Chapter 4

DIRECTIONAL DRILLING

Introduction

Directional drilling is the art and science involving the intentional deflection of a wellbore in a specific direction in order to reach a predetermined objective below the surface of the earth.

Introduction

At one time it was thought that all wells were vertical

Methods to measure deviation were developed in the 1920's (initially acid bottle)

Directional drilling developed after 1929 when new survey instruments were available (inclination and direction)

Introduction

The first controlled directionally drilled well was drilled in the Huntington Beach Field in 1930 to tap offshore reserves from land locations.

Directional drilling became more widely accepted after a relief well was drilled near Conroe, Texas in 1934.

Introduction

Today, directional drilling is an integral part of the petroleum industry.

It enables oil companies to produce reserves that would not be possible without directional drilling.

Introduction

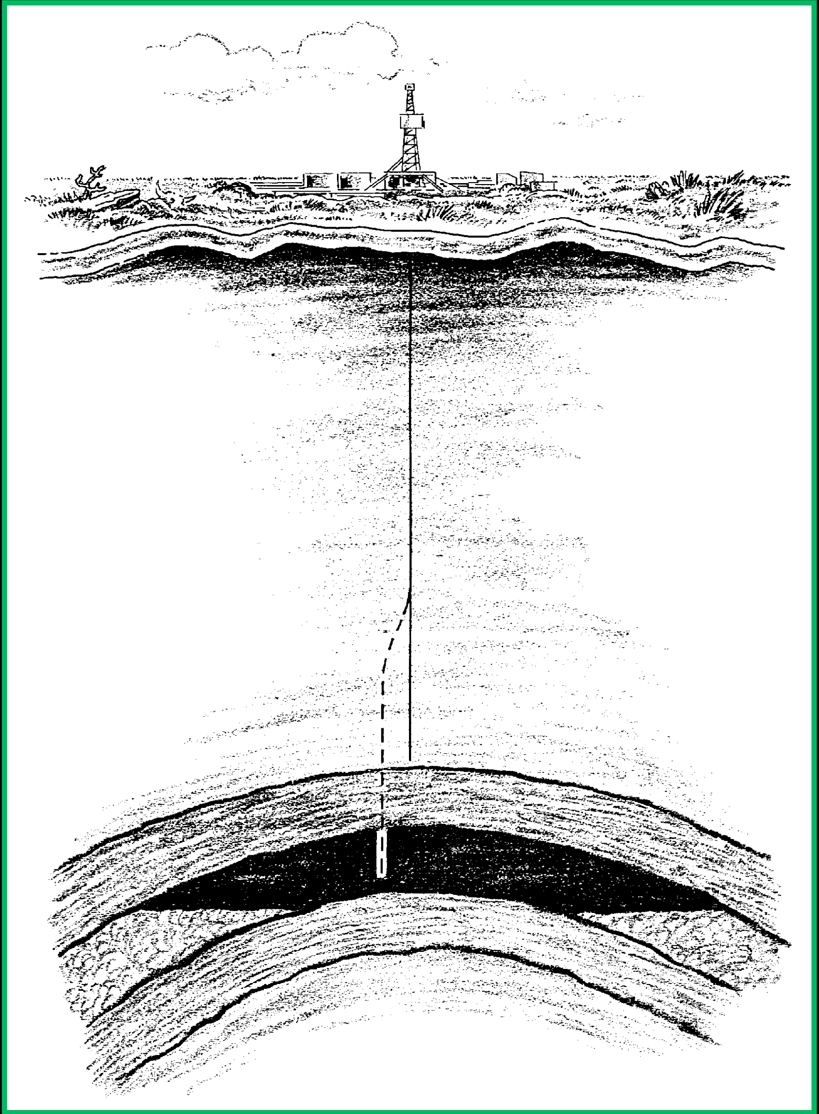
- Sidetracks
- Multiple sidetracks
- Spacing considerations
- Multiple wells from single structure or pad
- Inaccessible surface location

Introduction

- Drilling around salt domes
- Steeply dipped sands
- Fault drilling
- Relief well drilling
- Horizontal wells

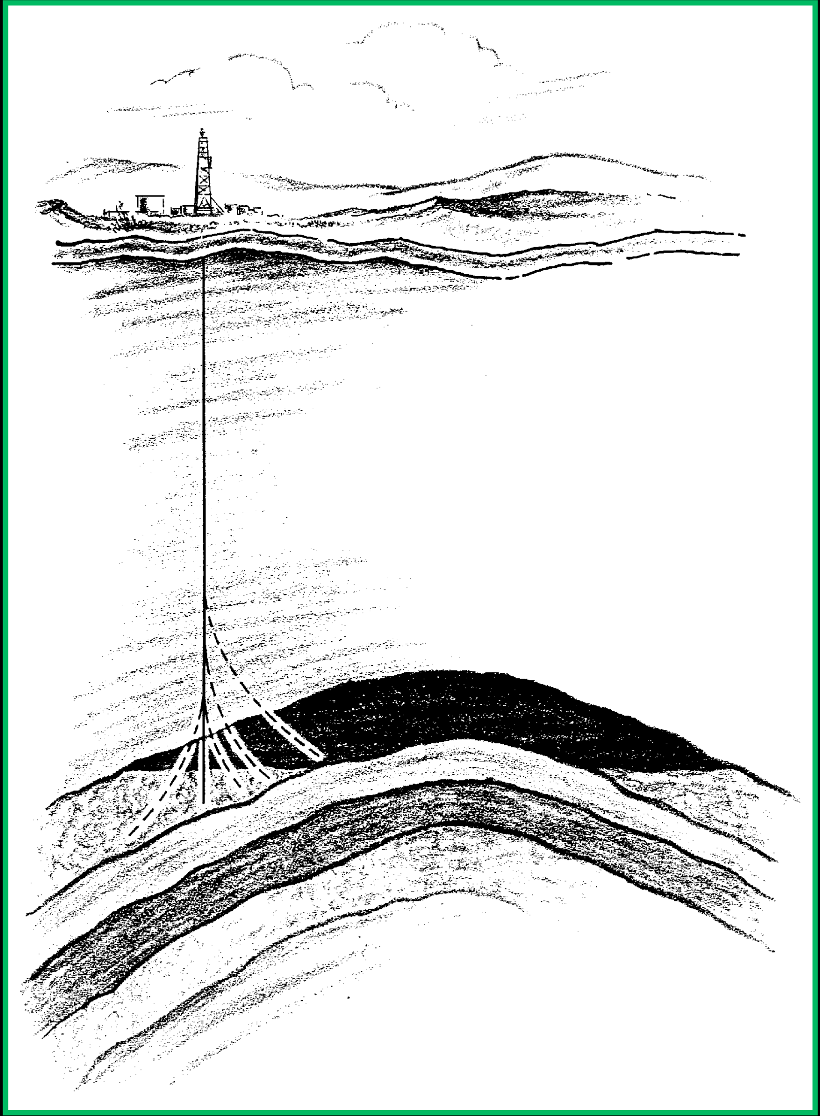
Introduction

One of the primary uses of directional drilling was to sidetrack a well even if it was to go around a stuck BHA



Introduction

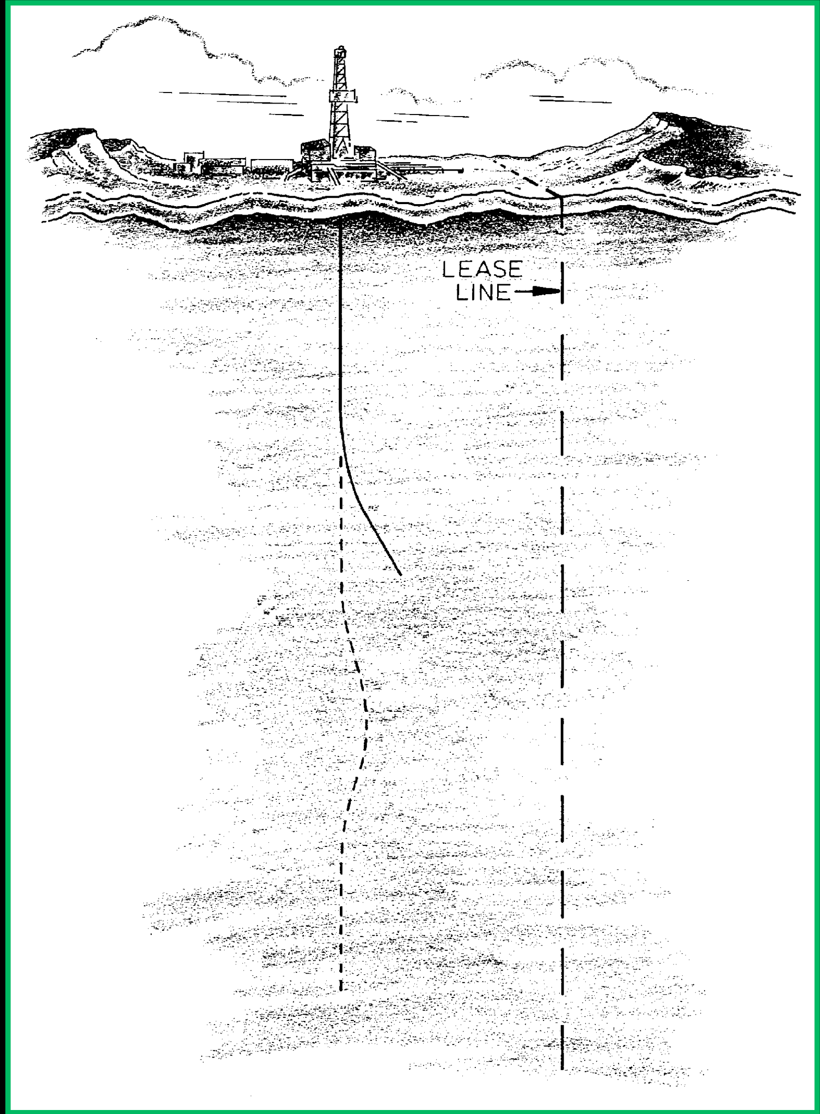
Sometimes multiple sidetracks are used to better understand geology or to place the wellbore in a more favorable portion of the reservoir



Introduction

Straight hole drilling is a special application of directional drilling

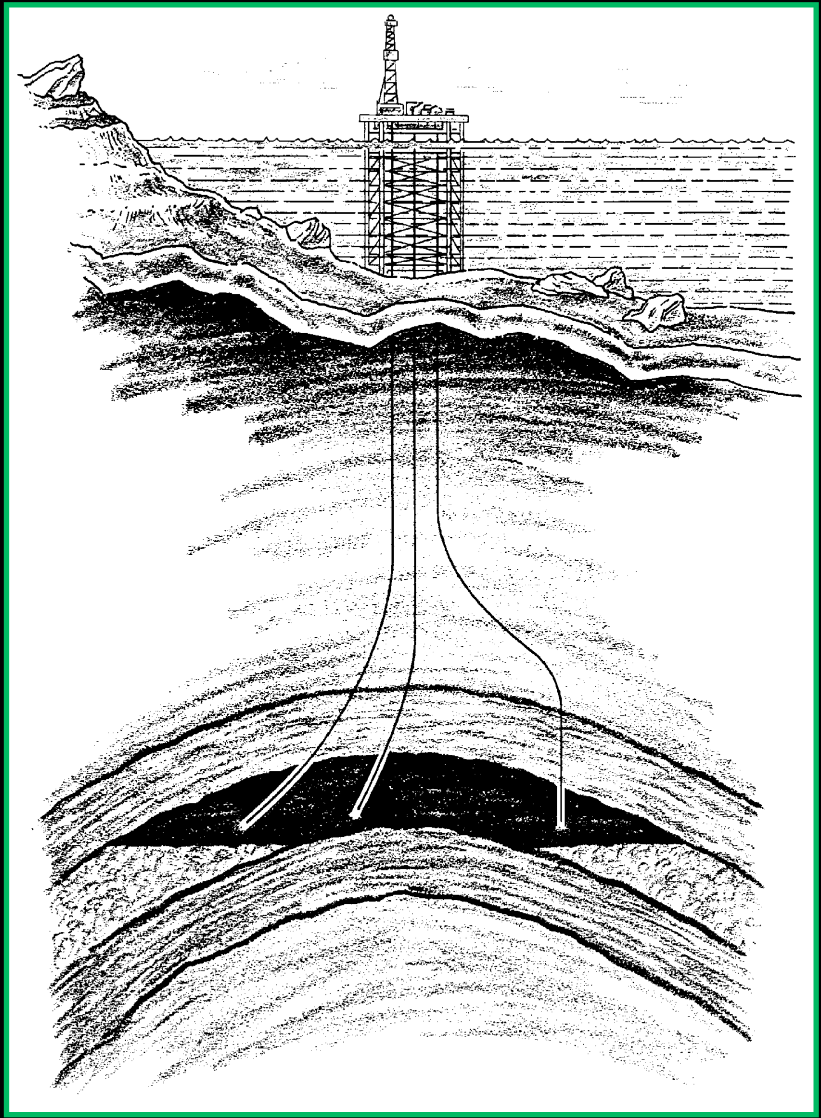
- To keep from crossing lease lines
- To stay within the specifications of a drilling contract
- To stay within the well spacing requirements of a developed field



Introduction

Drilling multiple wells from a single structure or pad

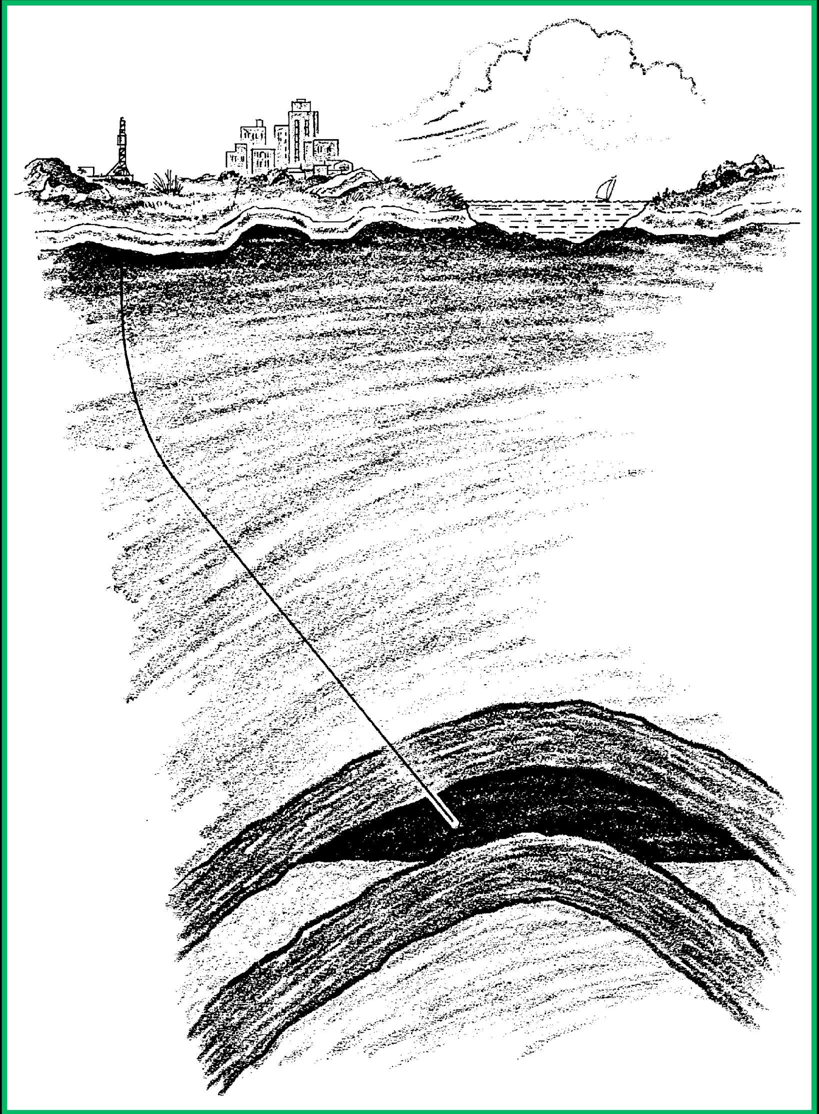
Most offshore development would not be possible without directional drilling



