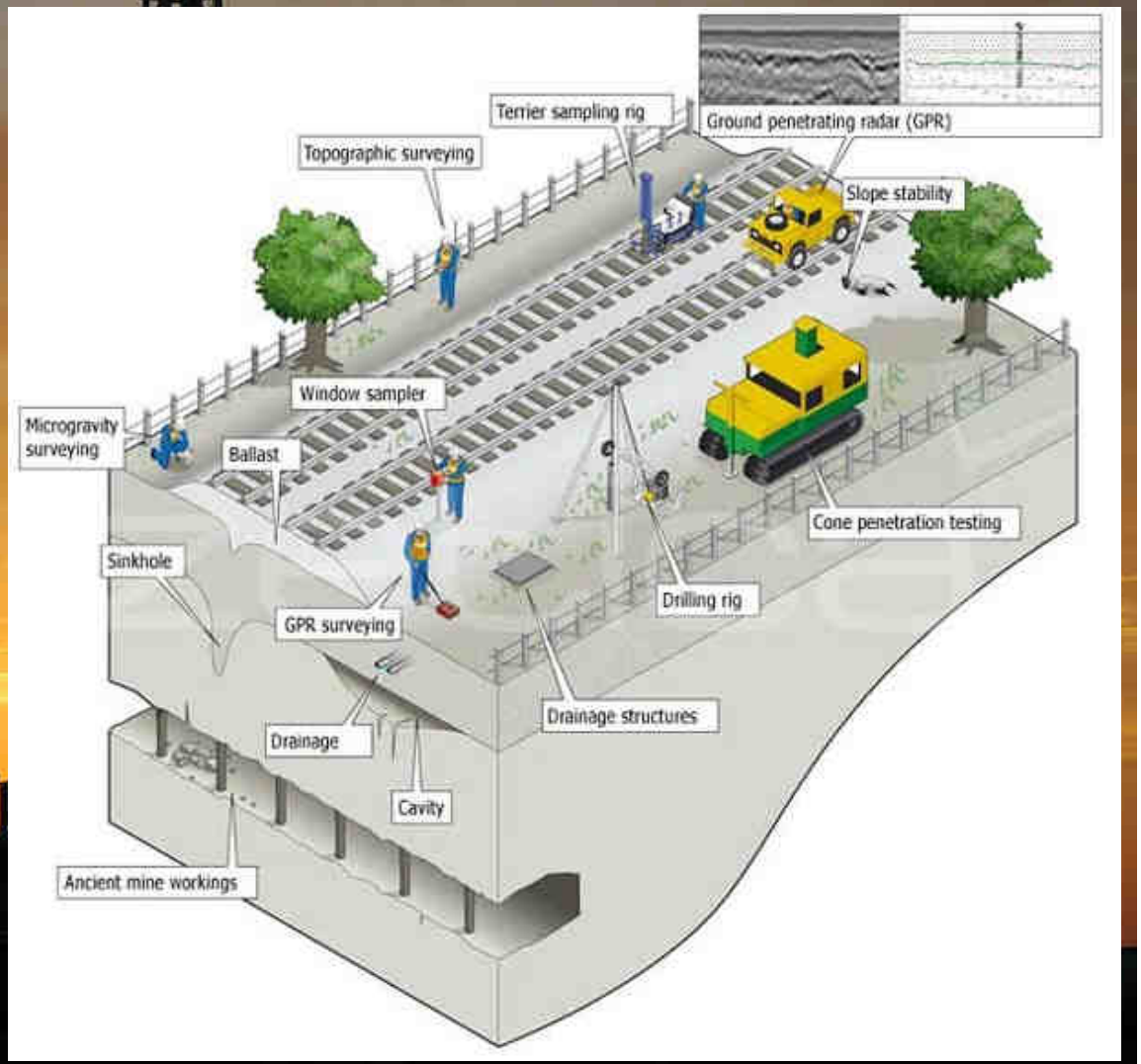
Site Investigation

- Scientific
- Foundation/Construction
- Environmental

Mining Exploration

Blast Hole/Seismic

- Quarry



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Mining Exploration

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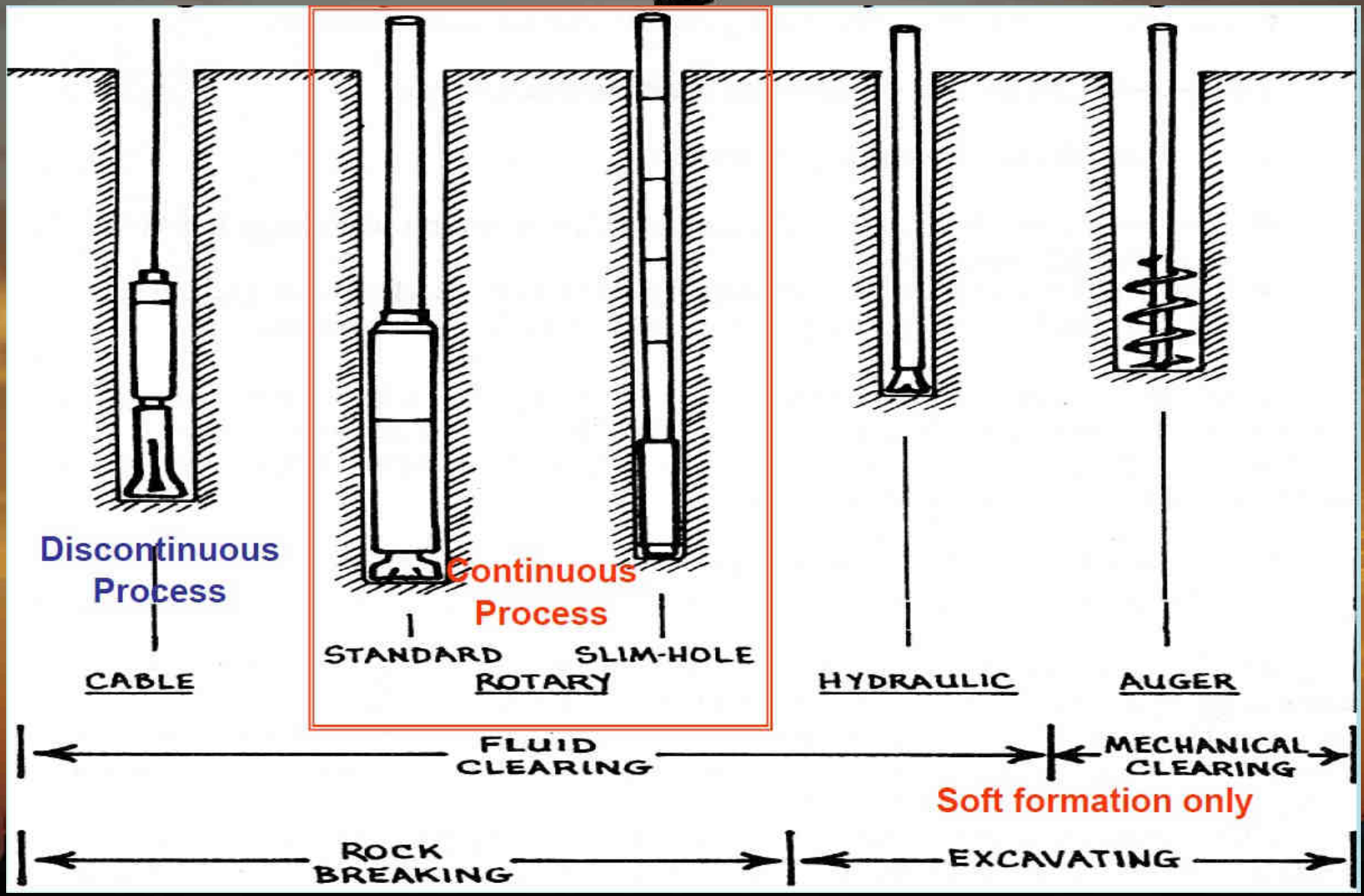
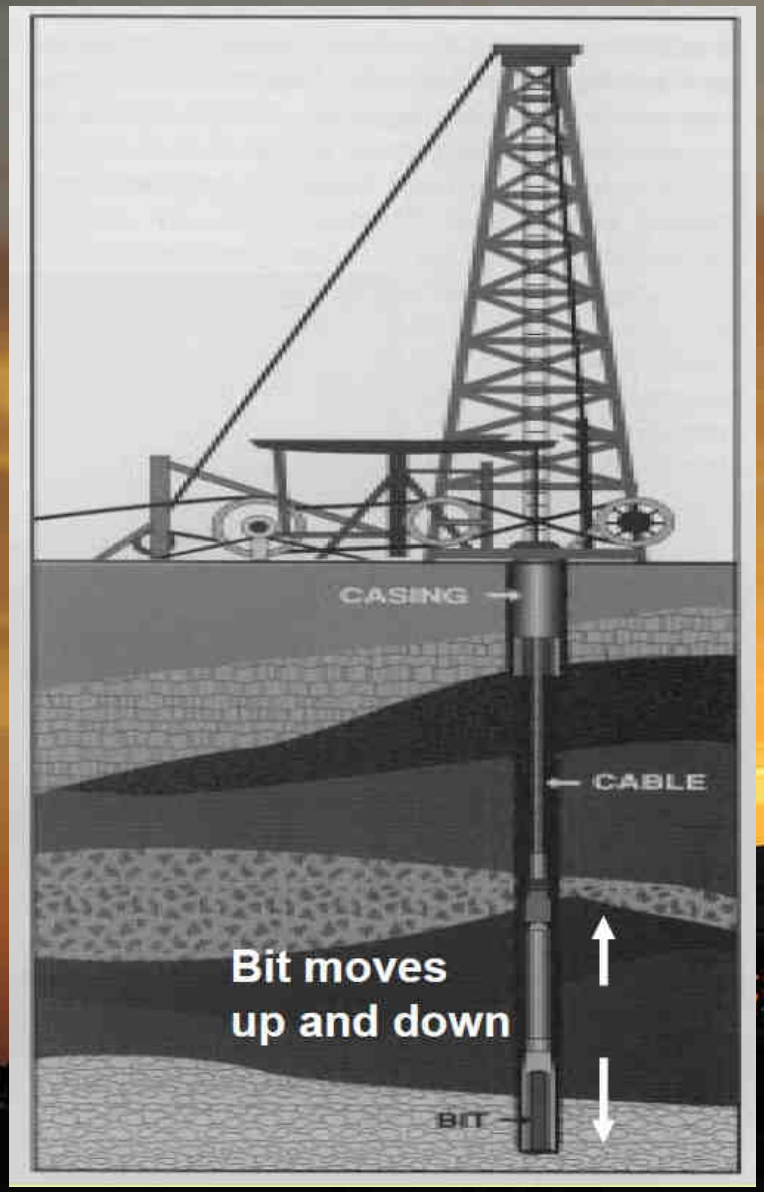
Drilling Techniques – Classification by Hole Making Methods



Principles of Drilling Techniques – Percussion Cabel Tool Drilling



very old drilling technique (applied more than 2000 years ago by the Chinese)

2 Phase Technique (discontinuous)

Phase 1: Rock Drilling
free falling bit strikes the bottom with a heavy blow – repeated lifting and dropping makes the bit drill

Phase 2: Removal of Cuttings
interruption of drilling to remove cuttings by bailing

- suitable only for hard rock
- total efficiency of drilling process is fairly low

Principles of Drilling Techniques – Percussion Cabel Tool Drilling

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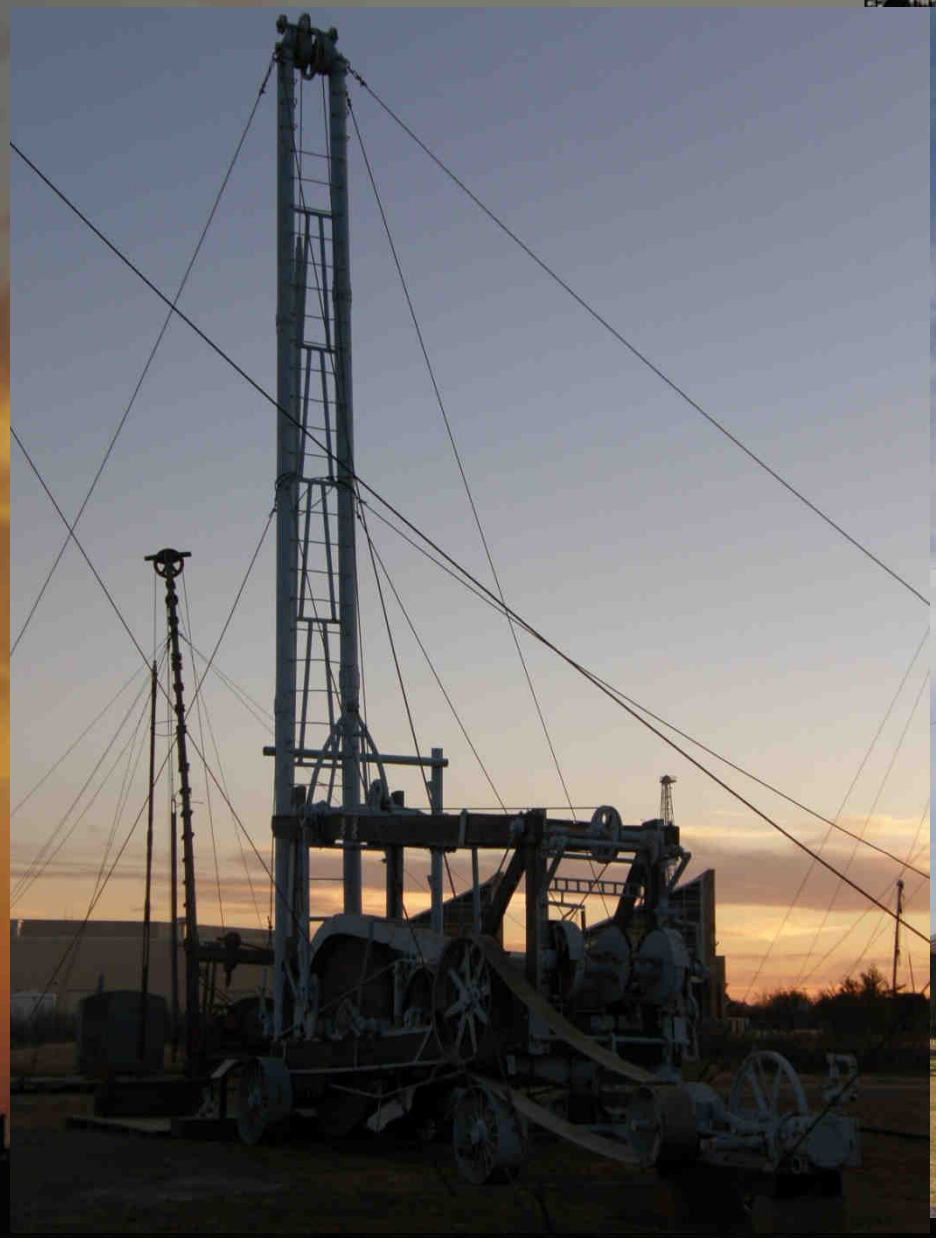
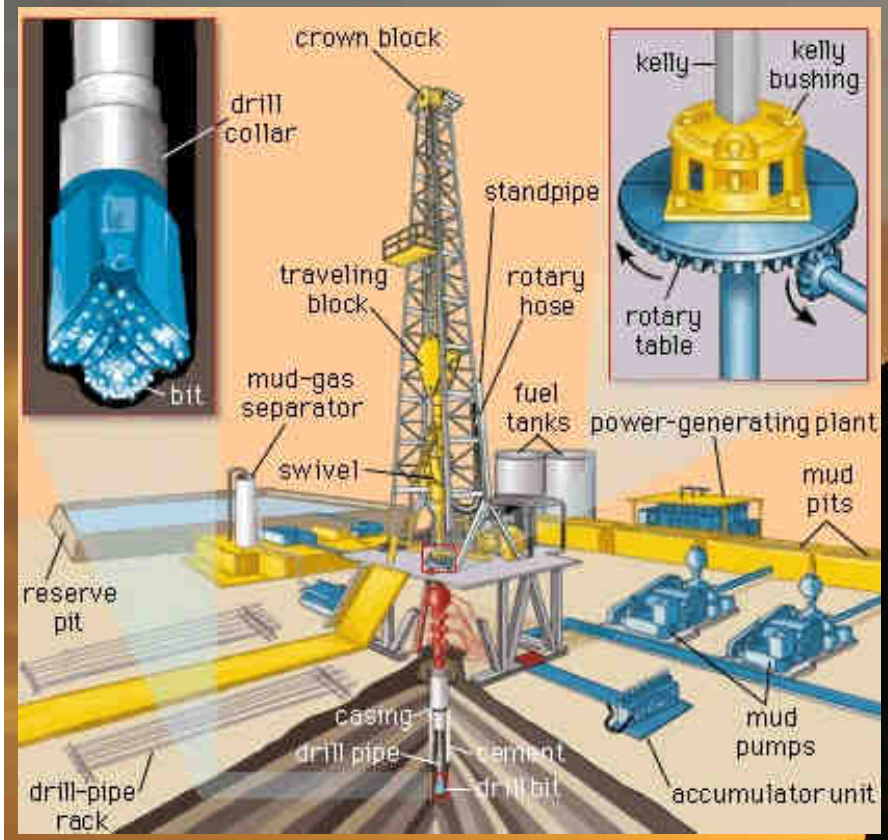