Introduction

Inaccessible surface location

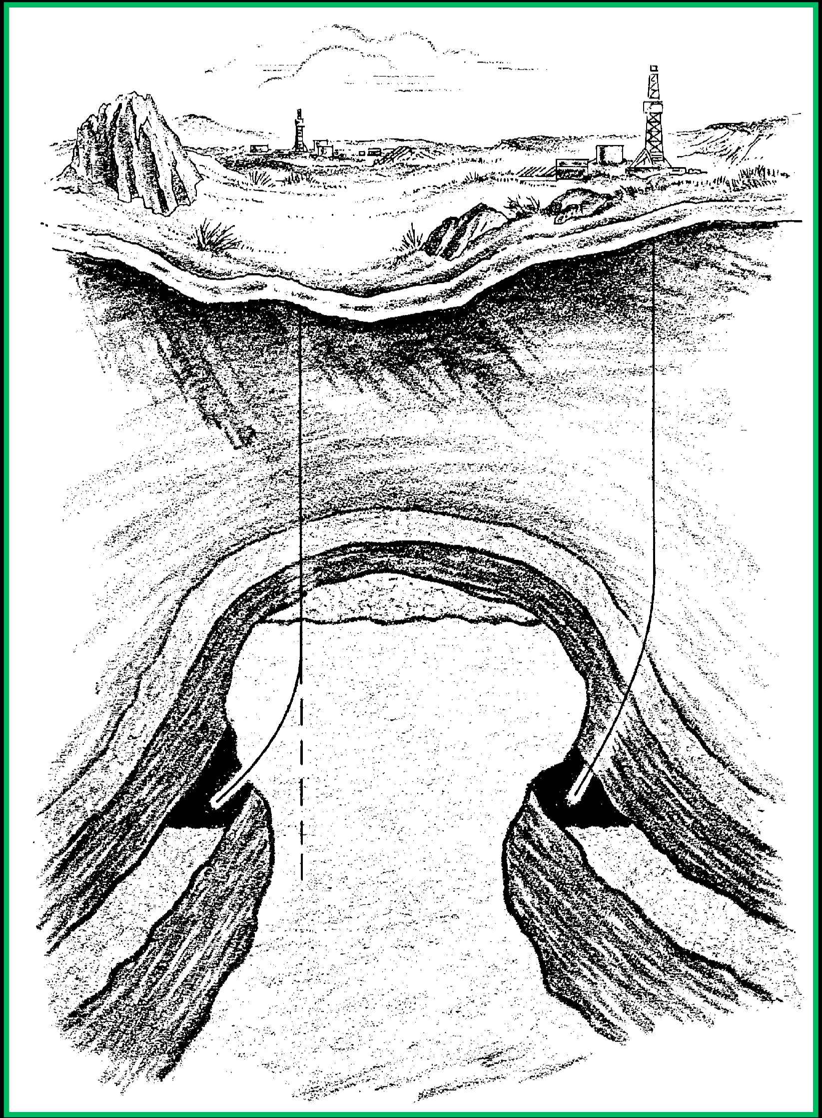
Drilling in towns, from land to offshore and under production facilities



Introduction

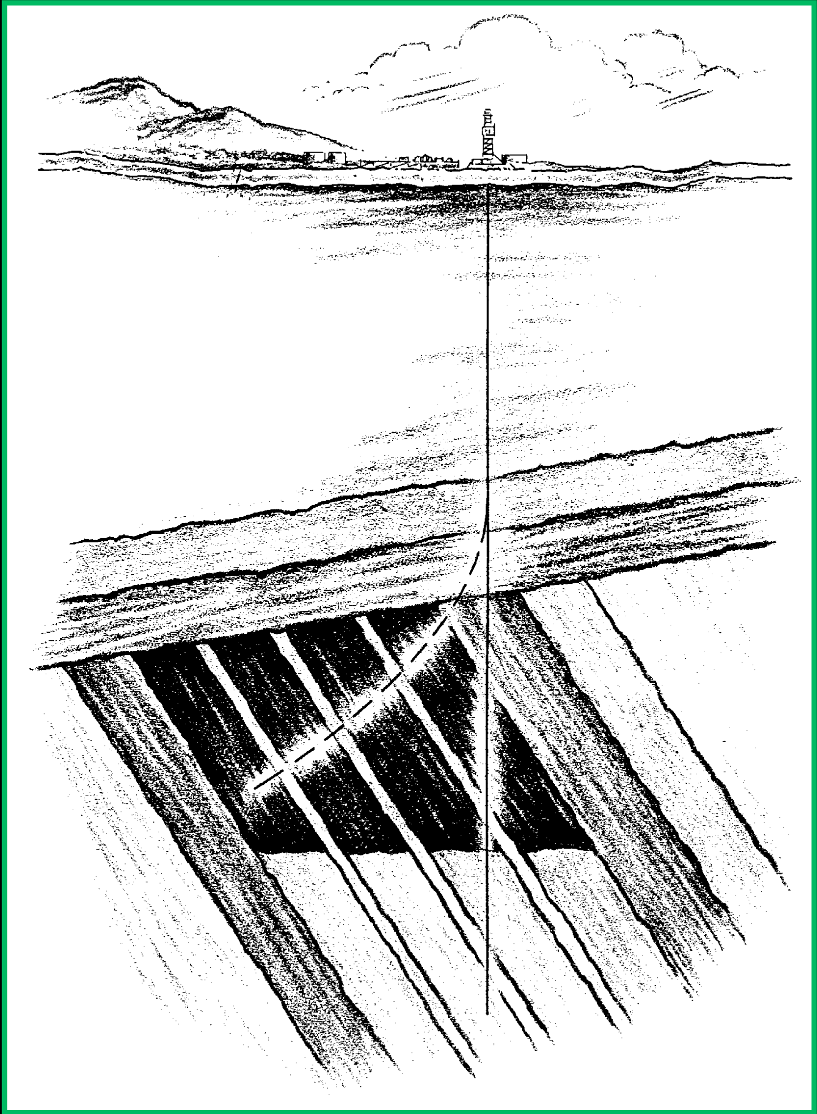
Drilling around salt domes

Salt can cause significant drilling problems and directional drilling can be used to drill under the overhanging cap



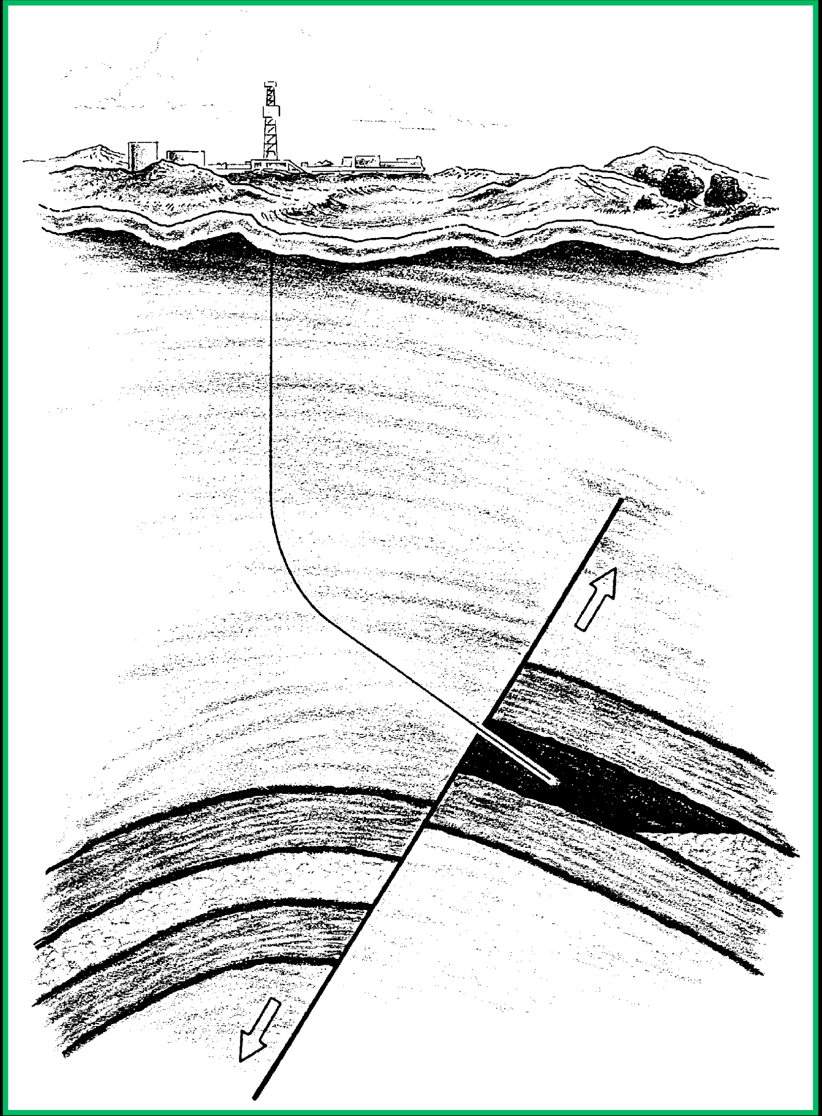
Introduction

Steeply dipping sands can be drilled with a single wellbore



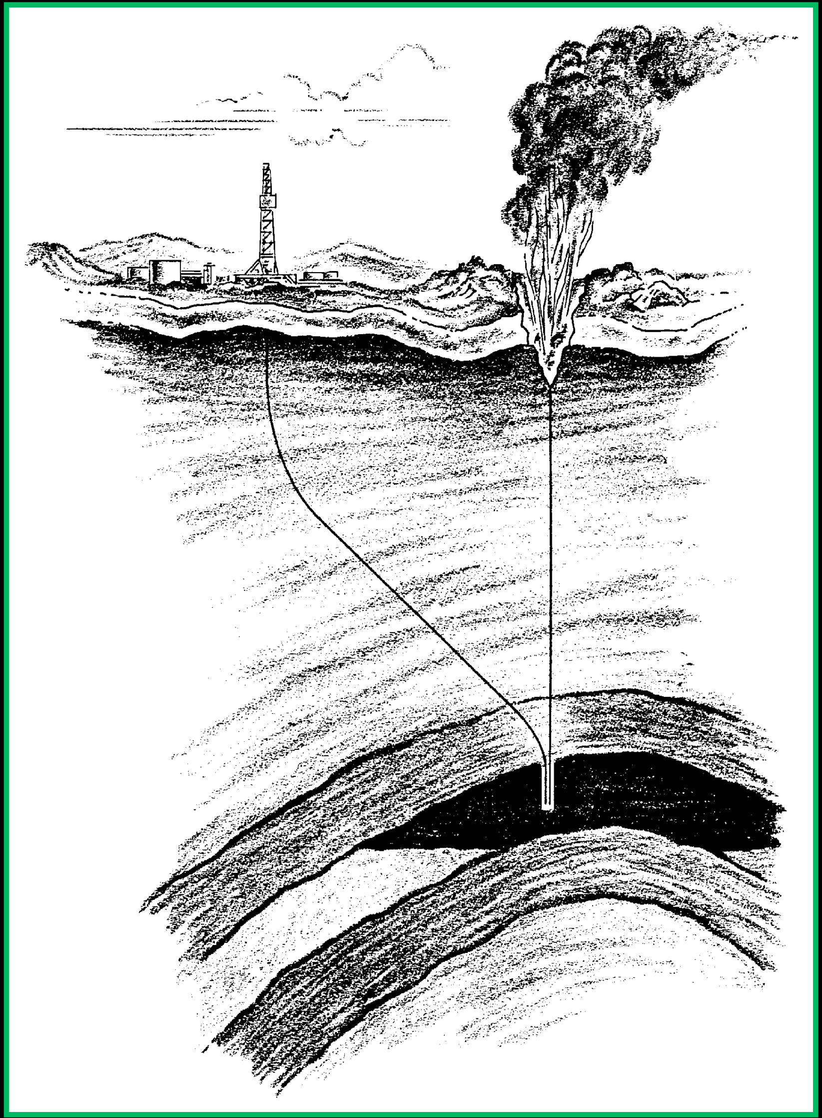
Introduction

Fault drilling
In hard rock, deviation can be a problem
Sometimes the bit can track a fault
Drilling at a higher incident angle minimizes the potential for deflection of the bit



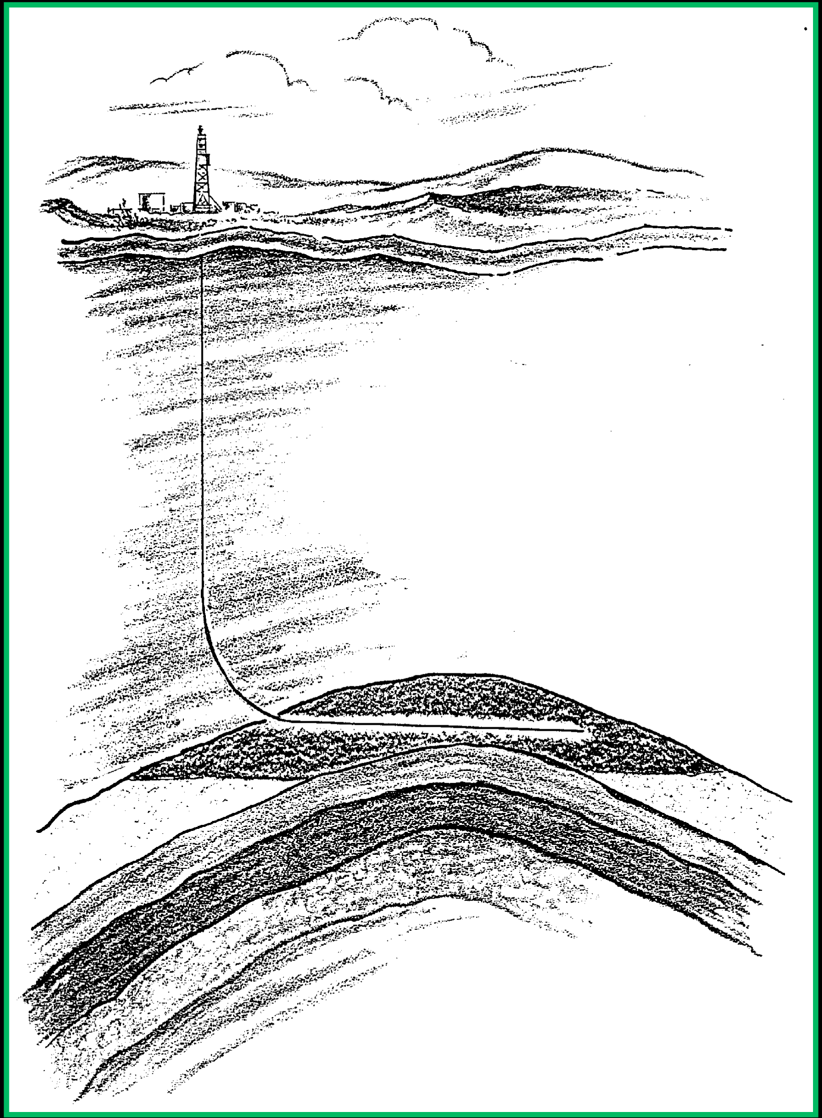
Introduction

Relief well drilling
Directional drilling into the blowout when the surface location is no longer accessible
Very small target and takes specialized equipment



Introduction

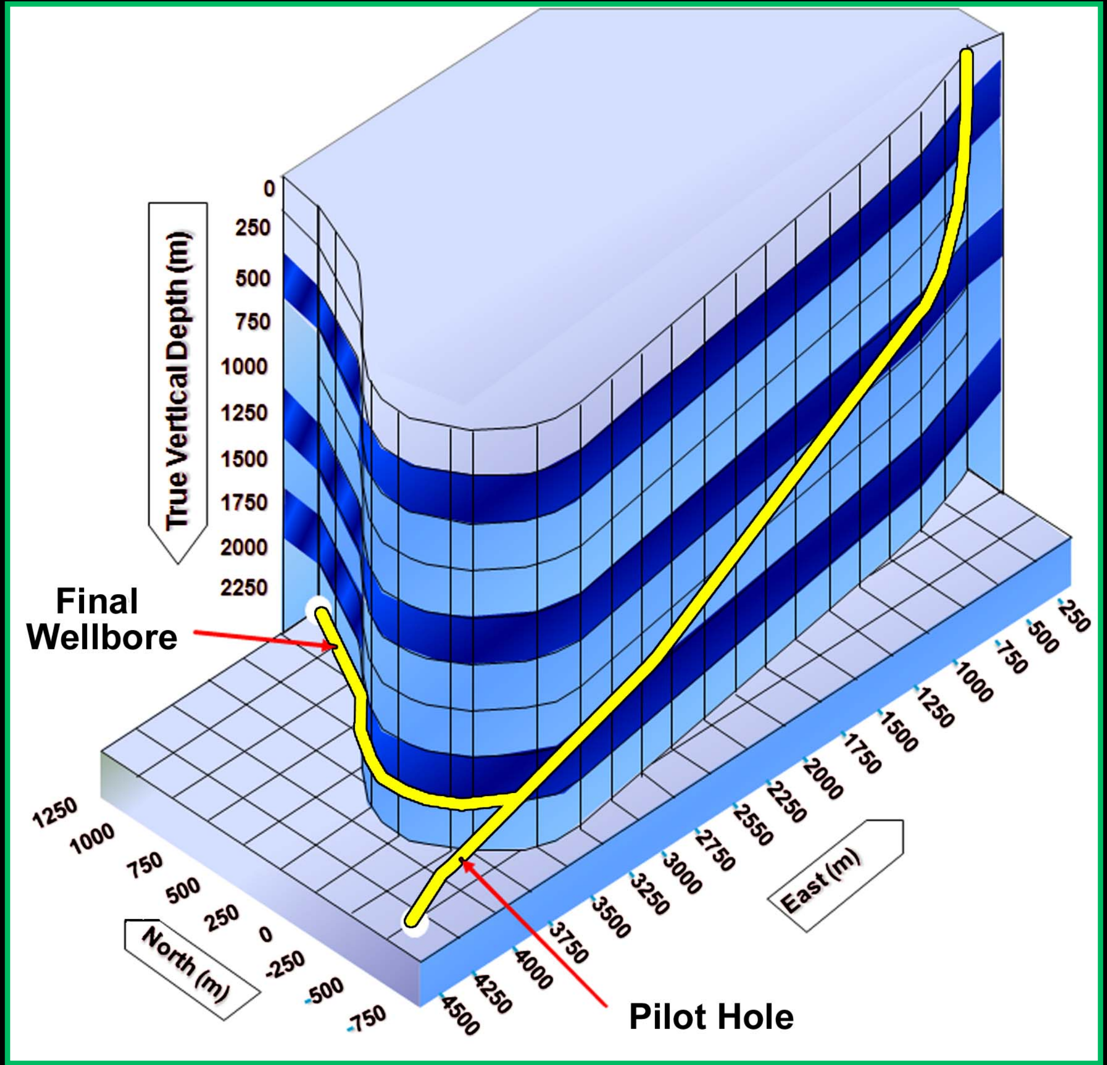
Horizontal drilling
Increasing exposure of the reservoir to increase productivity



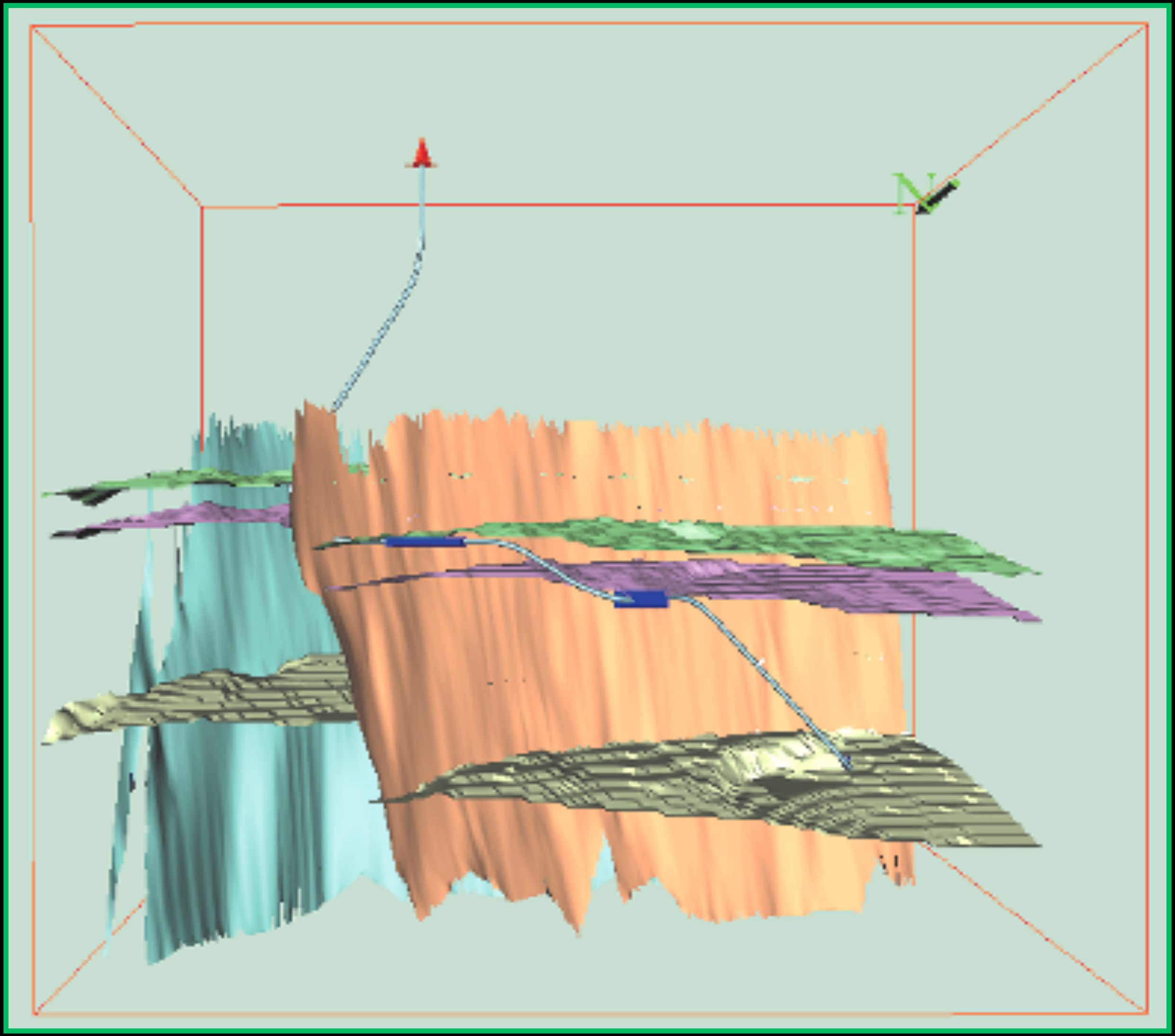
“Designer” Well

ERD Wells with significant azimuth change(s)