Principles of Drilling Techniques – Rotary Drilling



Drilling Fluid is circulated by being pumped down the **drill string**

The Drill String is rotated to turn the **bit**; it is fed down as the **bit** penetration

Bit is pushed into the bottom and rotation makes it cut

Return circulation carries cuttings up the annulus between the **drill string** and the wall of the hole

Key Elements:

- Drill Bit

-Drill String

- Drilling Fluid

Types of Rotary Bits

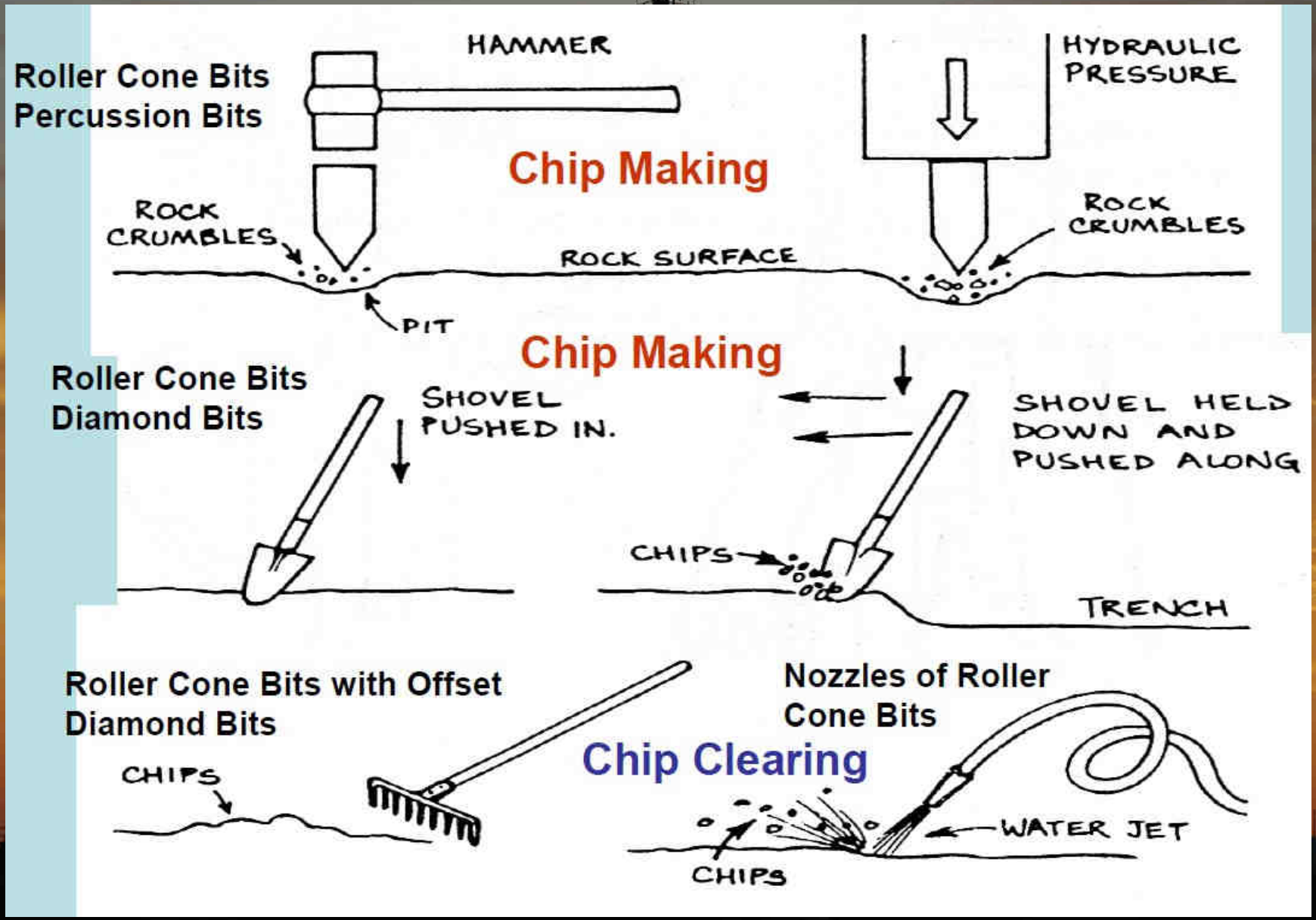
Performance Parameters of Drill Bits: Penetration Rate (Drilling Speed: m/h)
Bit Life (Meters Drilled)

Rock Characterization

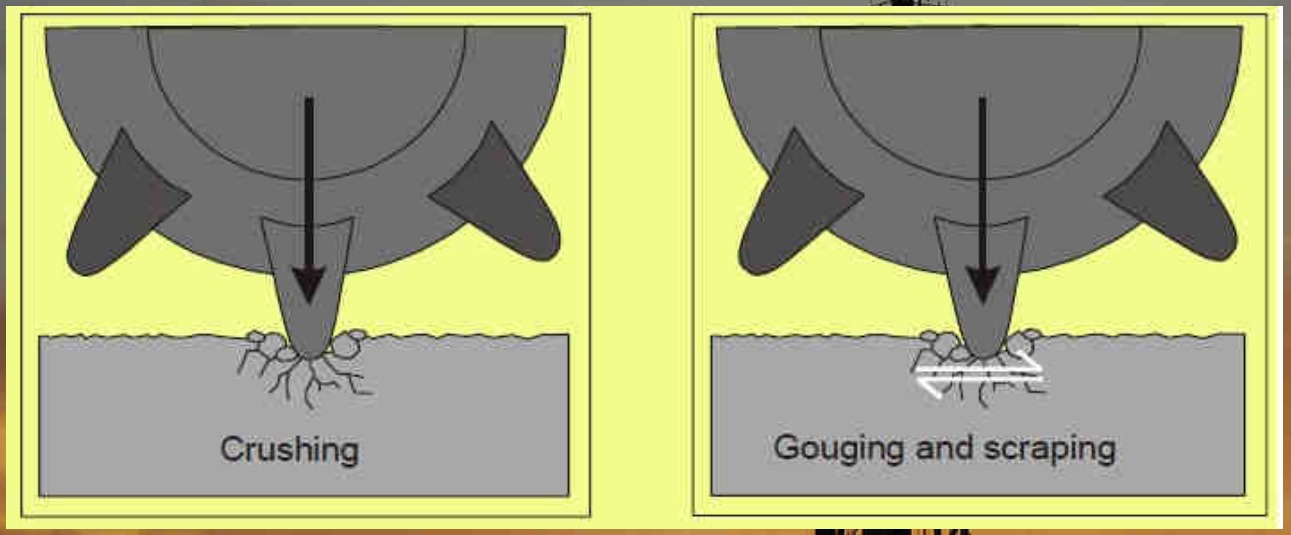
soft | very hard | medium hard | soft

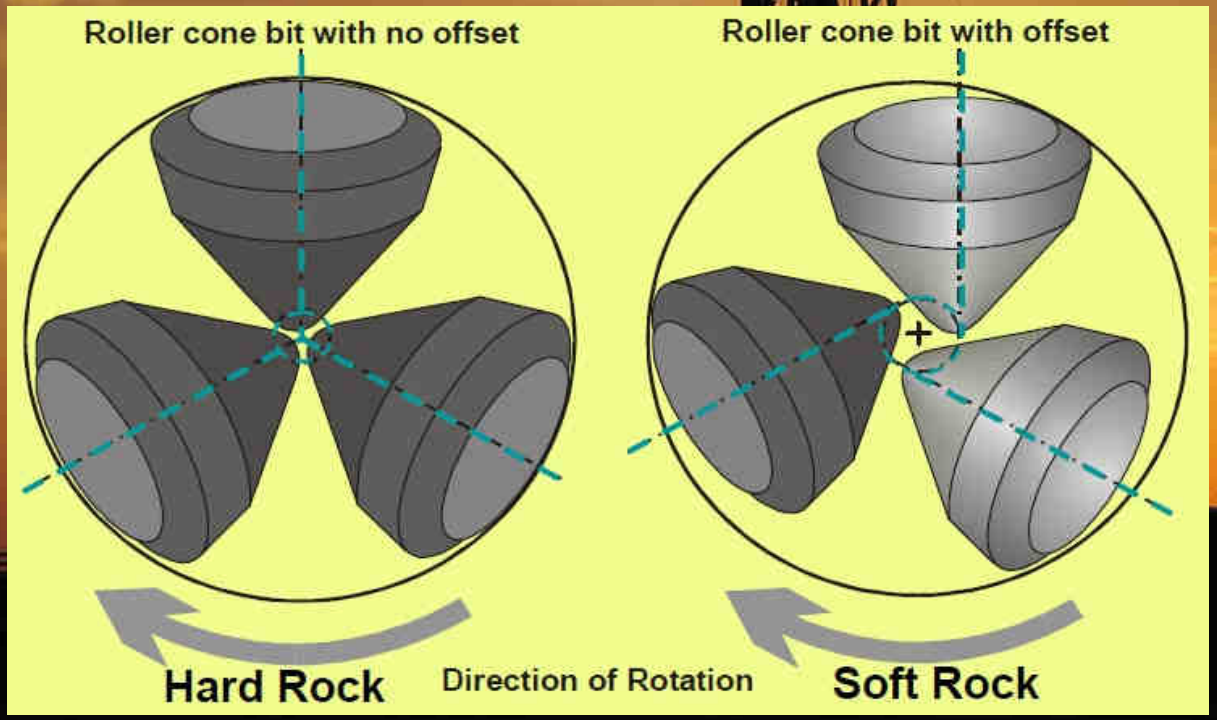
Roller Cone Bit **Milled Steel Tooth**	Roller Cone Bit **Tungsten Carbide** **(inserts)**	Diamond Bit **Natural Diamonds**	Diamond Bit **Polycrystalline Diamond Compact Cutters**

Cutting Action of Rotary Drill Bits



Cutting Action of Rotary Drill Bits

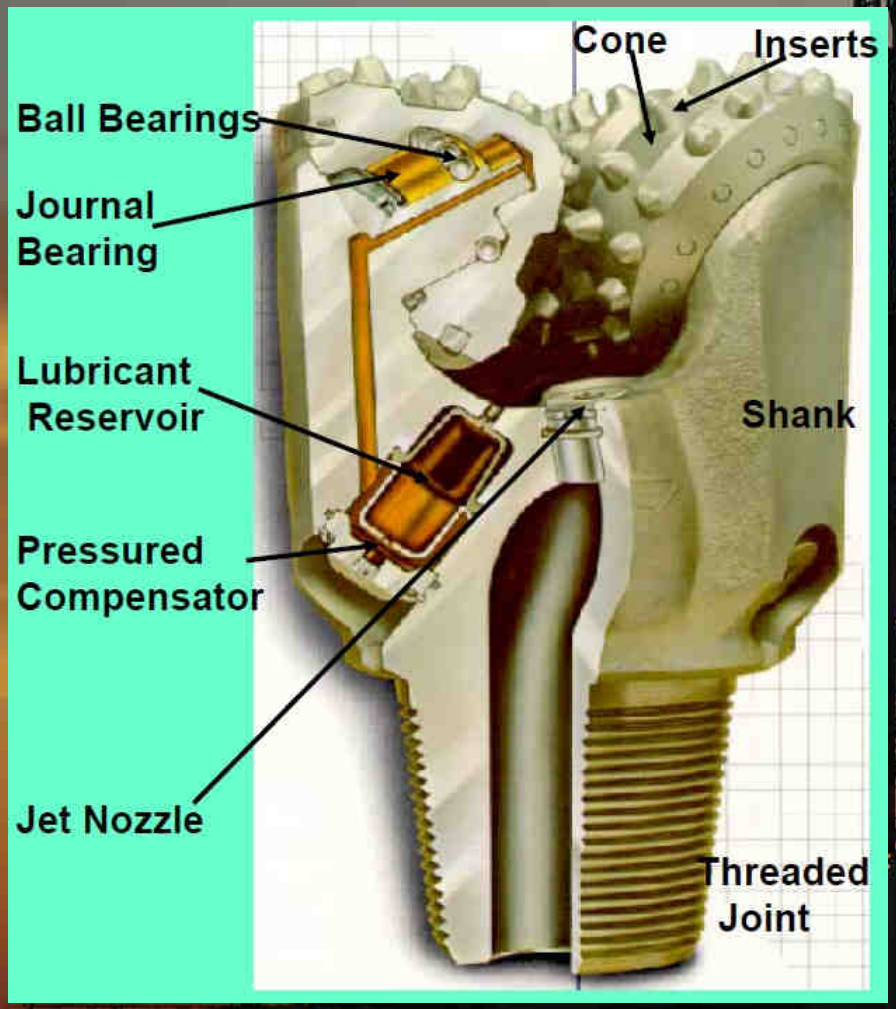




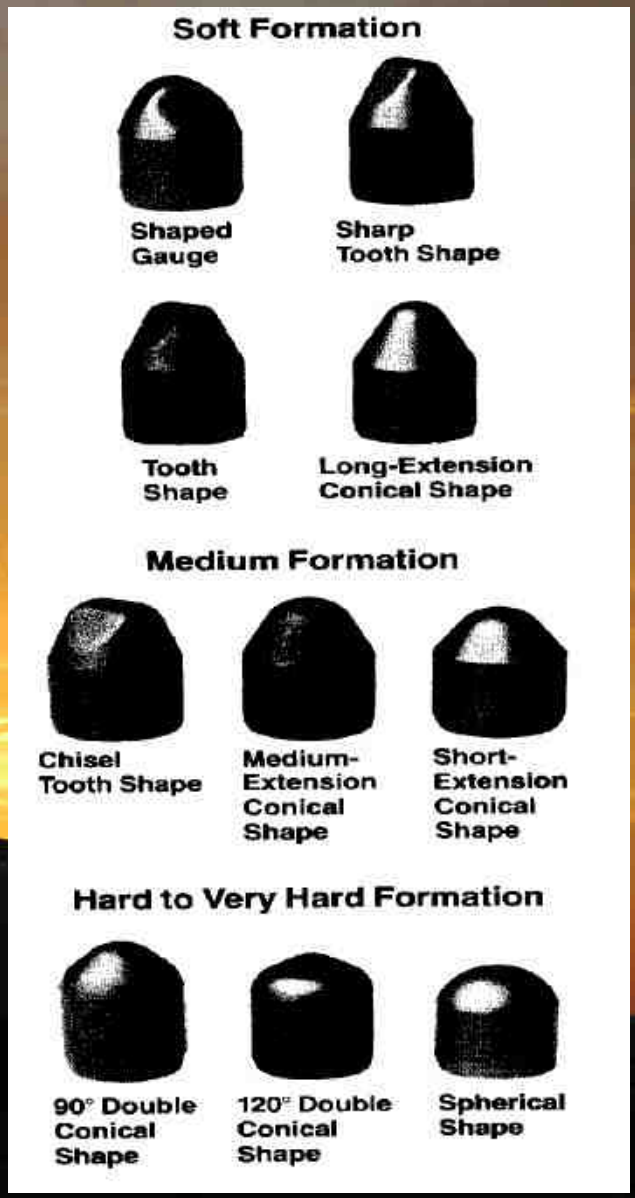
Cones of Roller Bits do only **roll** on the bottom but always **Slide, Tear and Gouge**

Offset of cones increases **Sliding, Tearing, Gouging** action

Elements of Roller Cone Bits

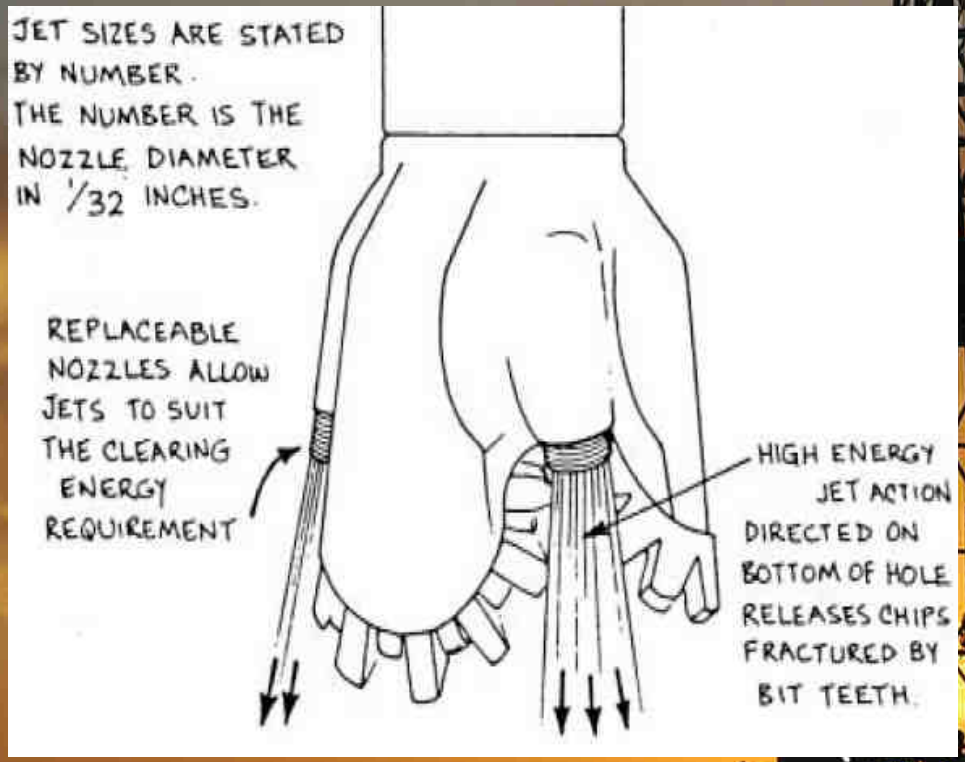


Shape Types of Inserts

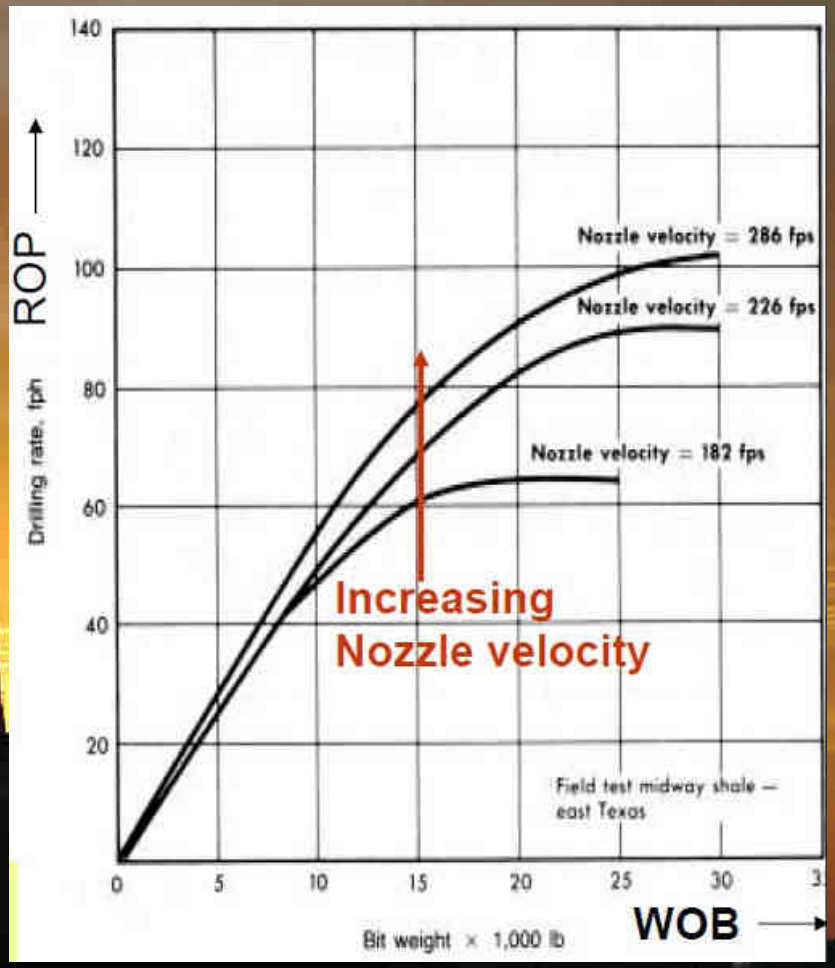


Bottom Hole Cleaning of Roller Cone Bits

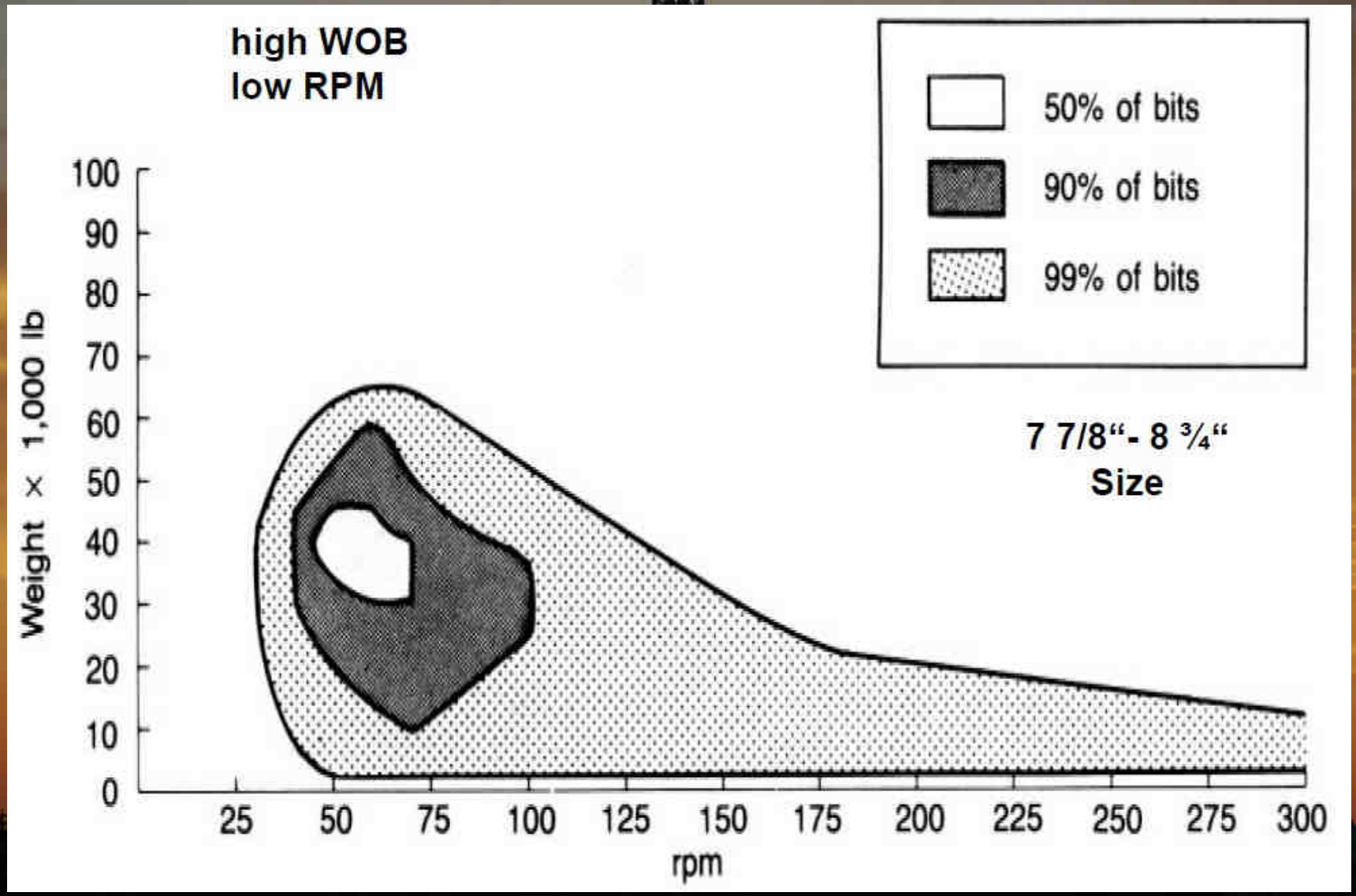
Schematic of Nozzles Action



Effect of Nozzle Velocity on Rate of Penetration

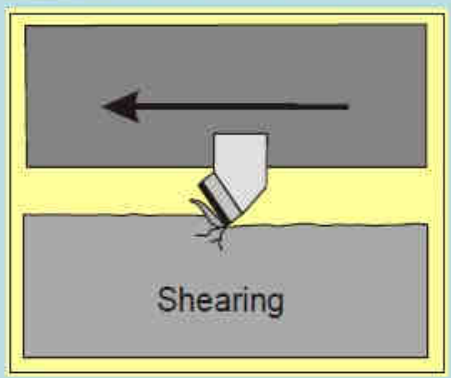


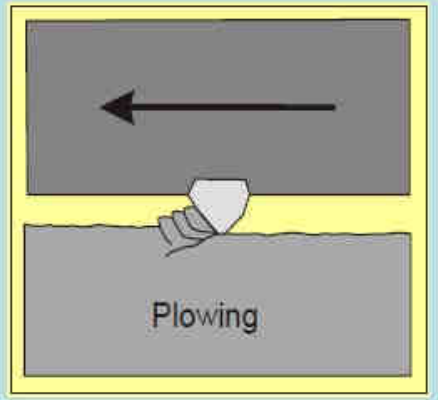
Typical Operating Parameters for Roller Cone Inserts Bits