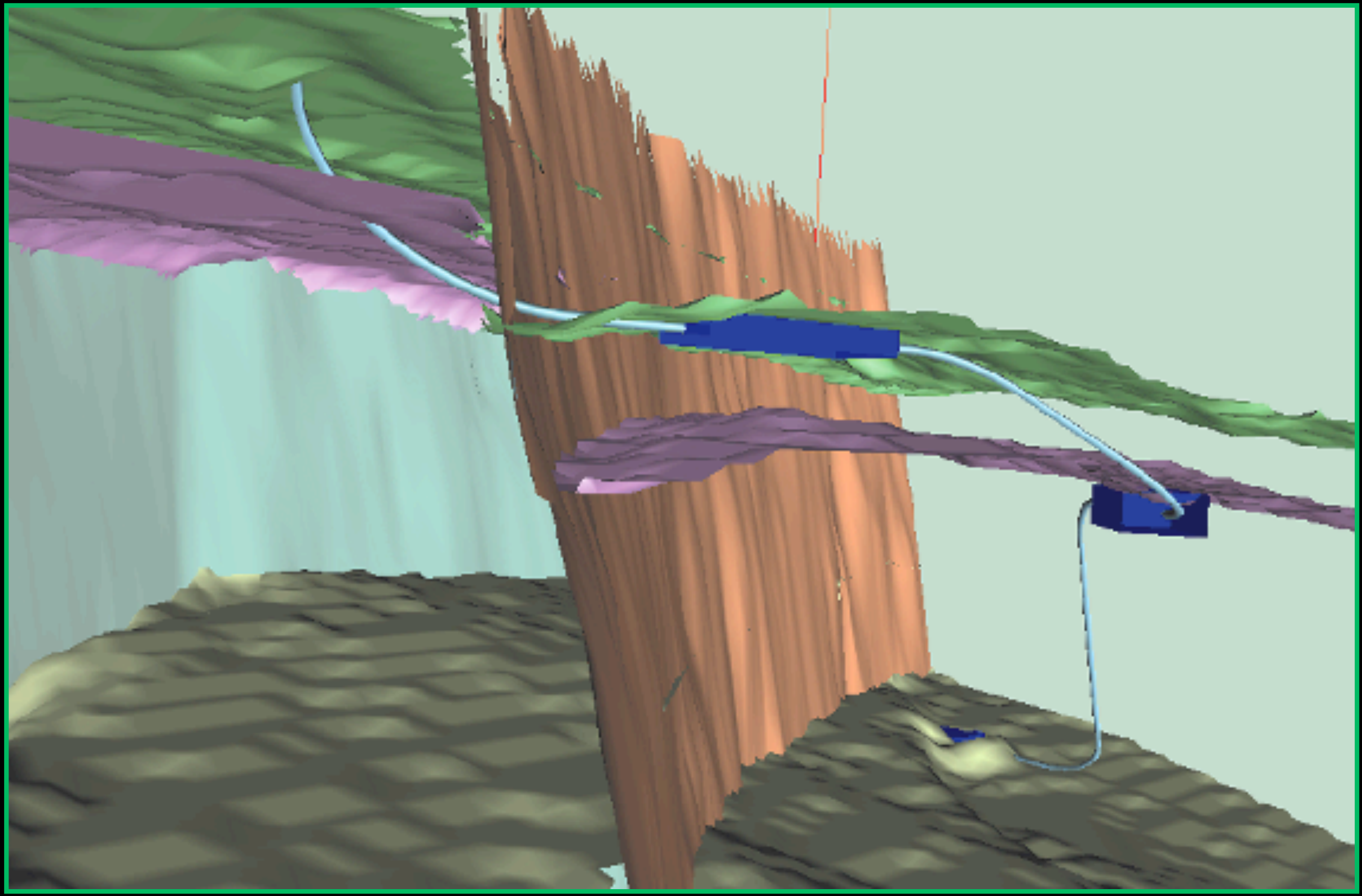
Highly engineered well plan required



Introduction

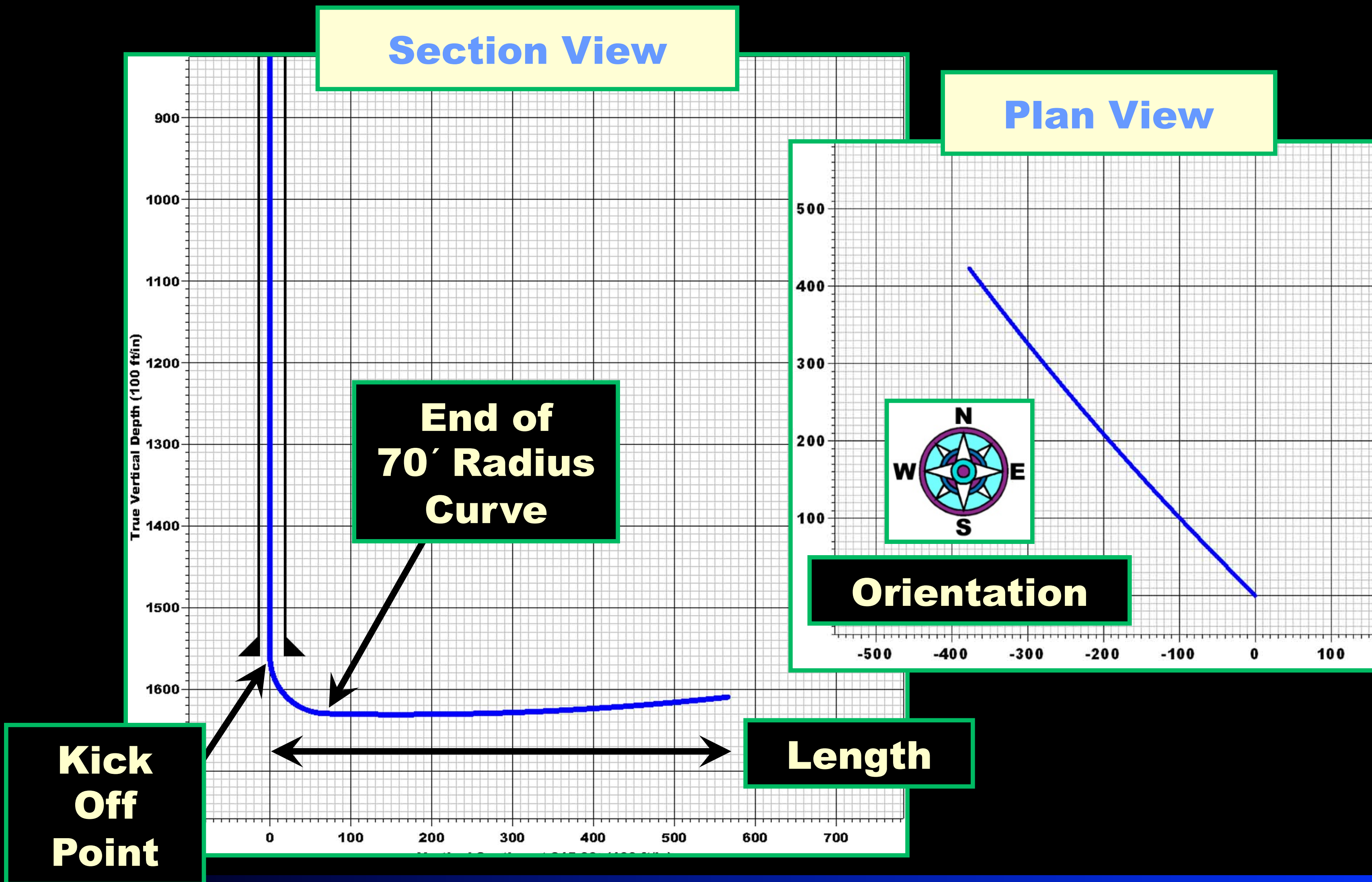


Introduction



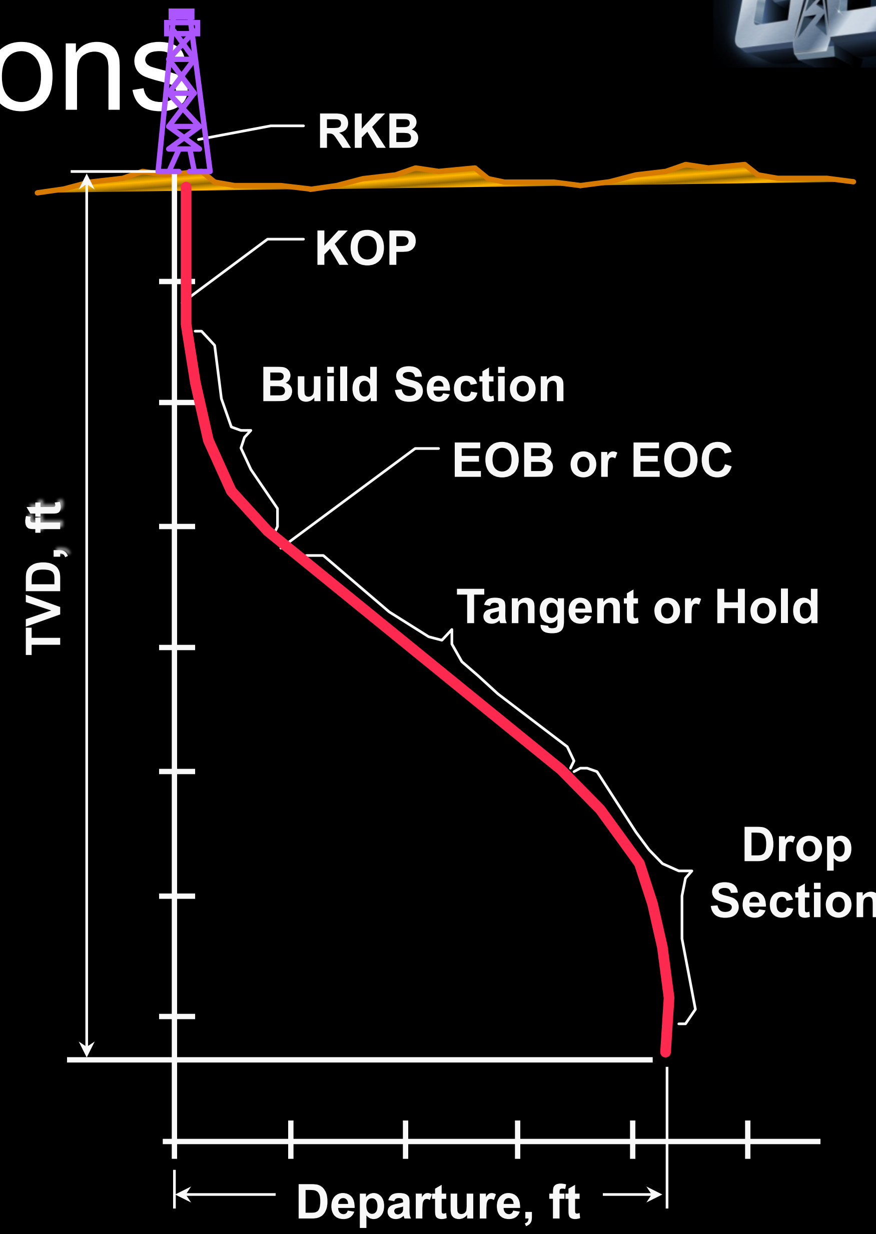
You did what???????

Survey Definitions



Survey Definitions

Common terminology for a directional profile



Survey Instruments

Survey instruments are used to measure the azimuth and inclination of the well.

Azimuth

Inclination

Survey Instruments

Magnetic surveys use the earth's magnetic field to determine the azimuth of the wellbore.

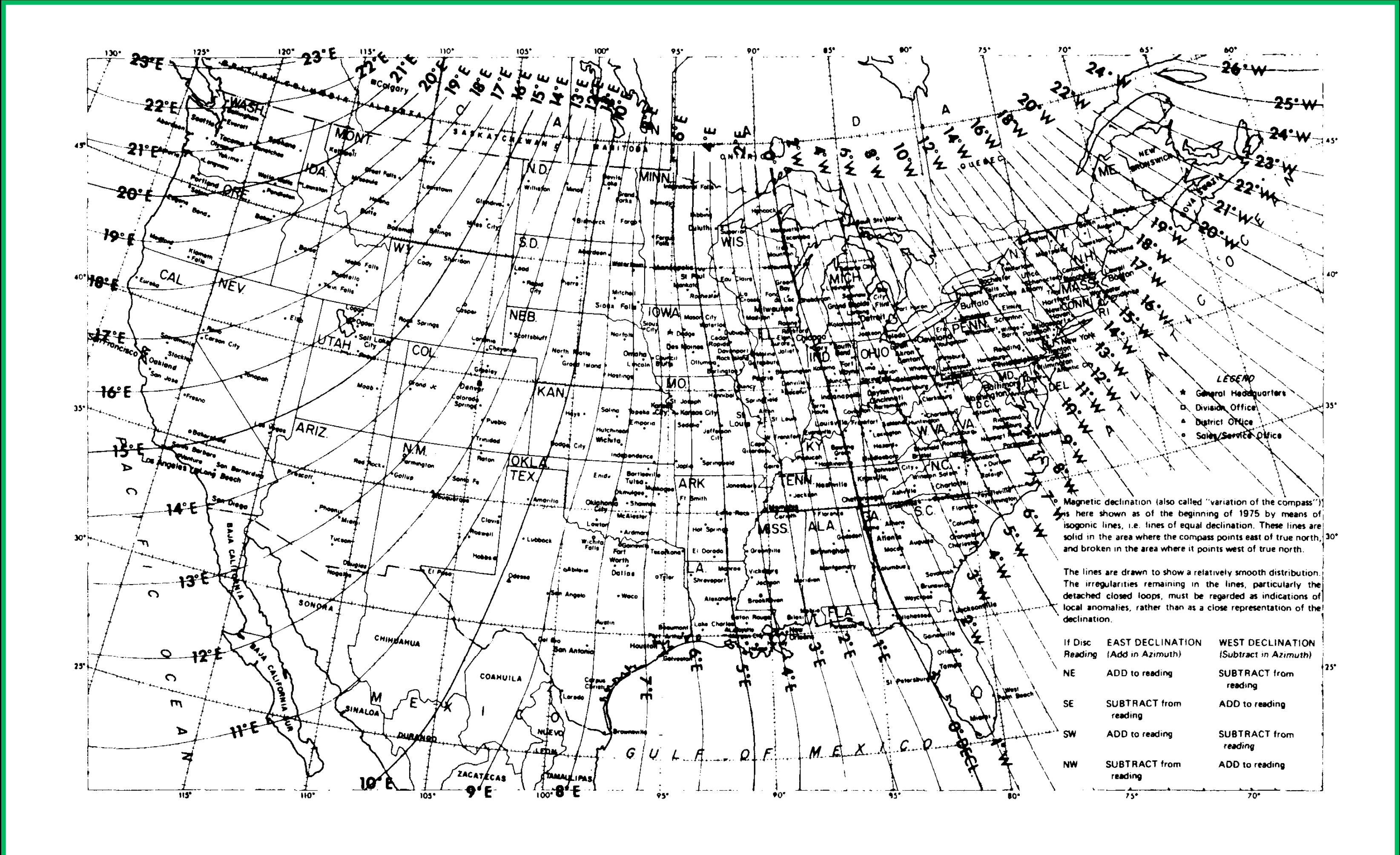
The magnetic north pole is not the same as the geographical north pole.

Survey Instruments

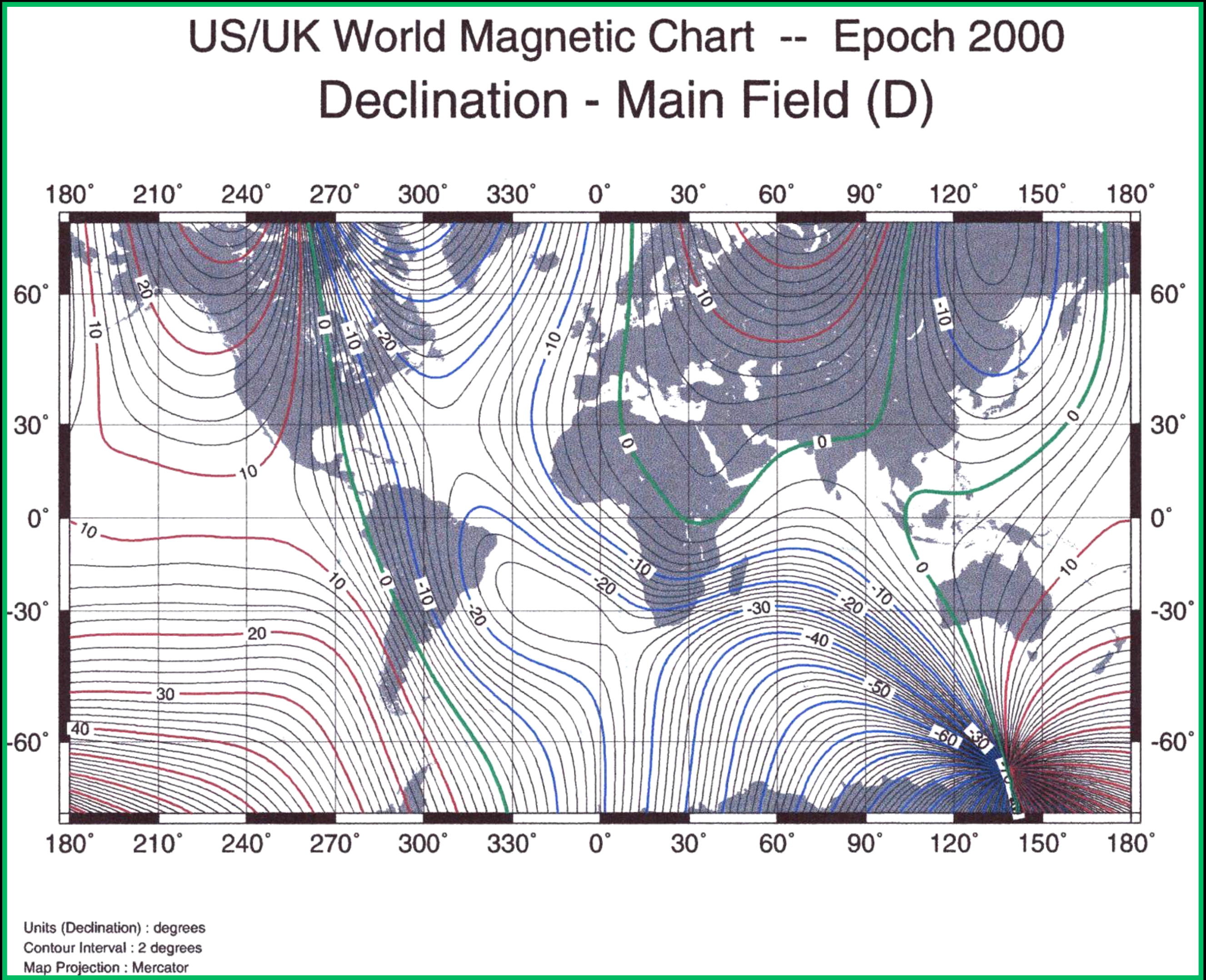
Declination is the difference between the magnetic north pole and the geographical north pole.

- It is either an east or west declination
- East declination is added to the azimuth
- West declination is subtracted from the azimuth