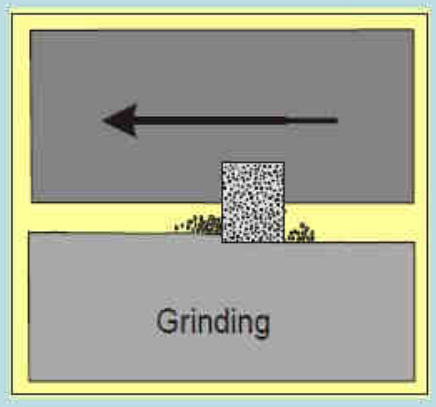


Cutting Action of Diamond Bit

Cutting Size





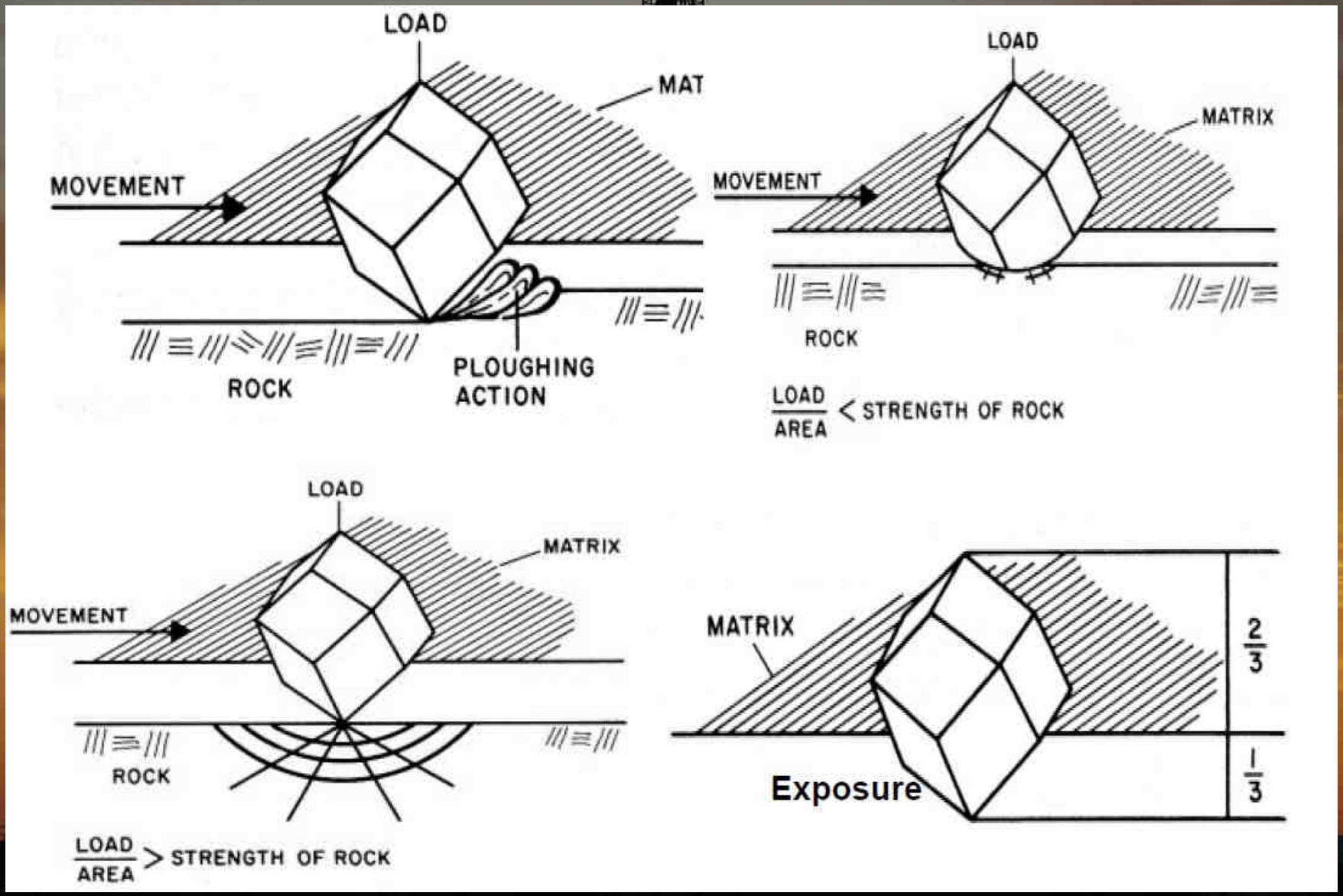


PDC-Bit

Surface set diamond bit

Impregnated Diamond Bit

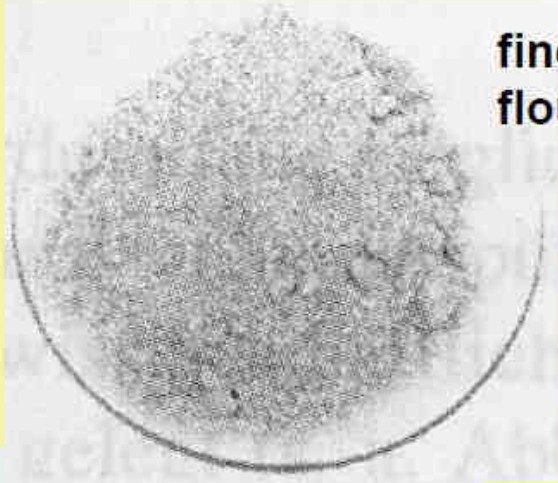
Cutting Action of Diamonds



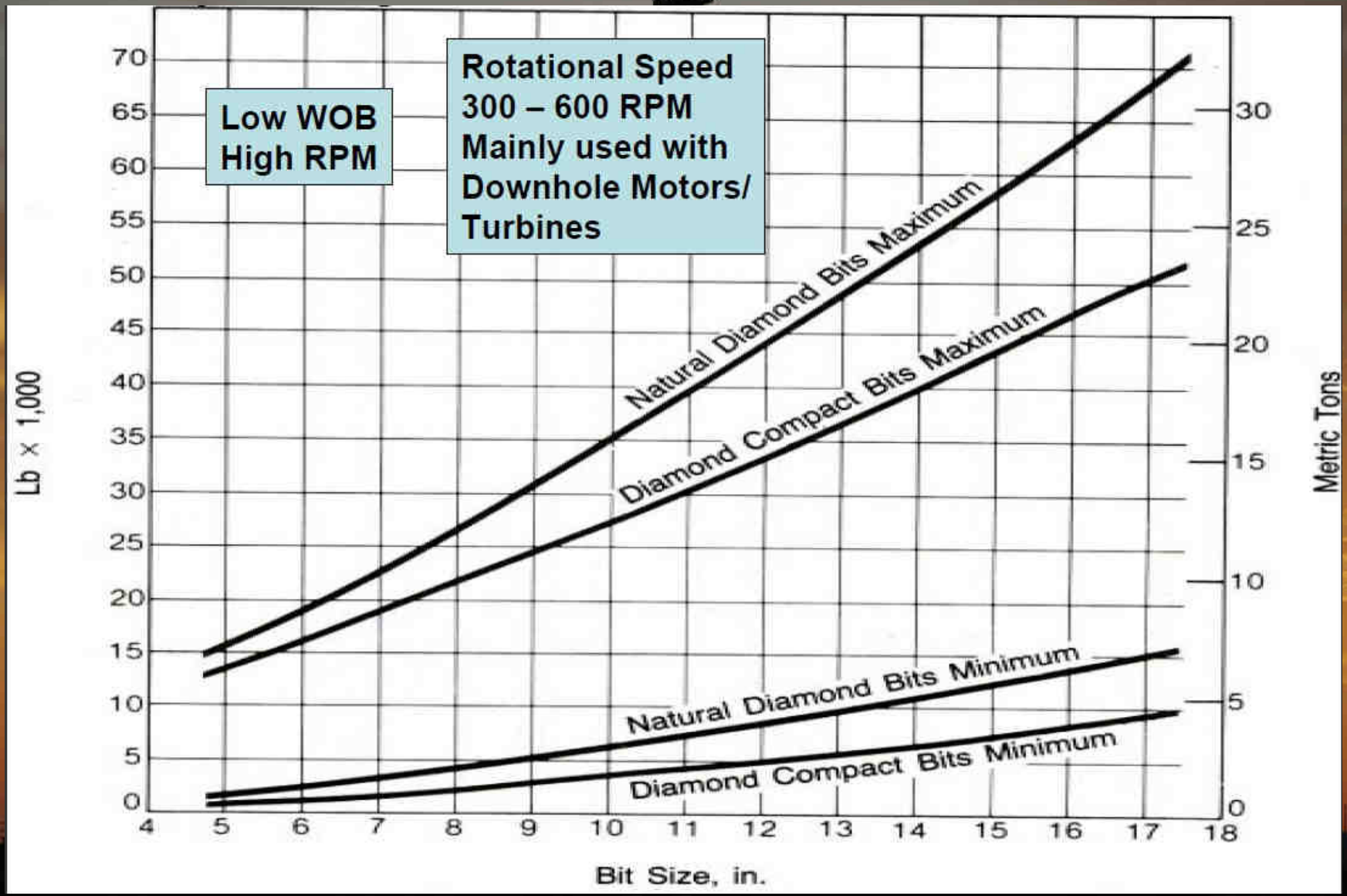
Sizes and Texture of Hard Rock Cuttings Dependent on Bit Type

coarse chips

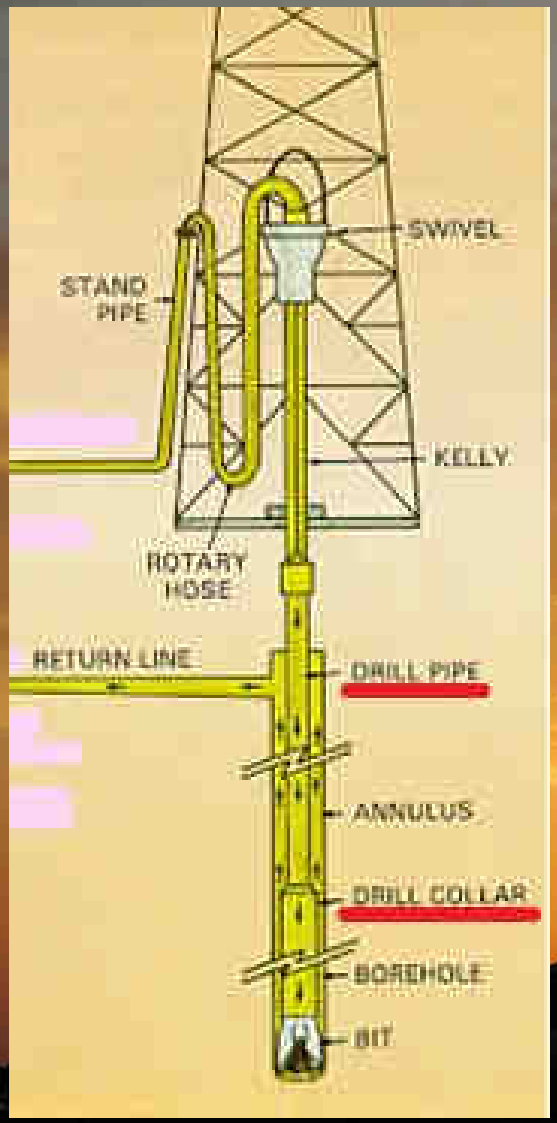
fine flour



Operating Parameters of Diamond Bits



Typical Rotary Drill String Assembly



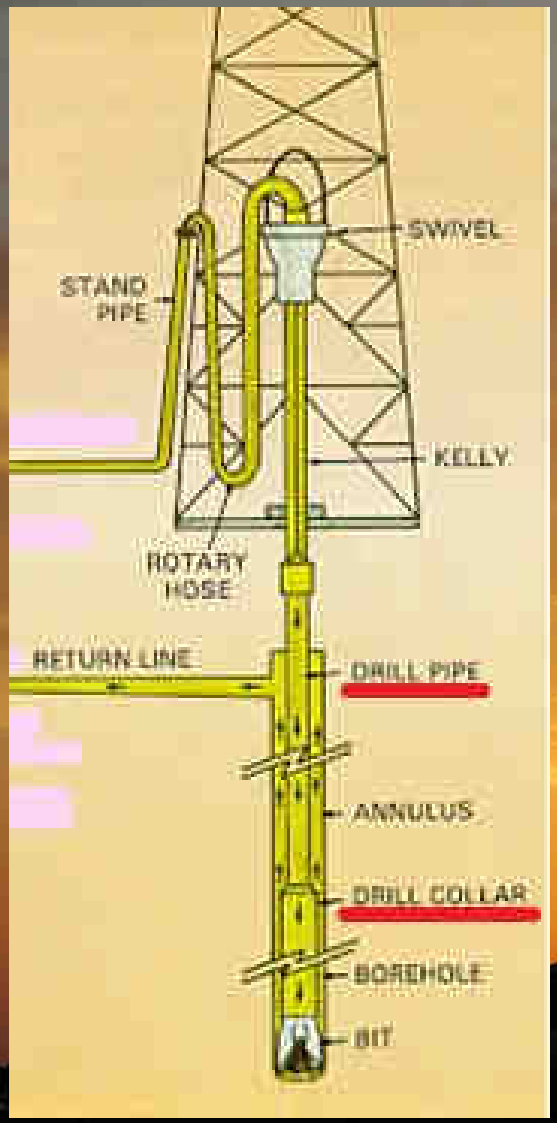
The drill string is the mechanical assemblage connection the rotary drive on surface to the drilling bit on bottom of the hole

Functions of the Drillstring:
- **flow line for circulating drilling fluid**
- **provides weight on bit**
- **transmits rotation and torque to bit**
- **guides and controls trajectory of the bit**

Main Components:
- **Drill Collars: thick wall steel pipe with Pin/Box threaded connection**
- **Drill Pipe: steel pipe with Pin/Box threaded toolioints**

Ancillary Components:
- **crossover subs**
- **stabilizers**
- **reamers**

Typical Rotary Drill String Assembly

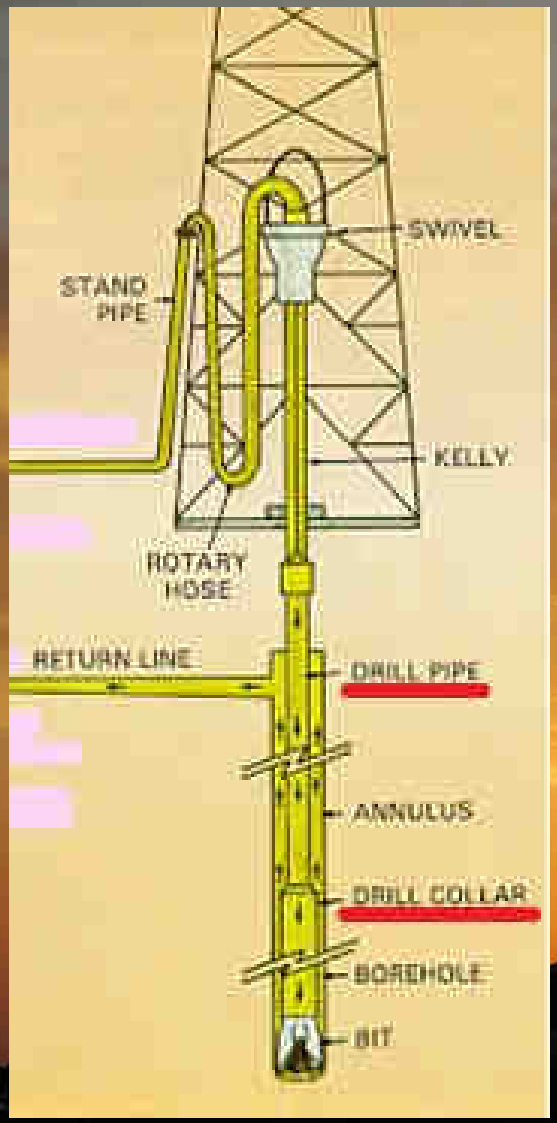


The drill string is the mechanical assemblage connection the rotary drive on surface to the drilling bit on bottom of the hole

Functions of the Drillstring:

- **Reamers**

Typical Rotary Drill String Assembly



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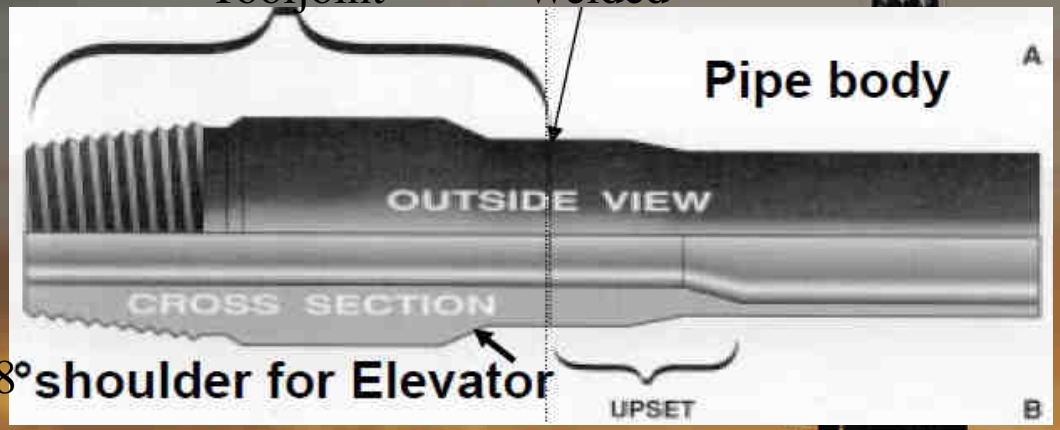
Rotary Drillpipe Characteristics



Pin and Box Tooljoint

Rotary Drillpipes are standartized by API

Outer Diameter of Pipe Body	Steel Grades of Pipe Body	Nominal Weight of Pipe Body
5 ½“ 5“ 4 ½“ 4“ 3 ½“ 2 7/8“ 2 3/8“	E – 75 X – 95 G – 105 S - 135	Wall Thickness

1“ = 2,54 cm

Pipe Lenght

Range 1: 18 – 22 ft
Range 2: 27 – 30 ft
Range 3: 38 – 45 ft

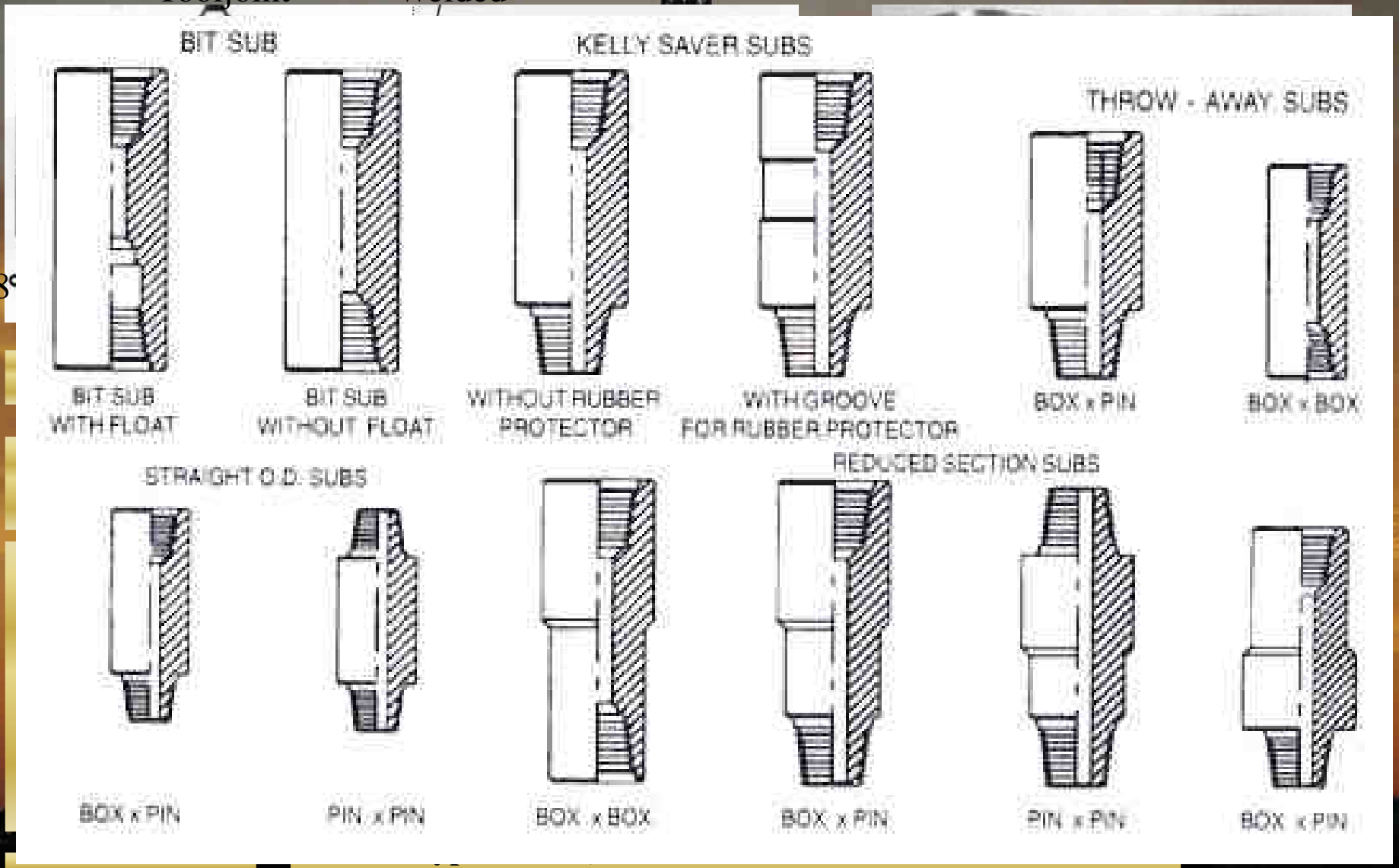
1 ft = 30,48 cm

Tool Joints Steel Grade: 120 000 psi (827,4 Mpa)
Thread Type: NC 50, NC 38
Friction welded with upset pipe body annealed and machined

Rotary Drillpipe Characteristics

Tooljoint Welded

Pin and Box Tooljoint



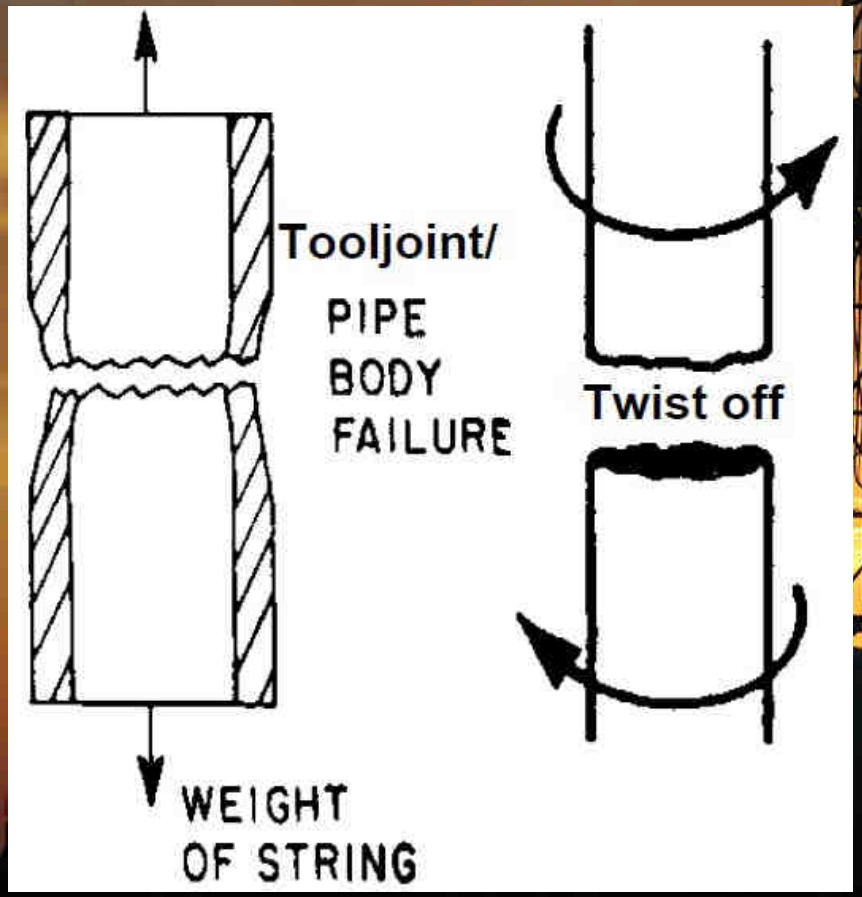
1“ = 2,54 cm

Friction welded with upset pipe body annealed and machined

Drill Pipe Problems

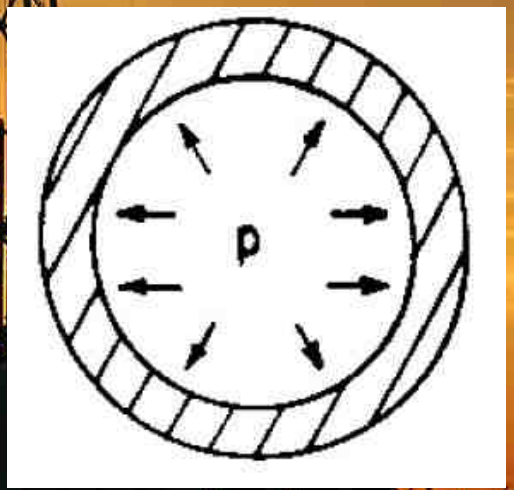
Drill pipe is the most stressed component of rotary equipment!!!

Tension



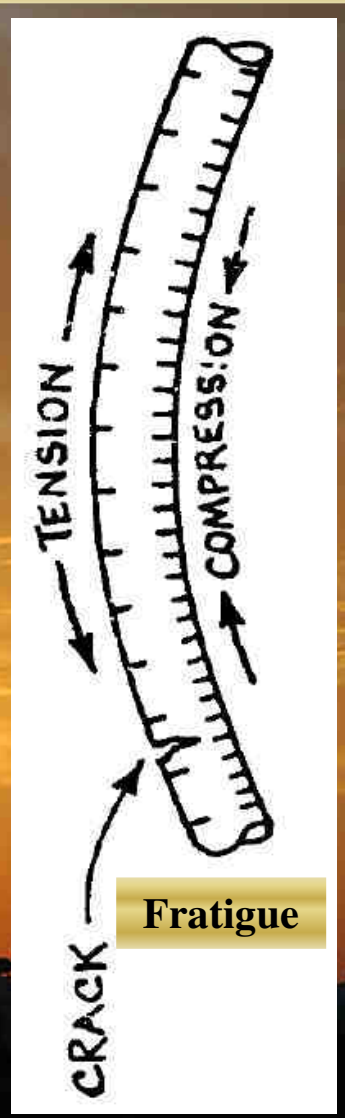
Torque

Burst (Inside Pressure)



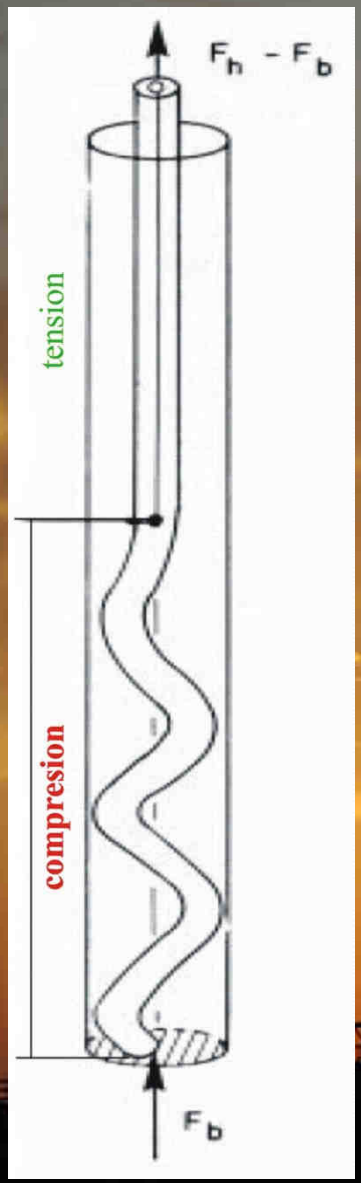
Bending (While Rotation)