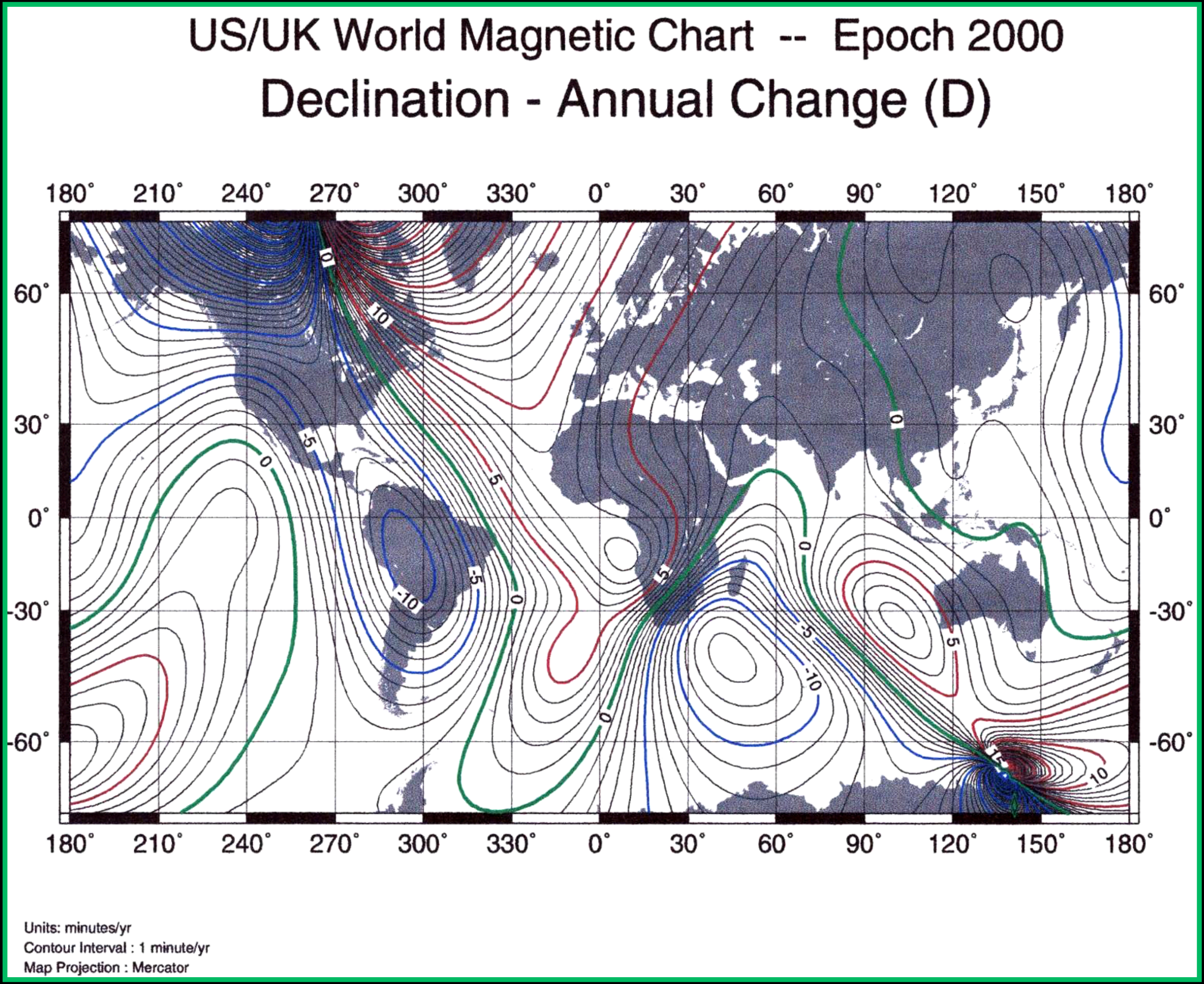
Survey Instruments



Survey Instruments



Survey Instruments



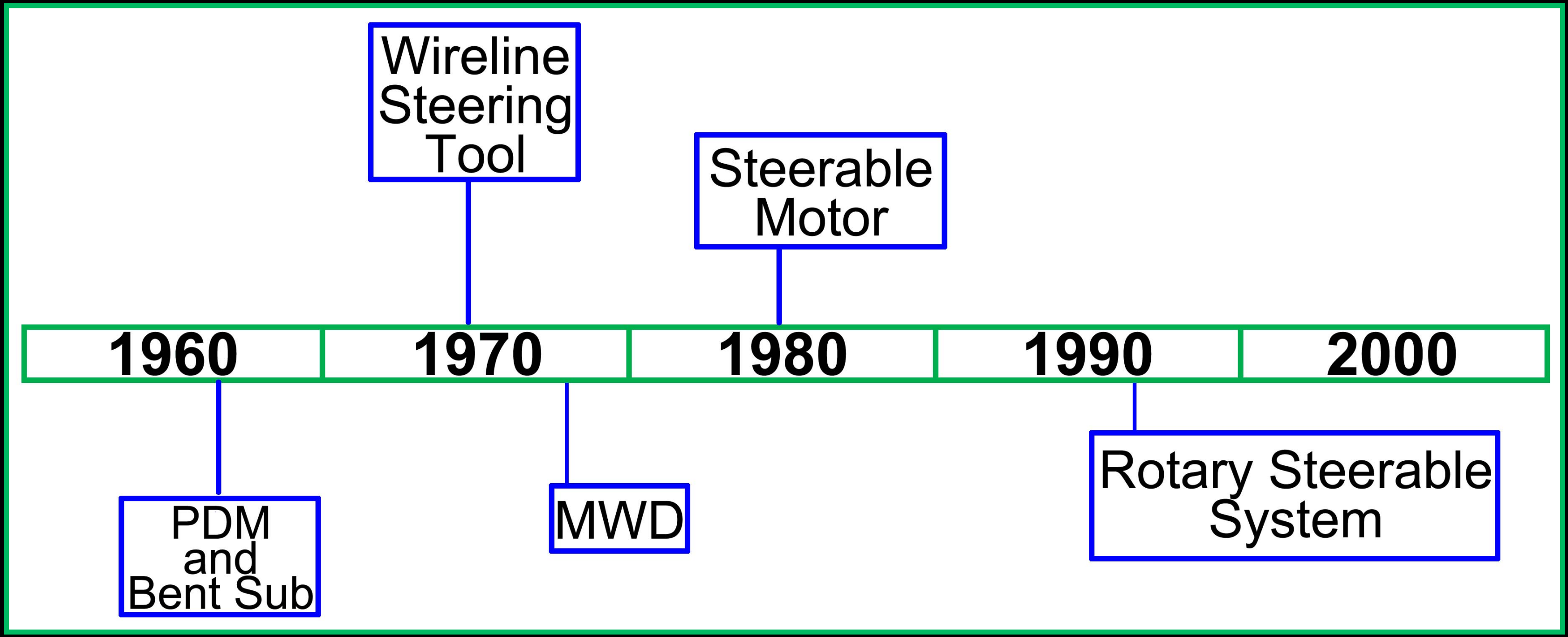
Survey Instruments

For magnetic survey instruments you must use non-magnetic (monel) drill collars.

- The survey instrument must be placed within the collars to minimize magnetic interference
- Near the middle but not precisely the middle

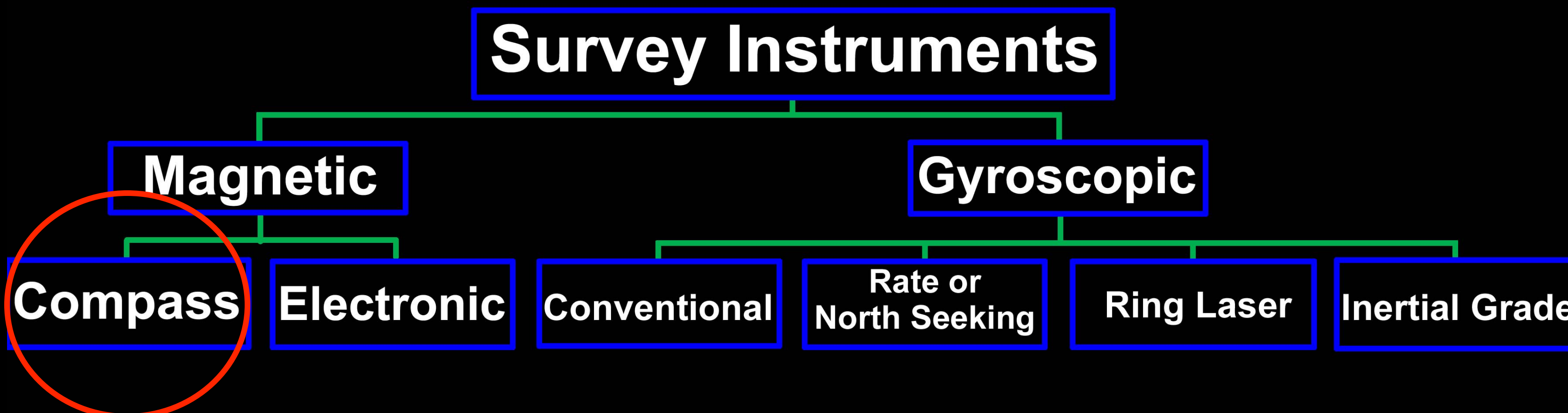
Survey Instruments

Significant advances in directional drilling technology.



Survey Instruments

Magnetic survey instruments



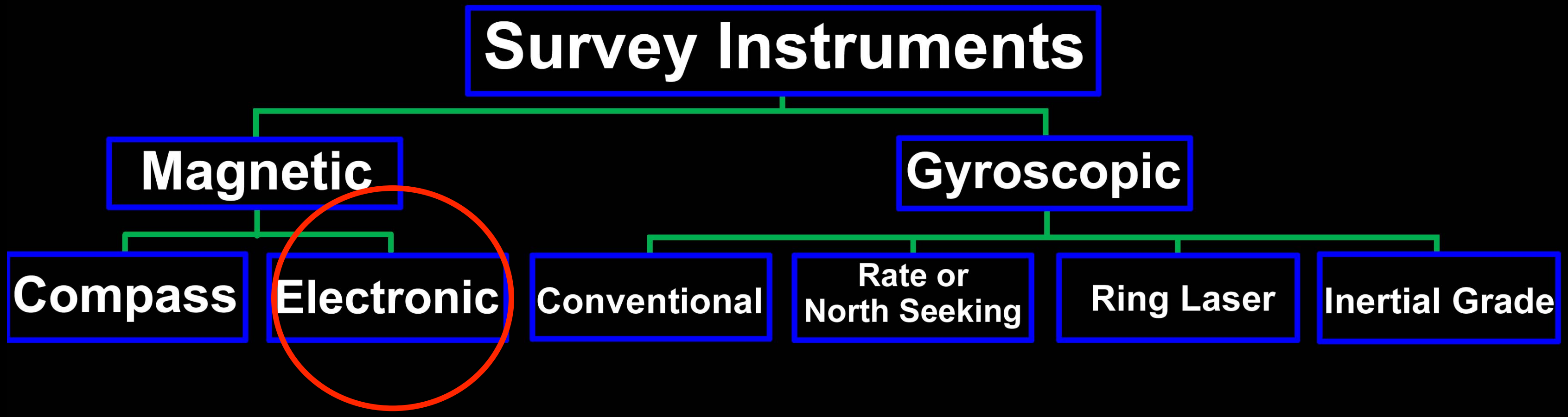
Survey Instruments

Compass

- Singleshot
- Multishot
- Both use a compass and camera
- The camera takes a picture of the compass at various depths within the wellbore

Survey Instruments

Magnetic survey instruments



Survey Instruments

Electronic

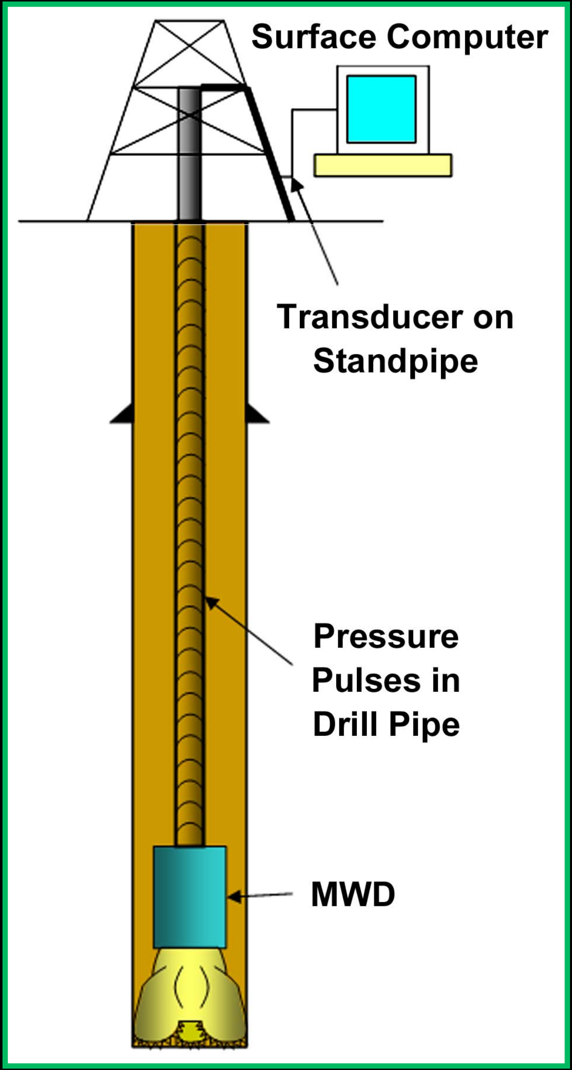
- Steering Tool
- MWD (Measurement While Drilling)
- EMS (Electronic Multishot)

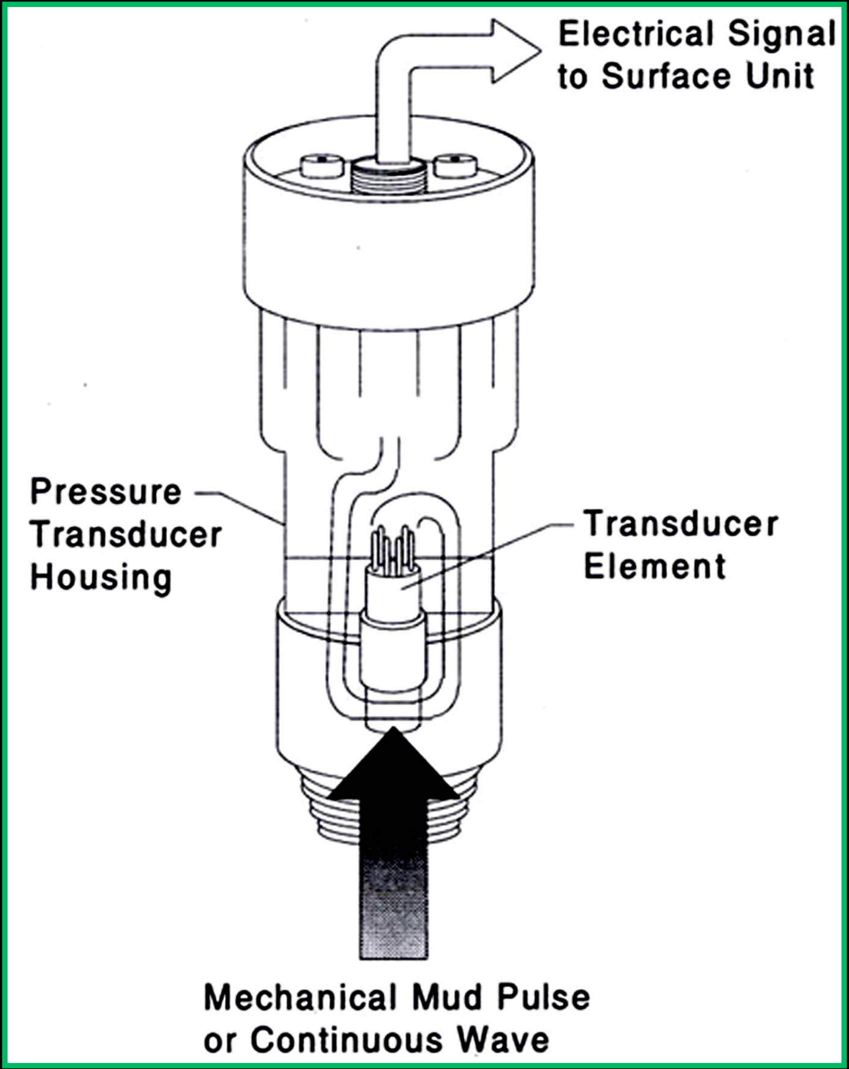
Survey Instruments

All electronic survey tools use the same instruments to measure the inclination and azimuth.