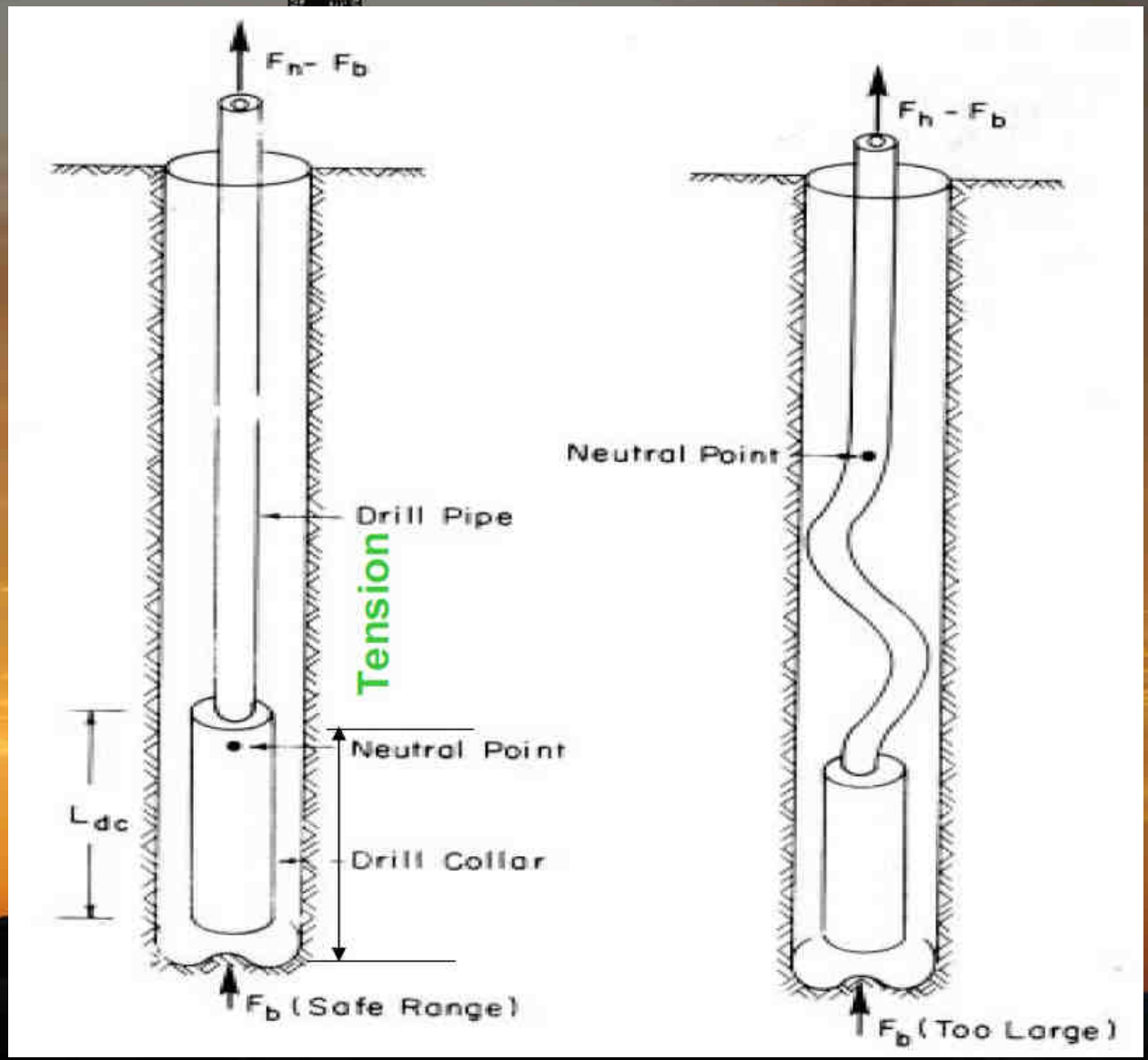
Reversal Stresses



Fratigue

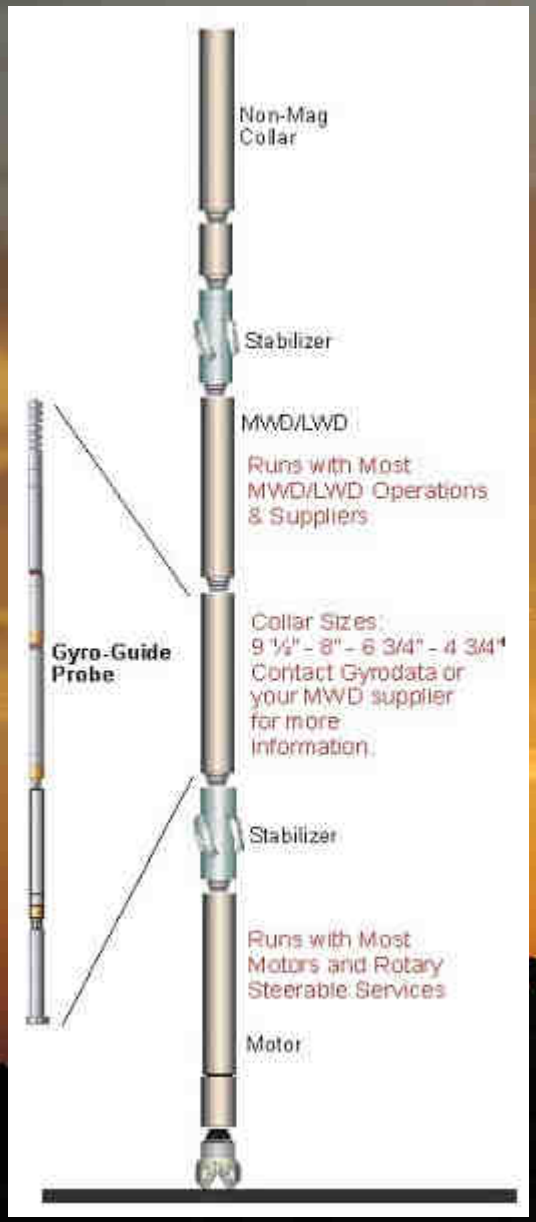
Putting Weight on Bit by Drill Collars

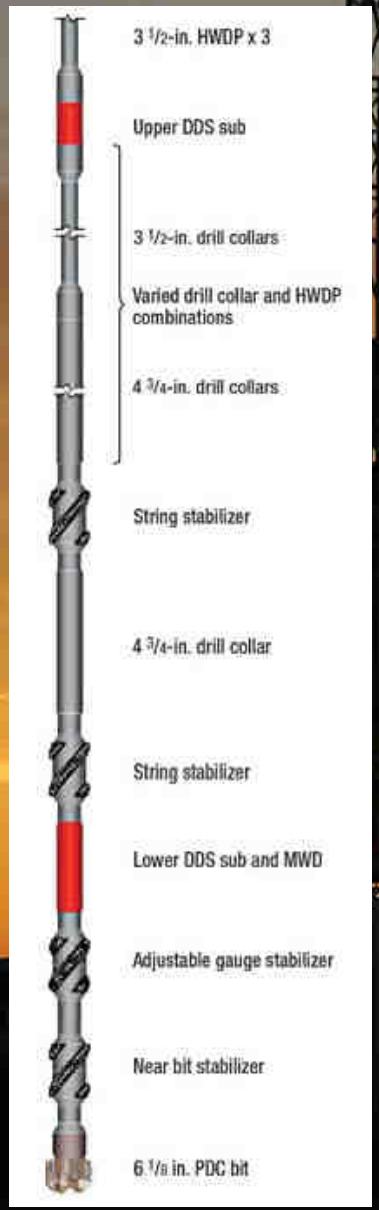




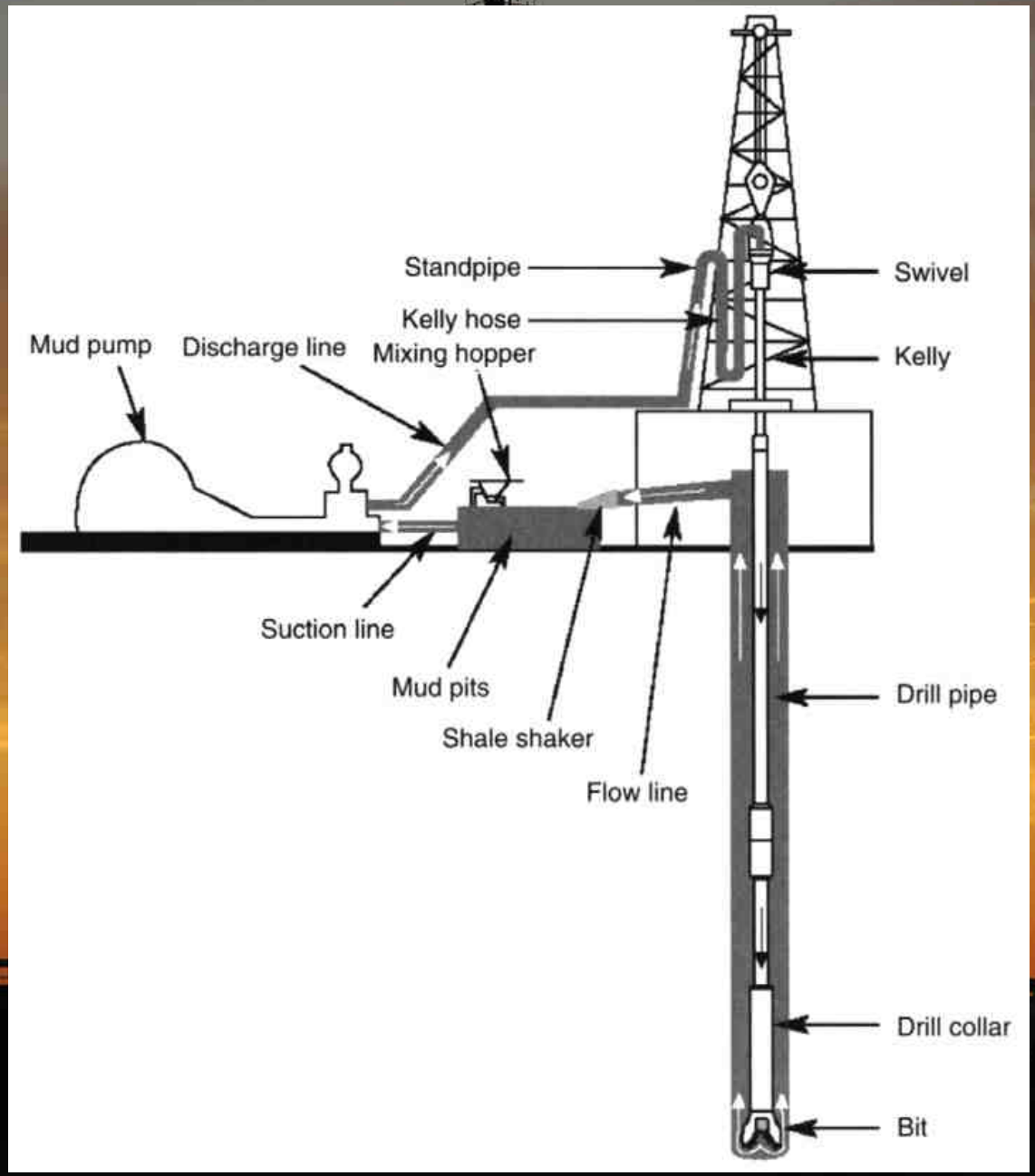
Buckling of Drillpipe under Compressional Load!

Typical Examples for Stabilized
Bottom Hole Assemblies (BHA)





Drilling Fluid – Why it´s Called MUD



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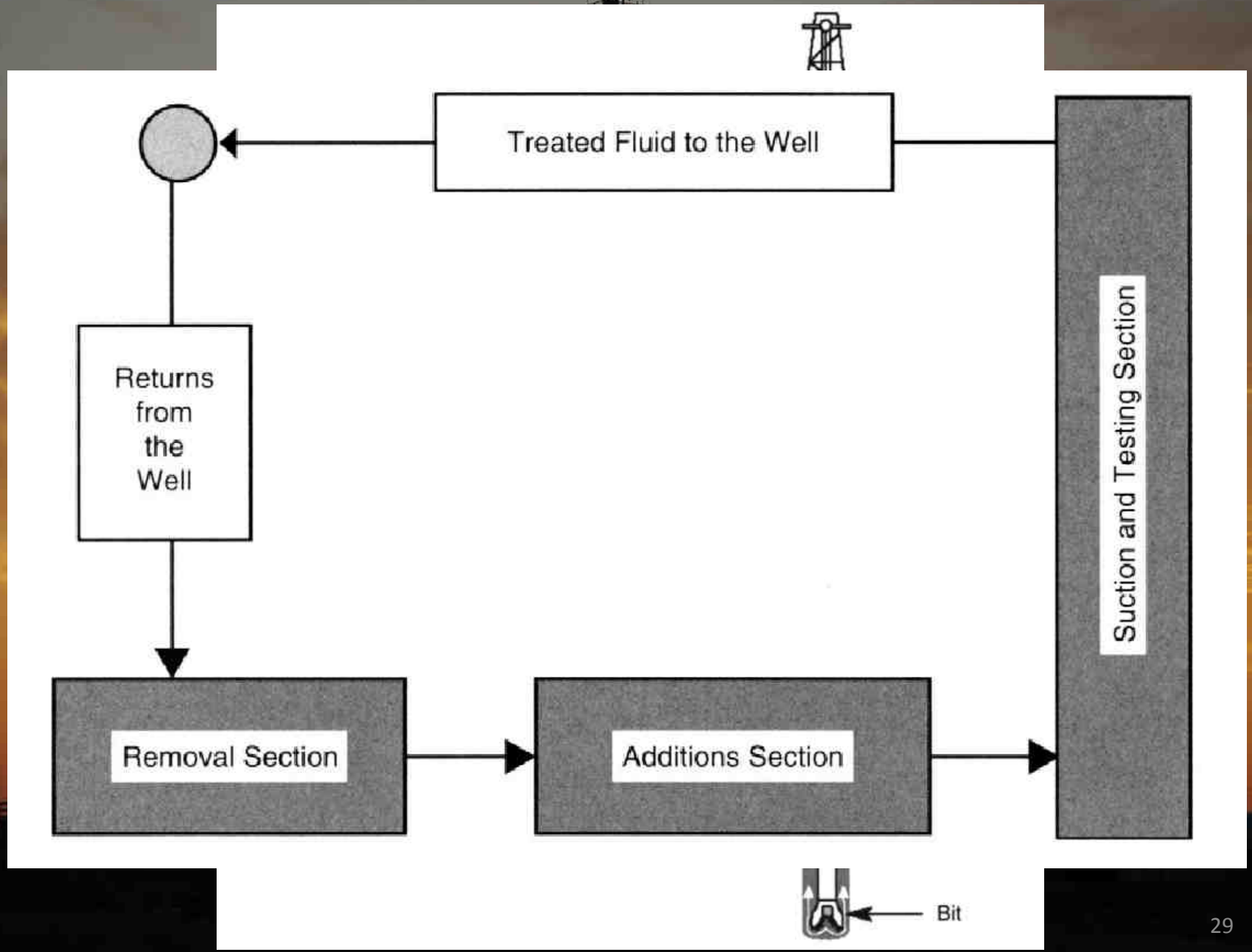
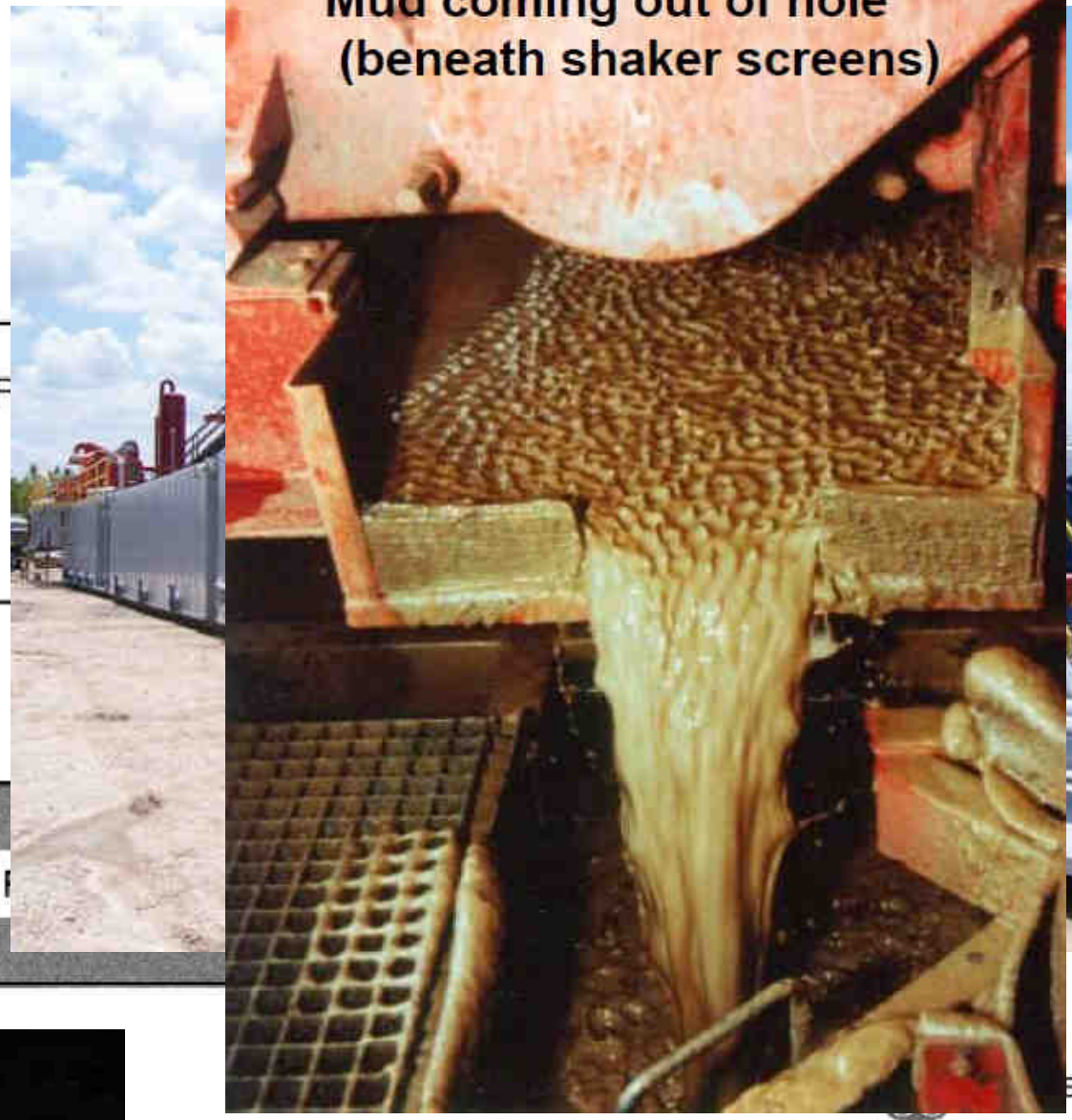


Drilling Fluid – Why it´s Called MUD

Suction and Testing Section

Bit

Drilling Fluid – Why it´s Called MUD



Drilling Mud – A Multipurpose Fluid

Major Functions:

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

Drilling Fluid Circulating Pumps

Typical Operating Parameters:

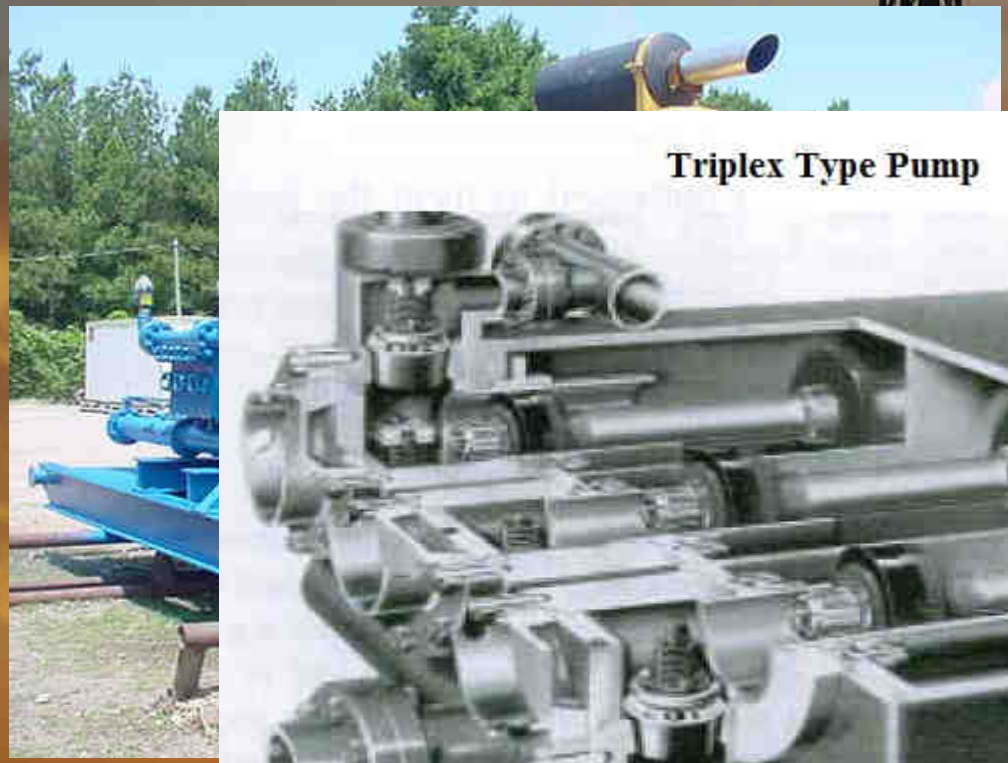
max pressure: 35 Mpa

17 ½“ = 3 500 l/min
12 ¼“ = 2 500 l/min
8 ½“ = 1 500 l/min
6“ = 600 l/min

heavyweight rigs =>
2 pumps 1 200kW

lightweight rigs =>
2 pumps 600 kW

Drilling Fluid Circulating Pumps



Typical Operating Parameters:

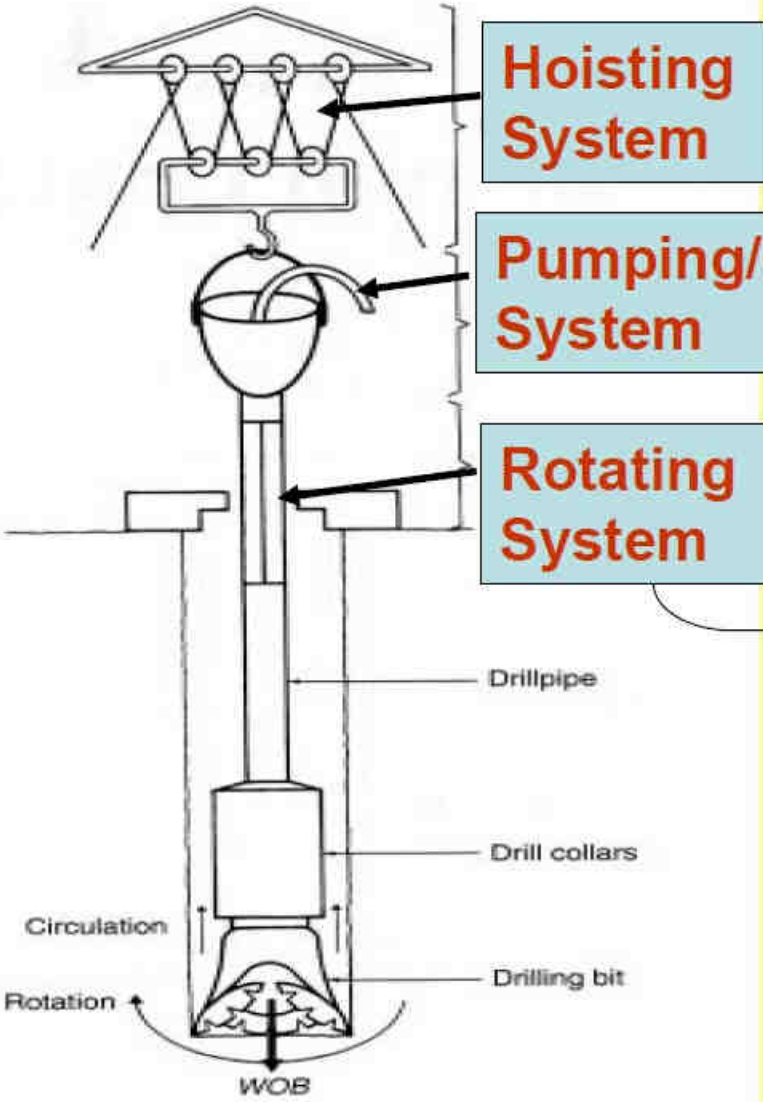
Mpa

>

mps 1 200kW

umps 600 kW

Principal Functions of a Rotary Drilling Rig



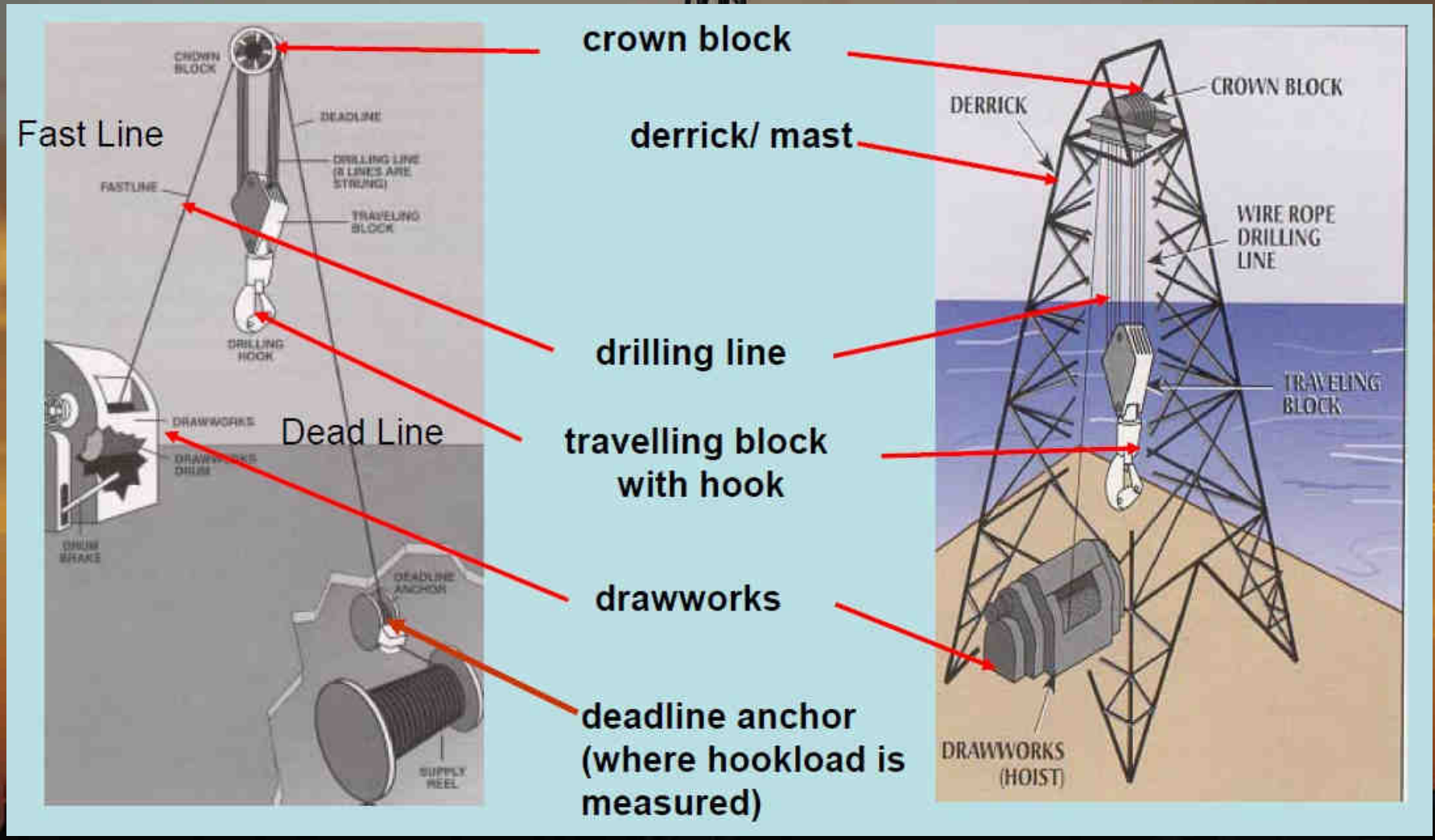
Hoisting System ← Put Weight on the Bit/ Handling the Drillstring

Pumping/Circulation System ← Circulate Fluid/ Solids Contol

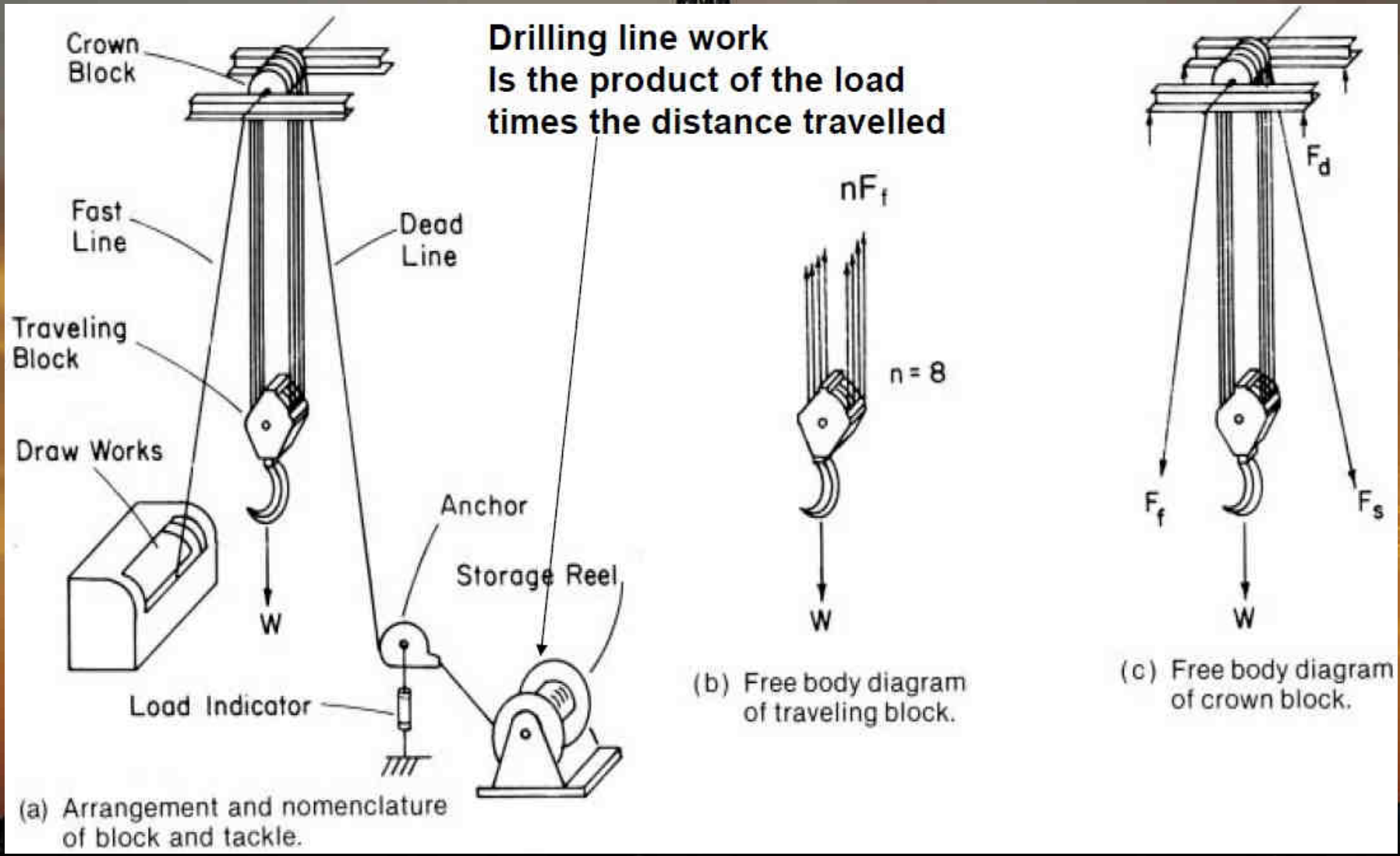
Rotating System ← Rotate the Bit

Power Supply

Main Components of the Hoisting System



Schematic of a Rotary Rig´s Block and Tackle



(a) Arrangement and nomenclature of block and tackle.

(b) Free body diagram of traveling block.

(c) Free body diagram of crown block.

Hoisting System of Drilling Rigs – Hoisting Tower

Structural tower assembled/ dismantled piece by piece

Assembling/ dismantling is time consuming

Used mainly offshore

Square shaped rig floor

Derrick

Hoisting System of Drilling Rigs – Hoisting Tower

A-shaped structure which can be pulled or lowered to a upright position by the drawworks without completely assembling or disassembling

Good mobility

Used mainly with onshore rigs

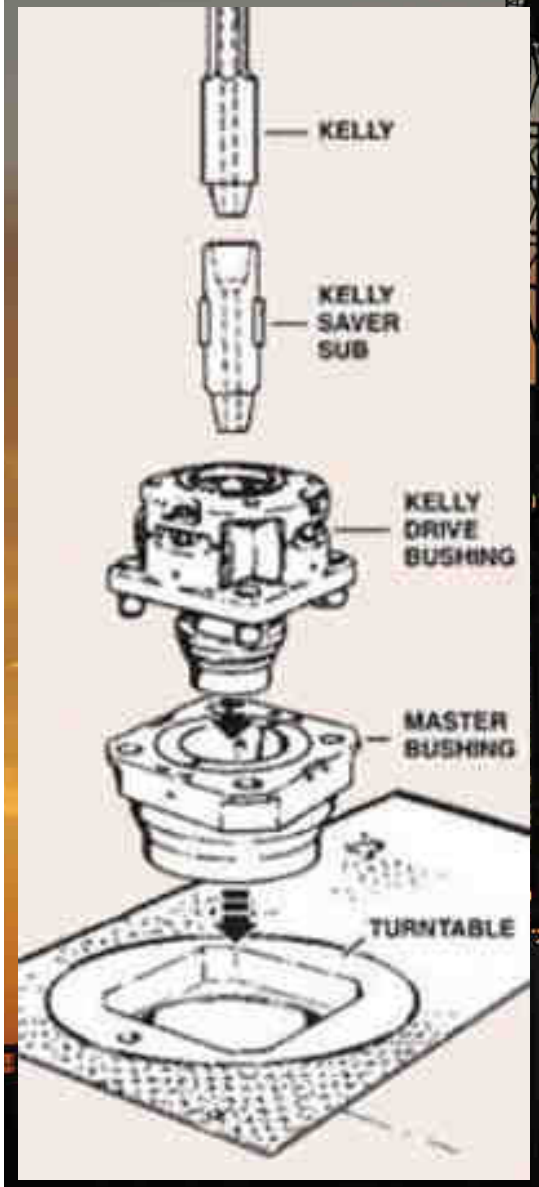
Mast

Rotary Rig Drawworks

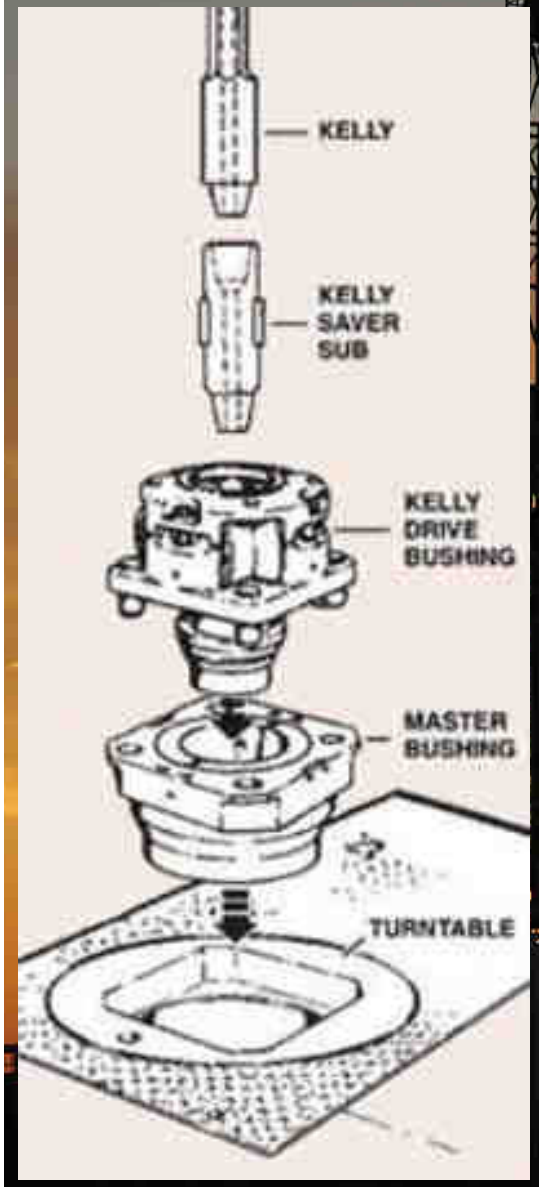
Advantages of Gear Driven Drawworks:

- high performance
- high availability
- less noise
- less vibration
- increased safety

Rotating the Drillstring with a Rotary Table



Rotating the Drillstring with a Rotary Table



Rotating the Drillstring with a Top Drive

TOP DRIVE means a Power Swivel which directly turns the drillstring without need for a kelly and rotary table

Advantages of a Top Drive Systém:

- **drill string can be pulled out while rotating and circulating → Back Reaming**
- **can be reconnected to the drill string at any mast height during tripping**
- **drilling with 3-joint stands of drill pipe is possible**
- **with hydraulic driven power swivel static torque can be applied for much longer time**

Save time!!!
Safer and easier operation!!!