- Accelerometers to measure the inclination
- Magnetometers to measure the azimuth

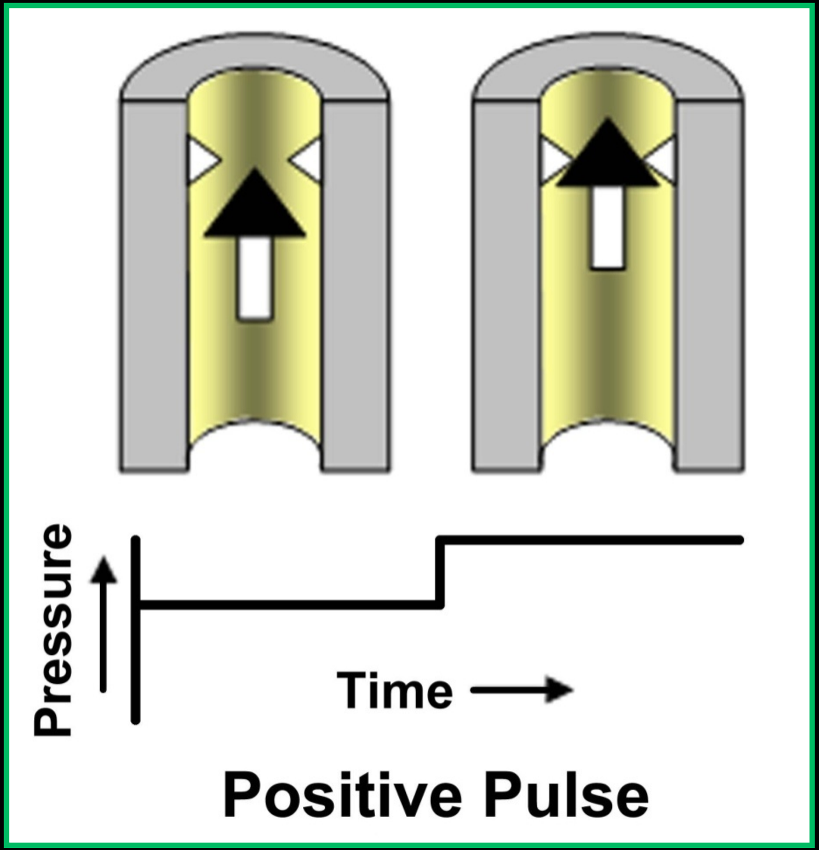
MWD Instruments



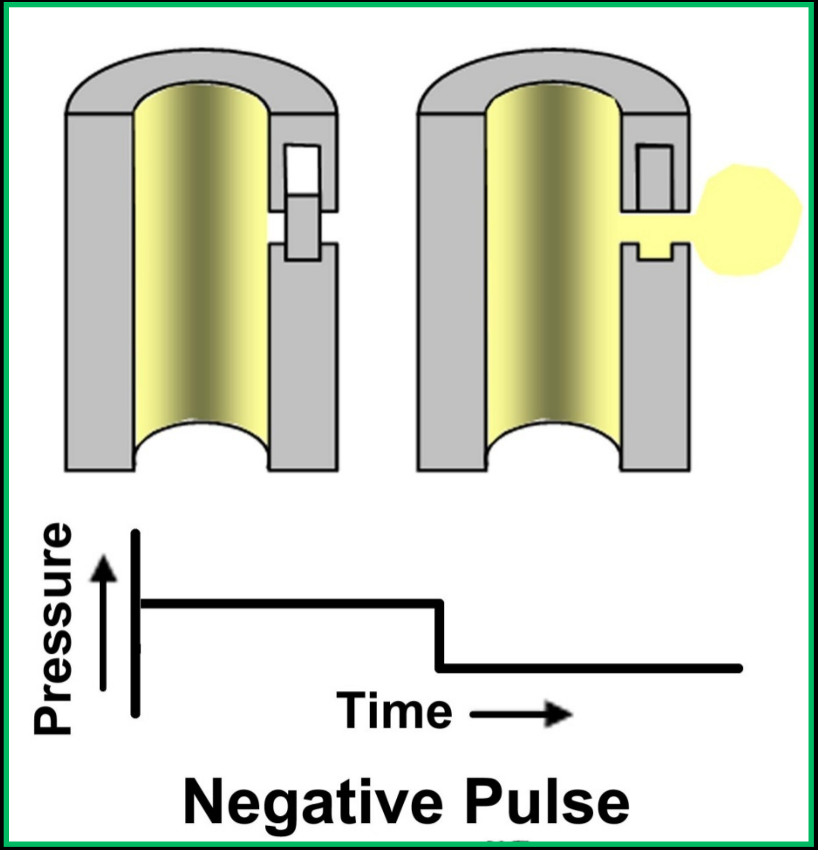


MWD Instruments

Positive pulse – a restriction in the MWD causes an increase in pressure 1’s and 0’s



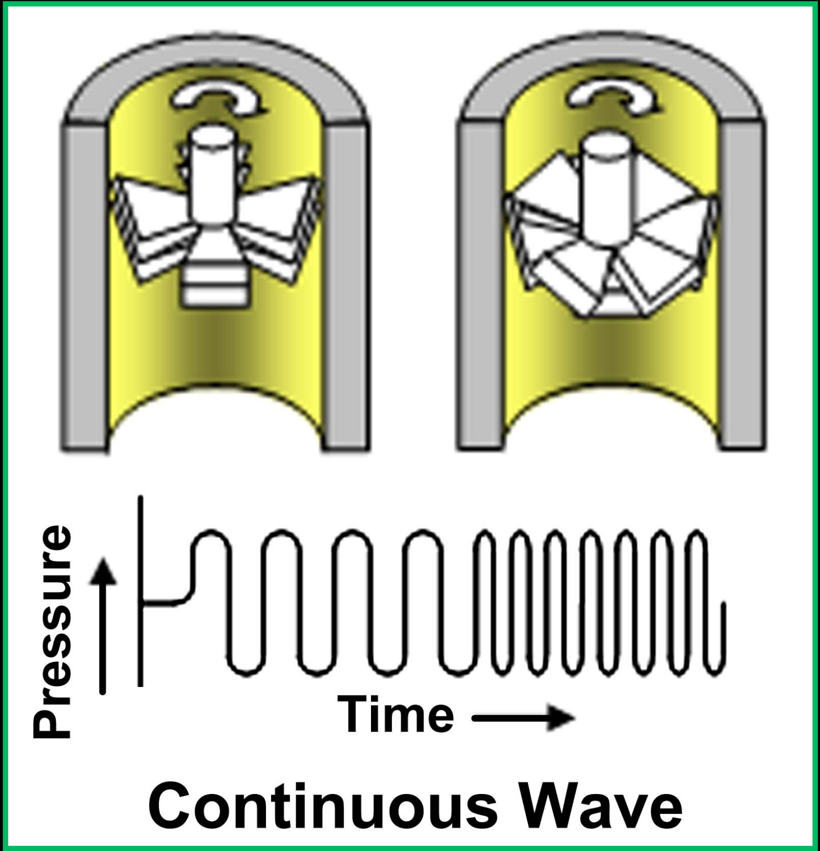
MWD Instruments



Negative pulse uses a valve in the side of the MWD to bypass some of the fluid reducing the standpipe pressure

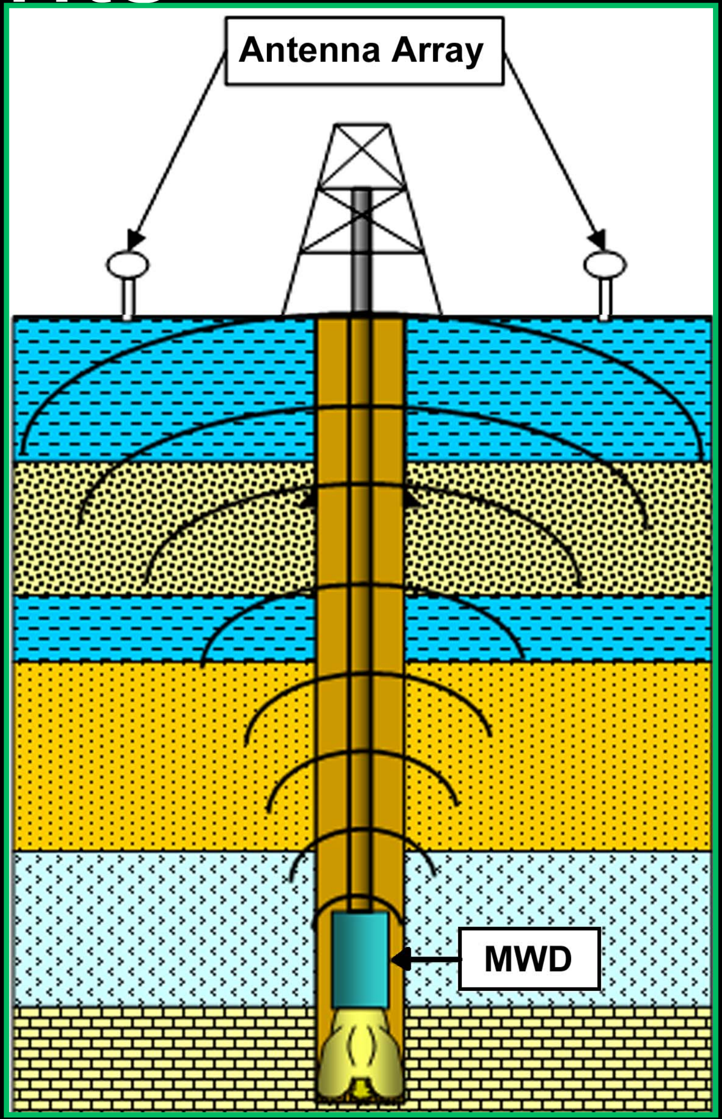
MWD Instruments

Continuous wave modulates the frequency to generate 1's and 0's



EMWD Instruments

Electromagnetic MWD uses radio waves
Works in compressible fluids (underbalanced)



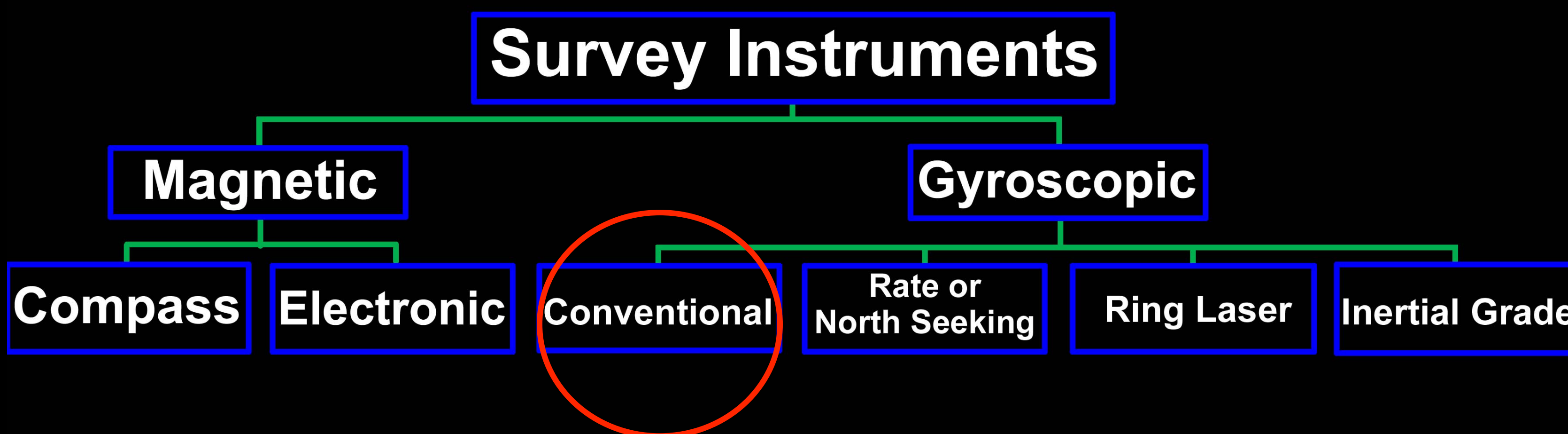
Survey Instruments

The EMS or electronic multishot stores the information in a computer chip (memory). Once the tool is retrieved from the hole, the survey data is downloaded into a computer.

Survey Instruments

Gyroscopic tools

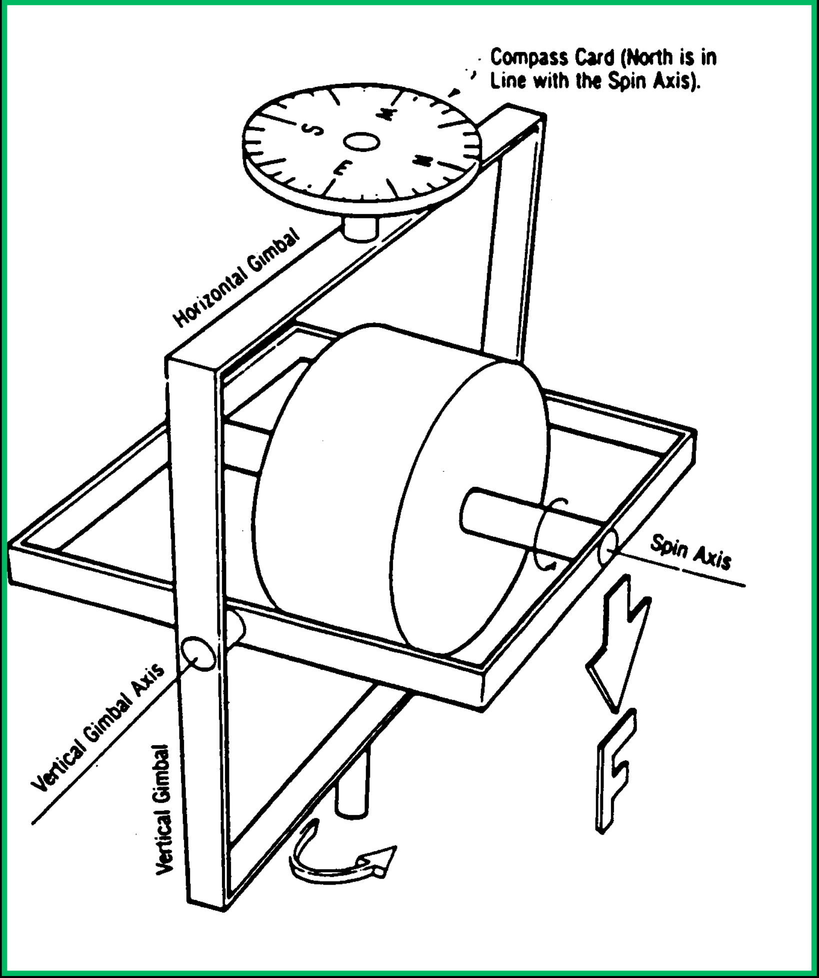
- Conventional Gyro
- Rate or North Seeking Gyro
- Ring Laser Gyro



Survey Instruments

Conventional gyro

- Get direction only and not inclination
- Inclination is still with accelerometers

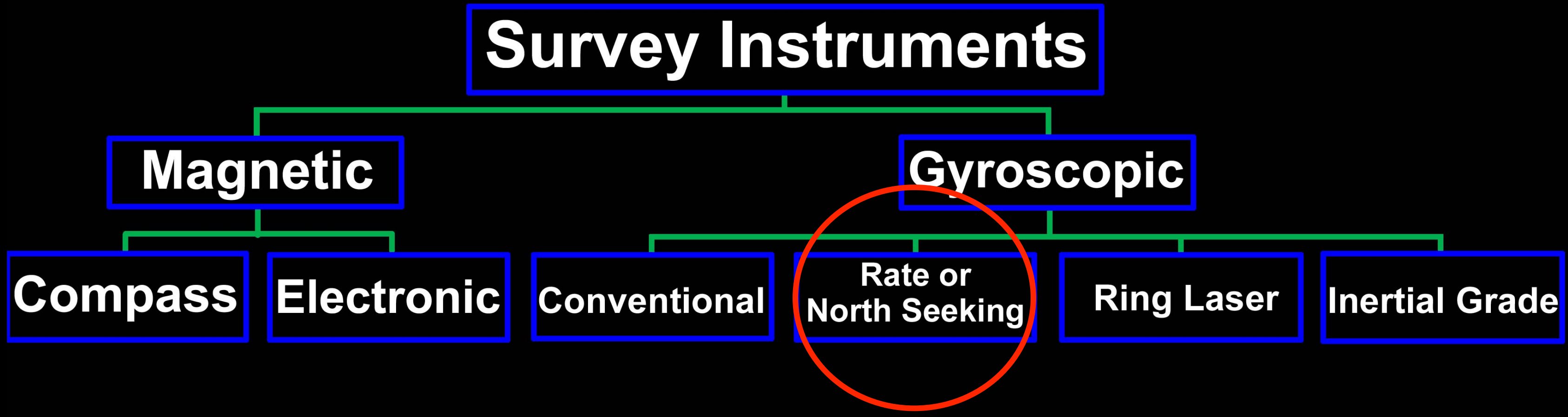


Survey Instruments

A conventional gyro must be referenced. You have to know which way the axis is pointing. The conventional gyro has drift due to imperfections in the gyro and the earth's rotation.

Survey Instruments

Rate or North Seeking Gyro



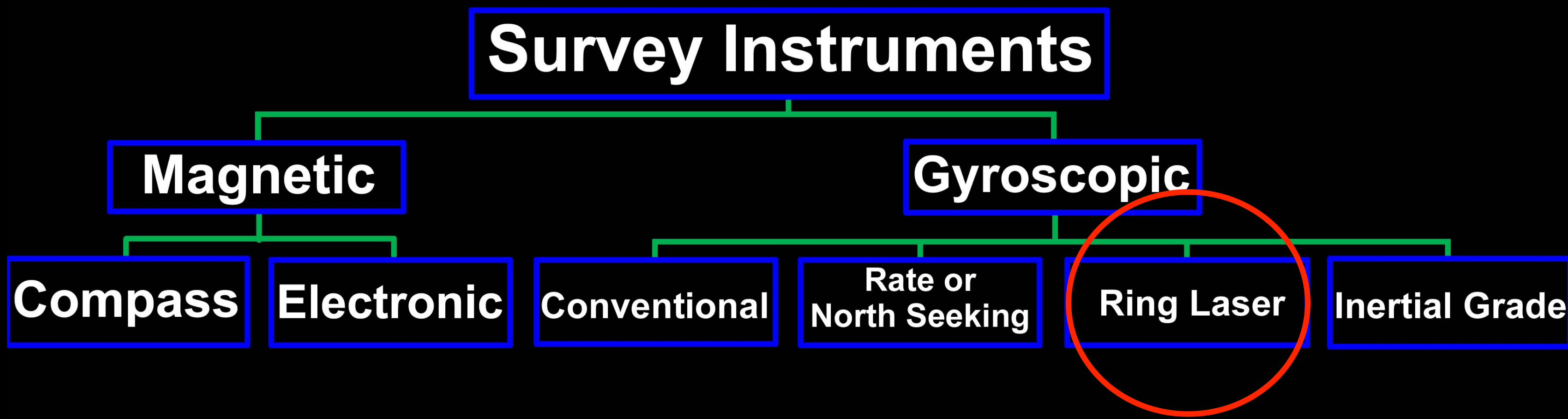
Survey Instruments

Rate or North Seeking Gyro

- Determines which way is north without referencing.
- Automatically adjusts for drift electronically.
- More accurate than the conventional gyro.

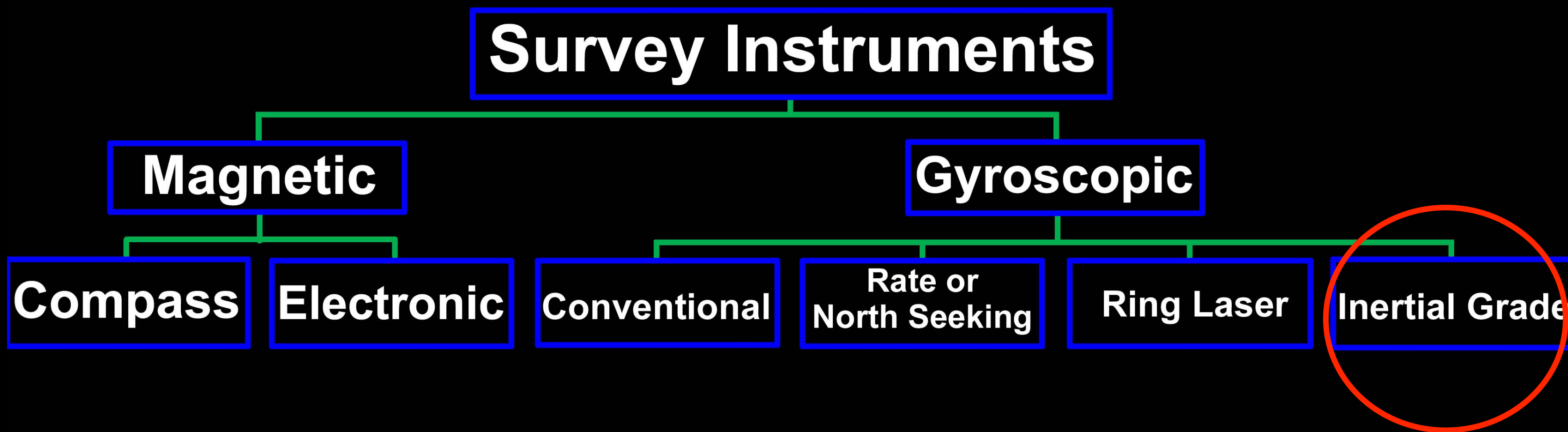
Survey Instruments

Ring laser gyro uses lasers to get direction.
More accurate than rate gyro. 5 1/4” OD



Survey Instruments

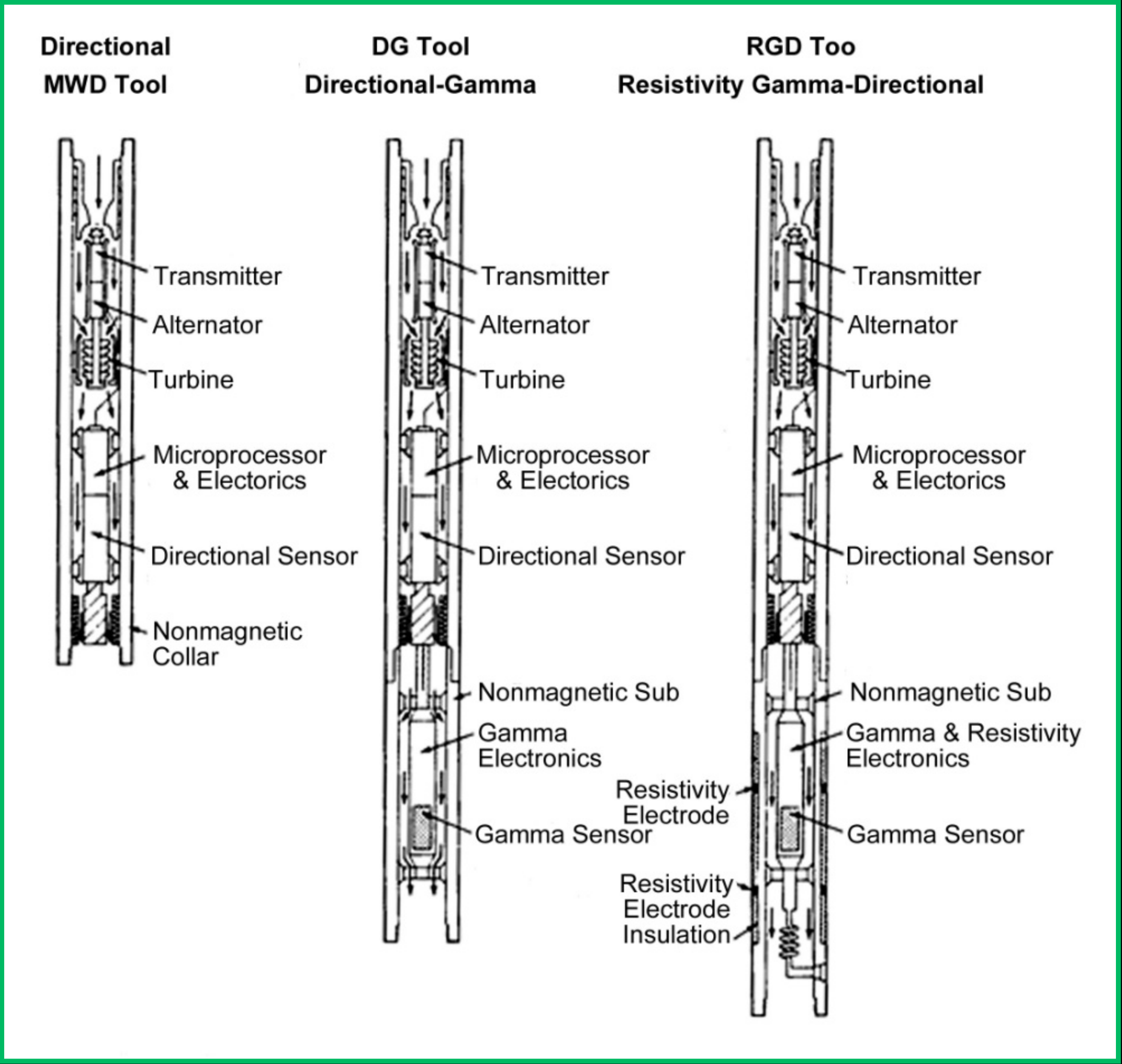
Inertial grade gyro is the same gyro used for navigation, 10 5/8” OD.



LWD

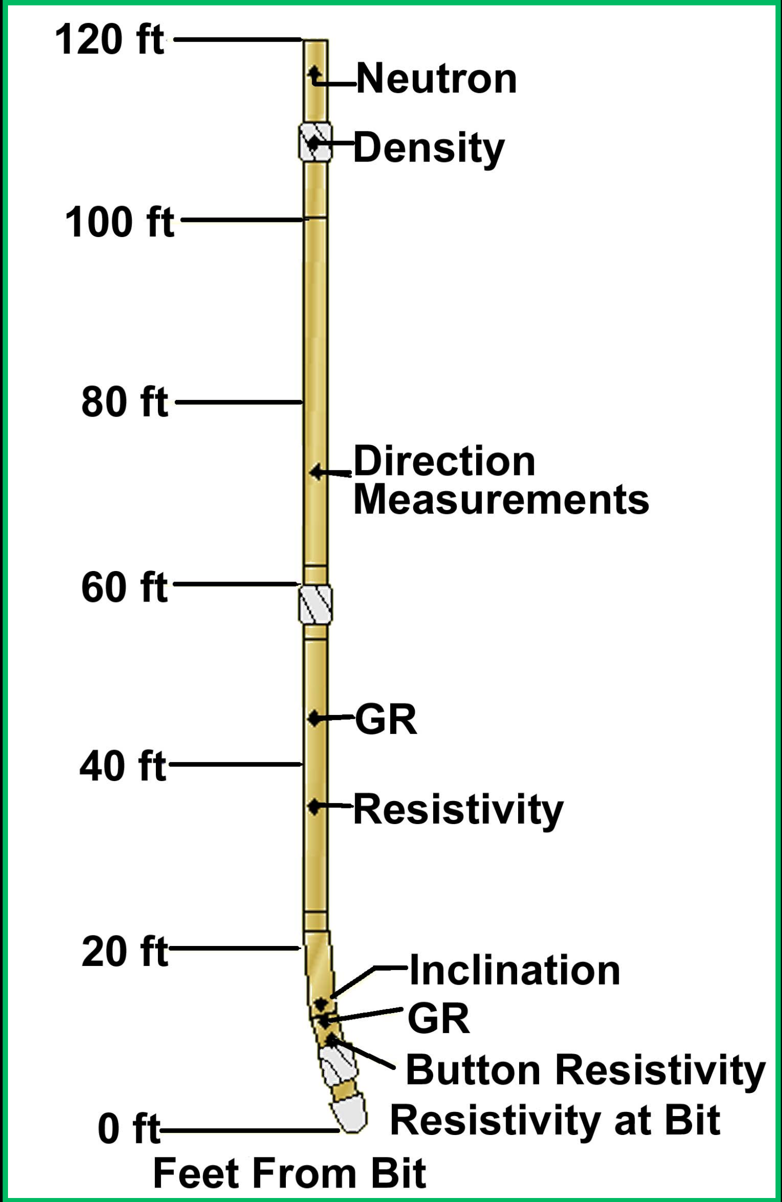
- LWD tools are added to the MWD tool and the MWD pulser sends the information to the surface.
- Some of the LWD data may be stored in memory and downloaded later

LWD


Directional
MWD Tool
DG Tool
Directional-Gamma
RGD Too
Resistivity Gamma-Directional
Transmitter
Alternator
Turbine
Microprocessor
& Electorics
Directional Sensor
Nonmagnetic
Collar
Transmitter
Alternator
Turbine
Microprocessor
& Electorics
Directional Sensor
Nonmagnetic Sub
Gamma
Electronics
Gamma Sensor
Transmitter
Alternator
Turbine
Microprocessor
& Electorics
Directional Sensor
Nonmagnetic Sub
Gamma & Resistivity
Electronics
Resistivity
Electrode
Gamma Sensor
Resistivity
Electrode
Insulation

LWD

Geo-Steering



Methods of Deflecting a Wellbore

Any number of directional tools can be used to deflect a wellbore or make the wellbore go where we want it to go.