Rotating the Drillstring with a Top Drive

TOP DRIVE means a **Power Swivel** which directly turns the drillstring wit
for a kelly and rotary table

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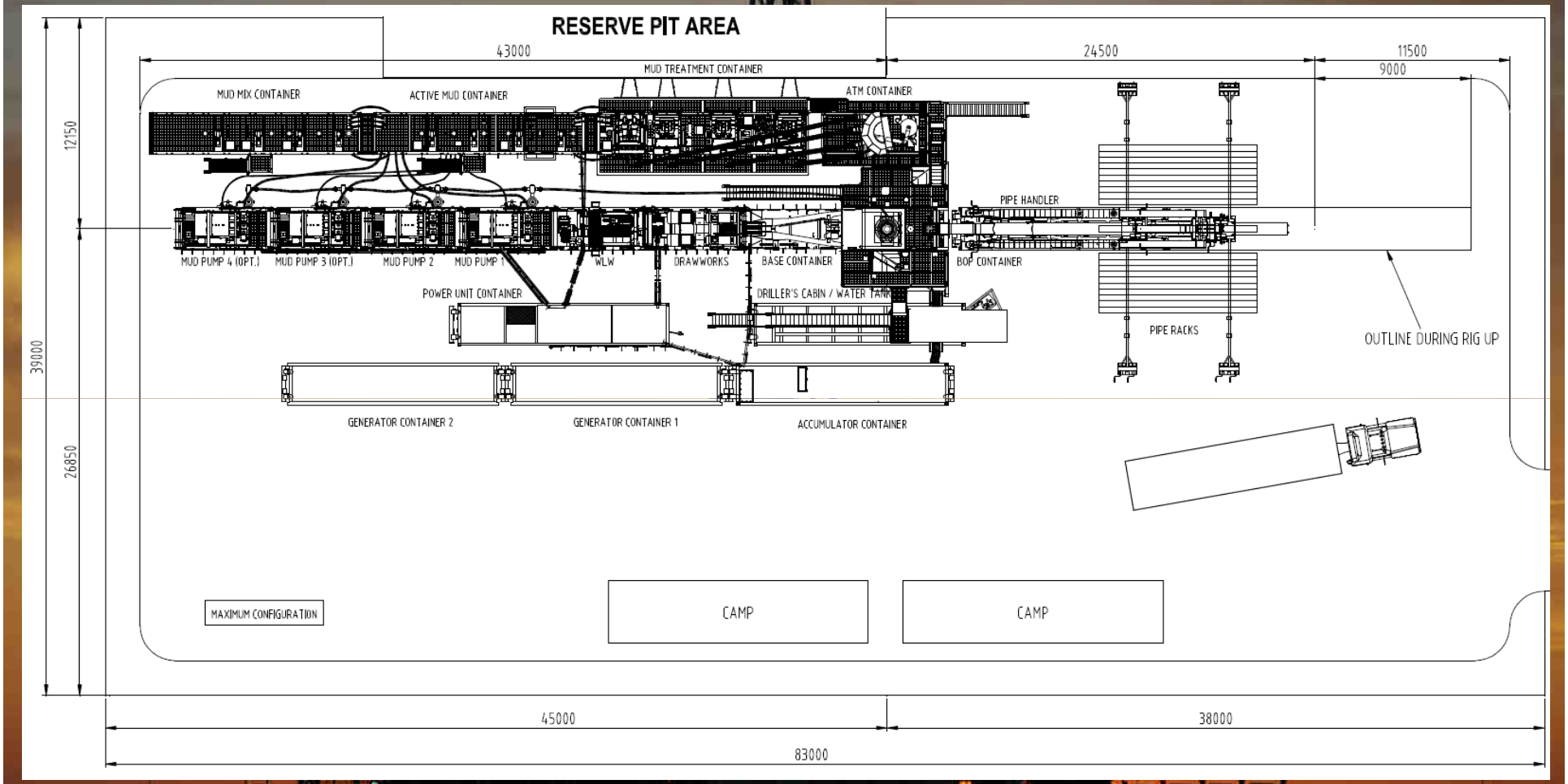
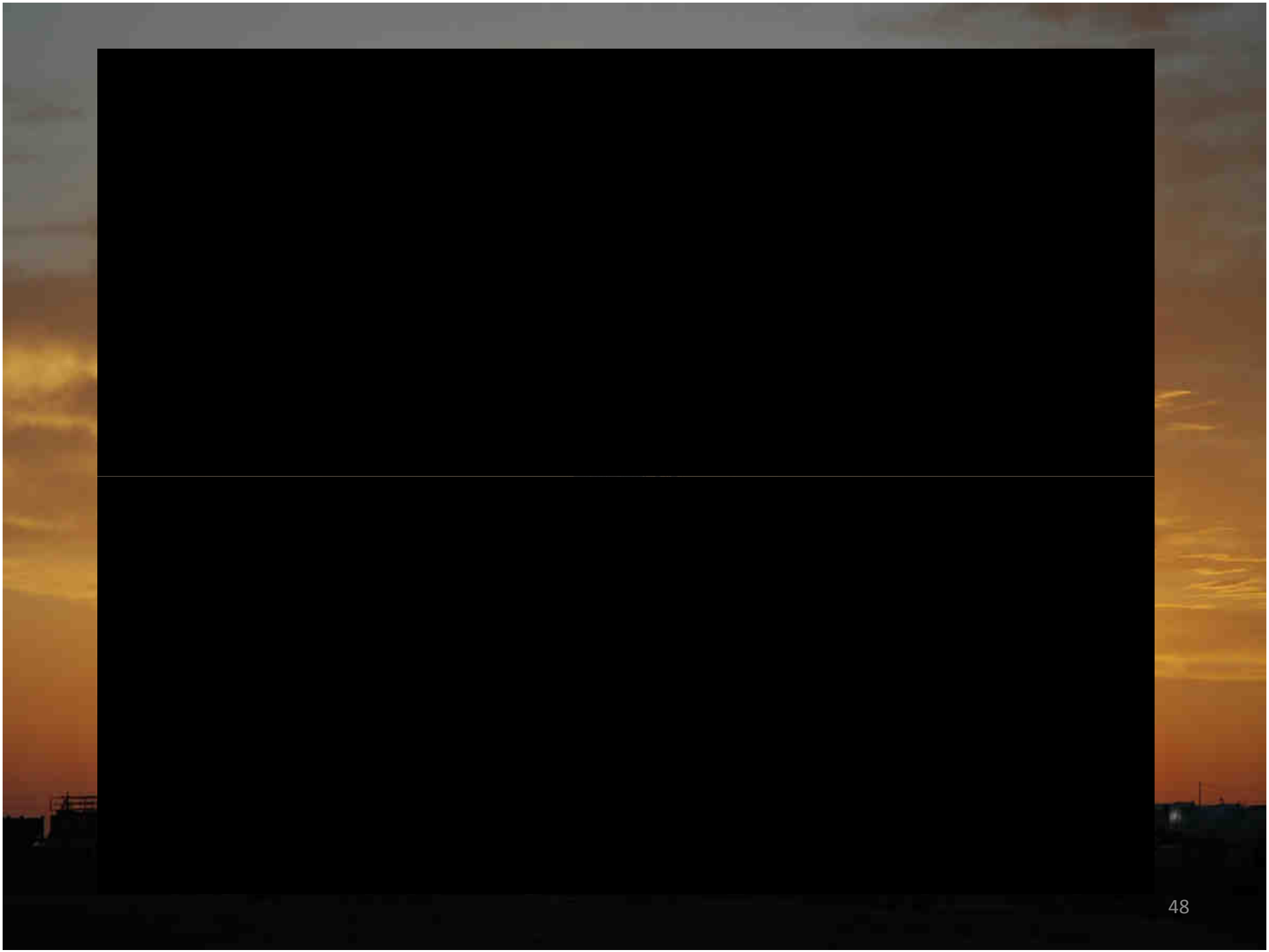
Drilling Rig – LOC 400



Drilling Rig – LOC 400



Classification of Drilling Rigs

Classification by Depth Rating:

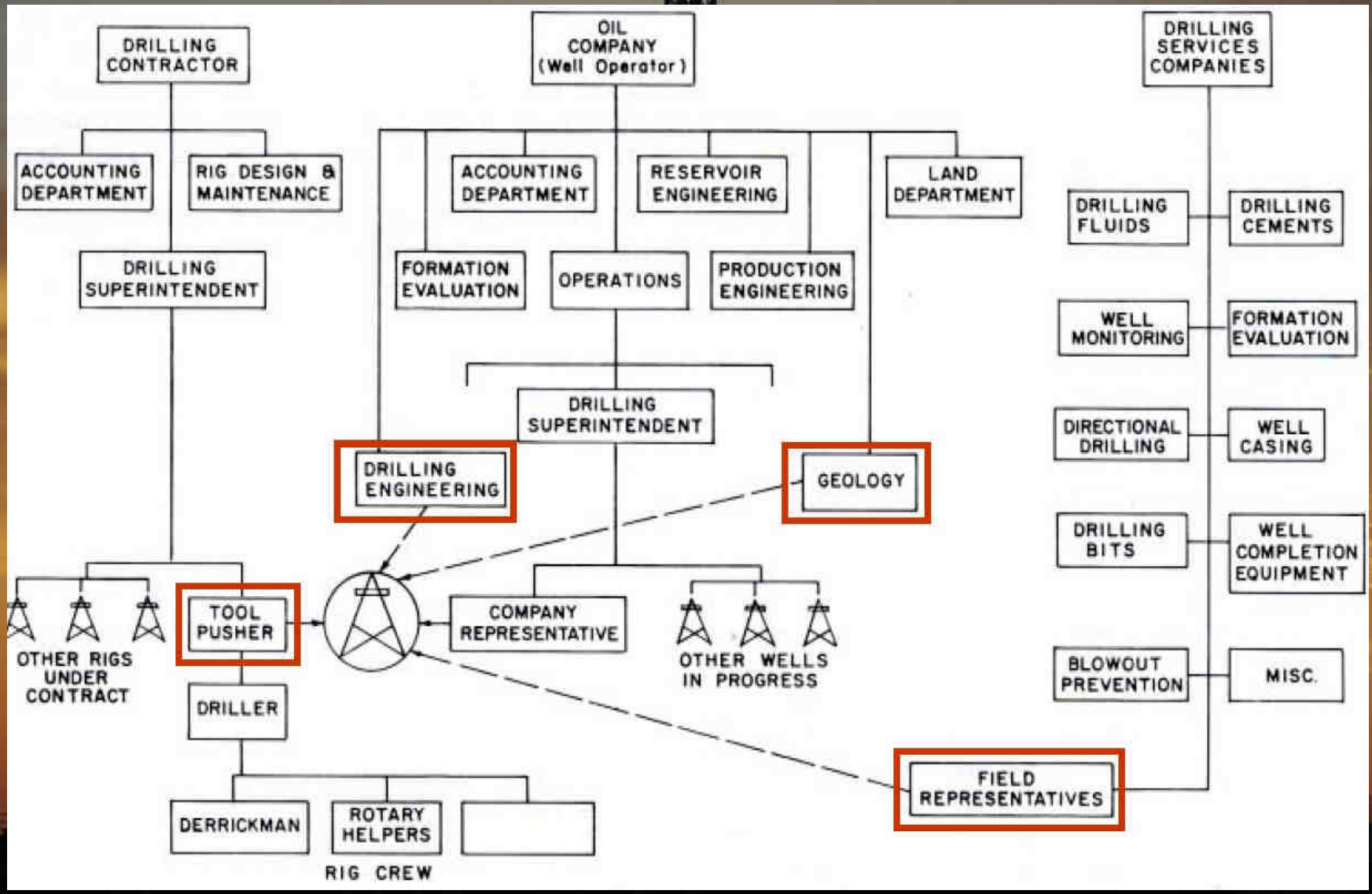
- **lightweight rigs: 1 500 – 2 000 m**
- **intermediate rigs: 3 500 m**
- **heavyweight rigs: 6 000 m**
- **ultraheavy rigs: 8 000 – 10 000 m**

Classification by Horsepower:

Rule of Thumb:
every 100 ft (30,5 m) of borehole requires 10 HP (7,5 kW) at drawworks

- lightweight rigs : 650 HP (484,7 kW)
- intermediate rigs : 1 300 HP (969,4 kW)
- heavyweight rigs : 2 000 HP (1491 kW)
- ultraheavy rigs : 3 000 HP (2 237 kW)

Typical Rig Organization Scheme



Drilling Contracts

Footage Contracts	Operator pays the contractor a **stipulated amount** for **each foot or meter** drilled **regardless of how long** it takes the contractor to drill it. **Contractor** assumes **many of the risks** of drilling
Daywork Contracts	Operator pays a **stipulated amount per hour** based on the work the rig and crew are doing •Drilling time •Standby Time (Logging, Testing, etc)
Combination Contracts	Combination of Footage and Dayrate Contracts
Turnkey Contracts	Operator pays an **agreed-on amount** when the contractor **completes the well**. Contractor furhishes all equipment, material and personnel to drill the well. Contractor **controls the entire drilling operation** with little or no supervision. **Contractor** assumes **all the risks** and **adjusts the price** charged to reflect these risks. **Operator** benefits by **not assuming any risks**.

THE END!!!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