Methods of Deflection

Whipstocks

Rotary BHA
- Rotary BHA with adjustable stabilizer

Motor
- Steerable motor

Rotary steerable assembly

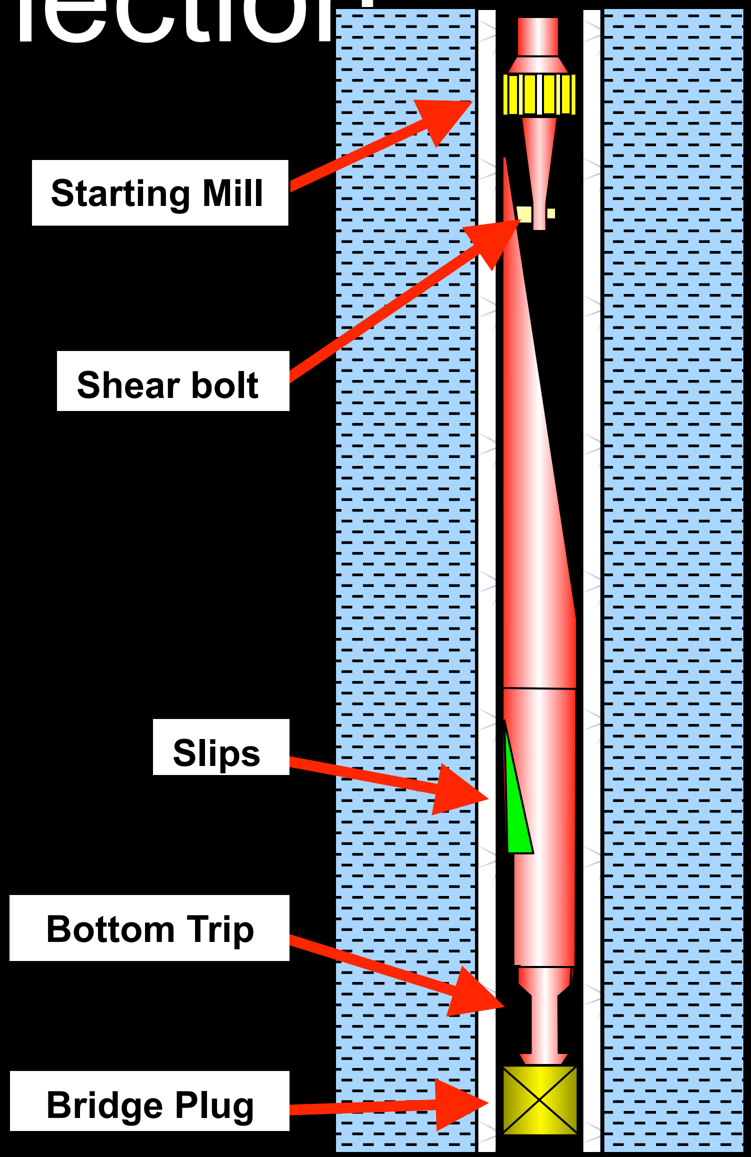
Methods of Deflection

Whipstock

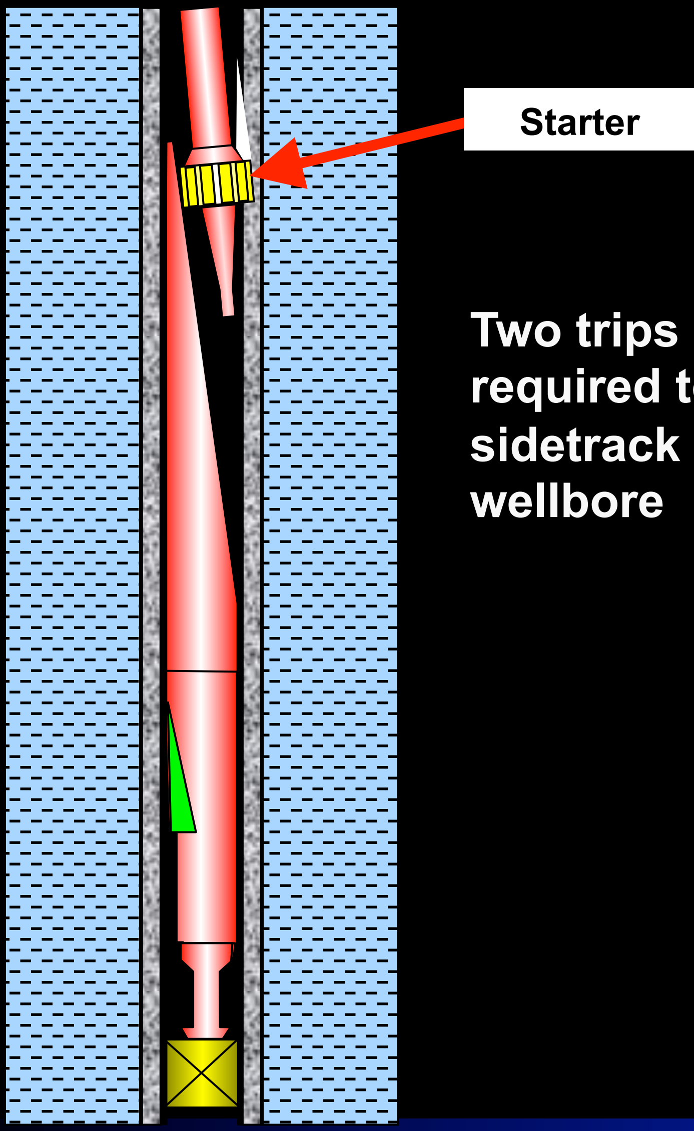
- One of the earliest tools.
- The whipstock is a metal wedge.

Methods of Deflection

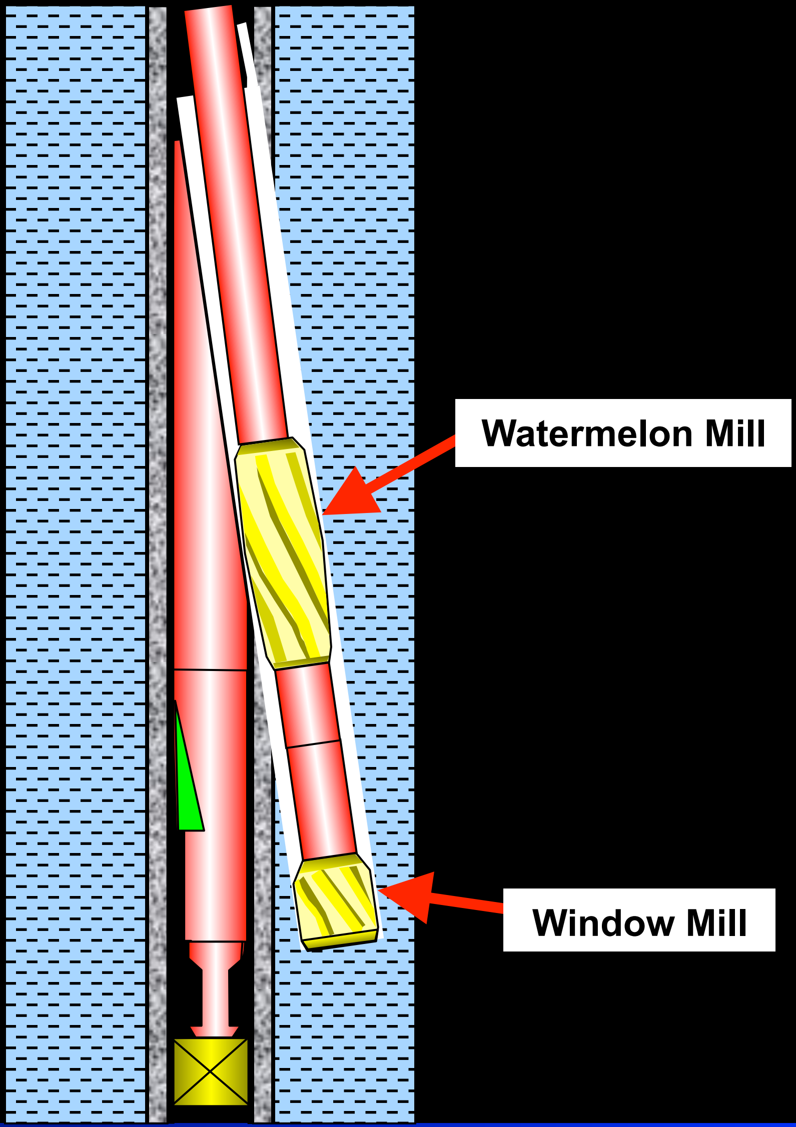
The primary use of a whipstock today is in sidetracking out of casing



Methods of Deflection



Two trips are required to sidetrack the wellbore



Methods of Deflection

Rotary BHA

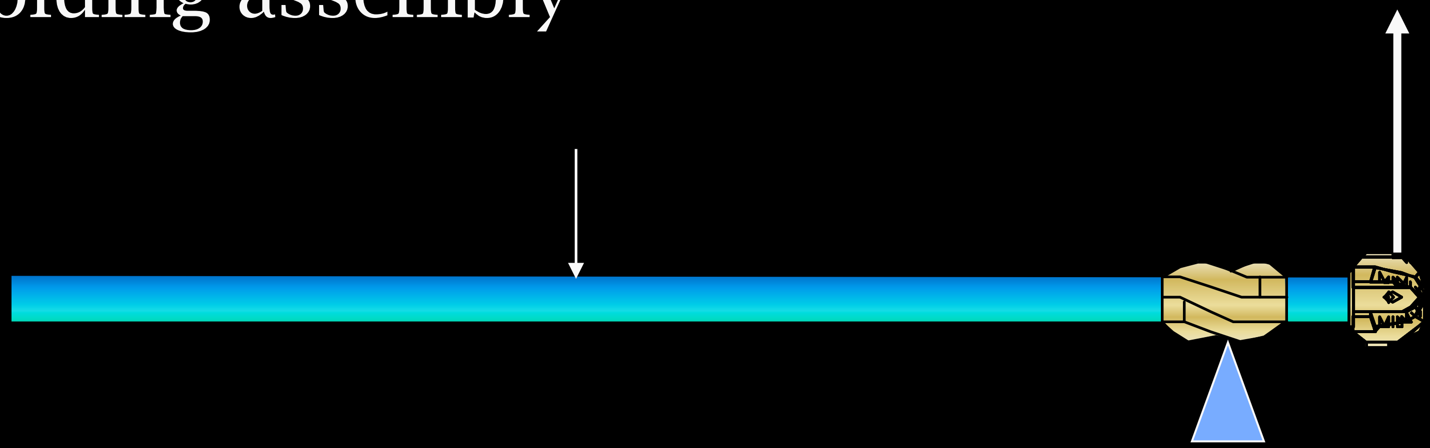
The rotary BHA consists of a bit, drill collars, stabilizers, reamers run below the drill pipe.

Methods of Deflection

Building assembly

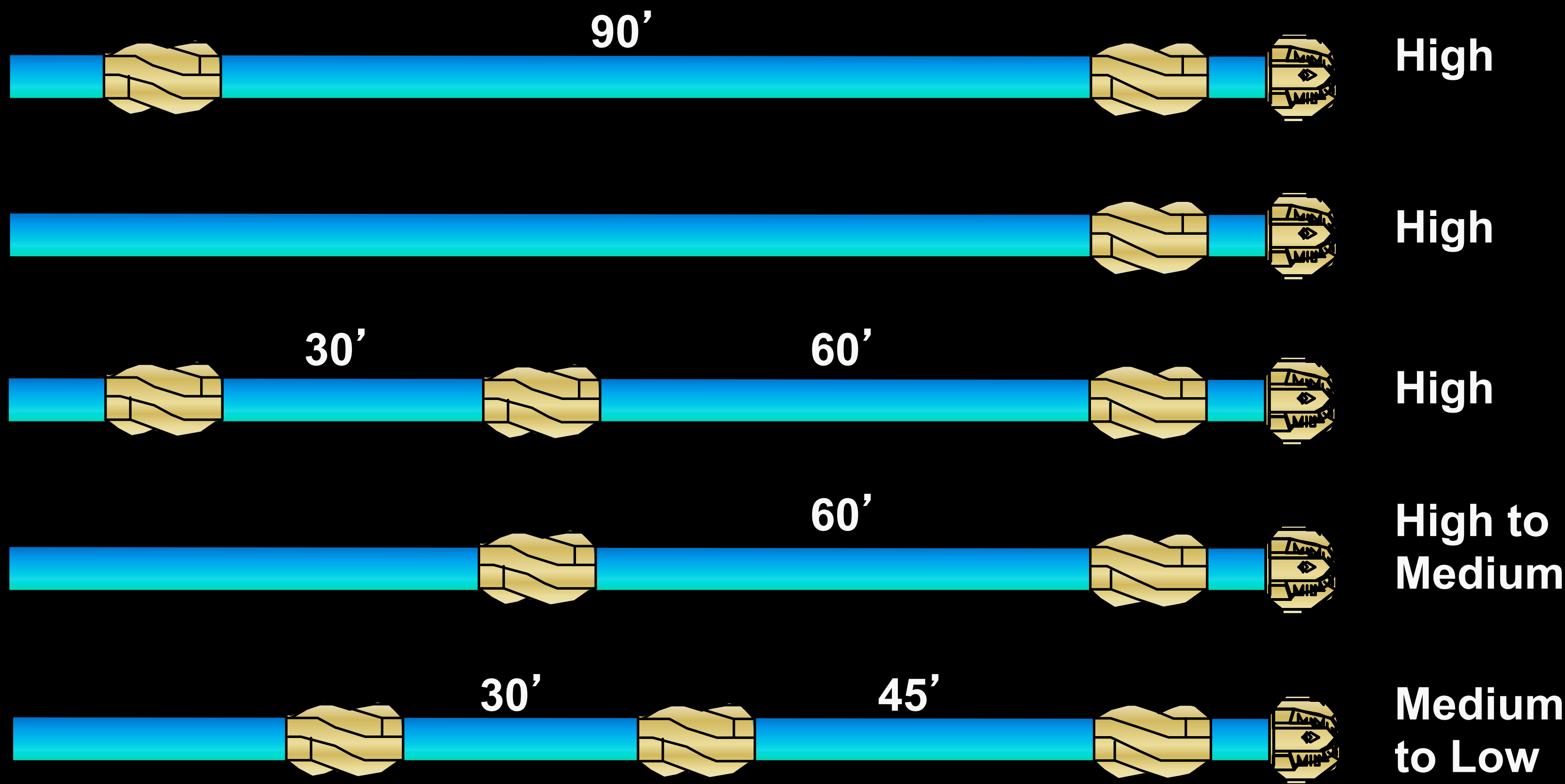
Dropping assembly

Holding assembly



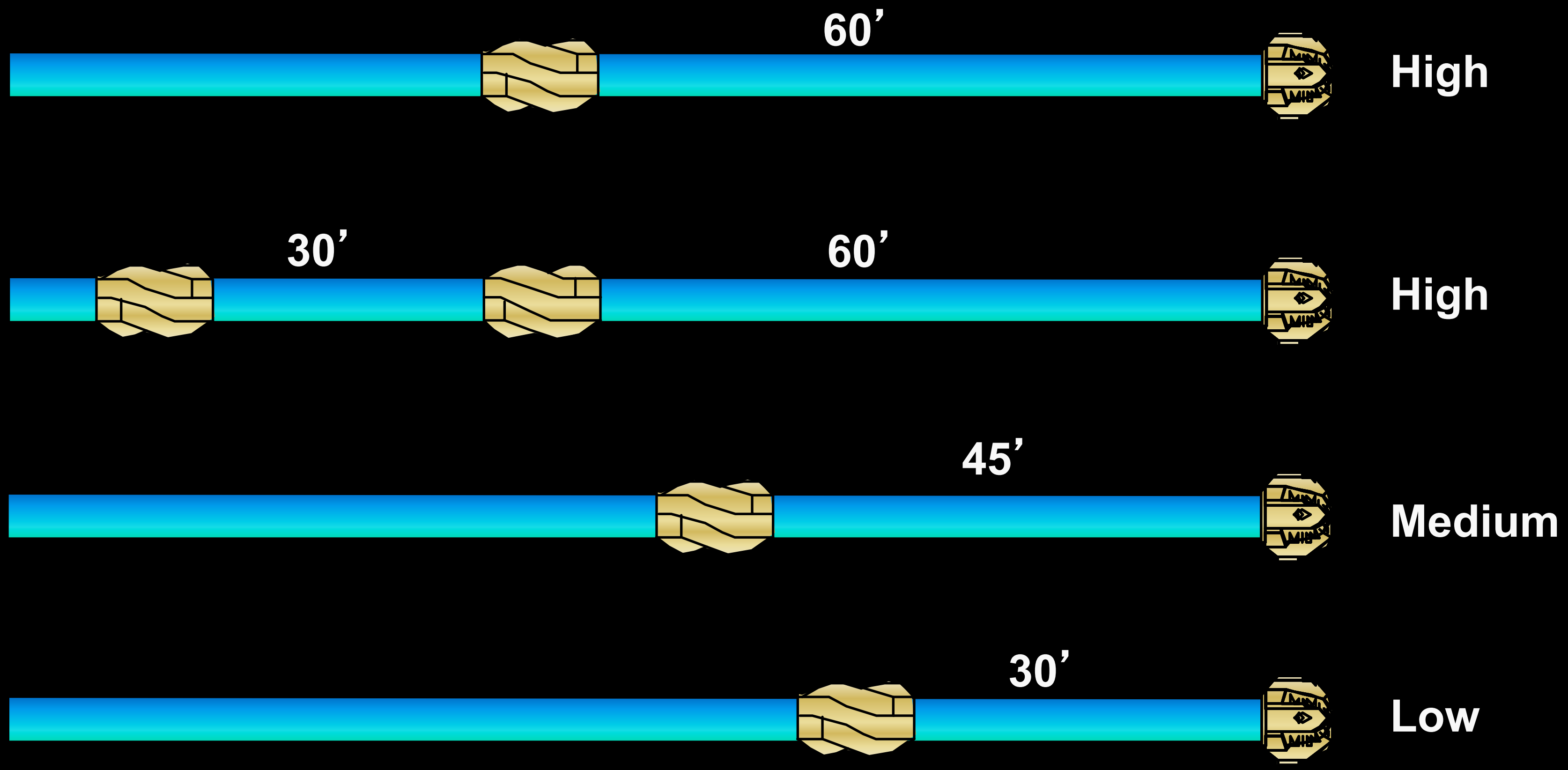
Methods of Deflection

Building Assemblies



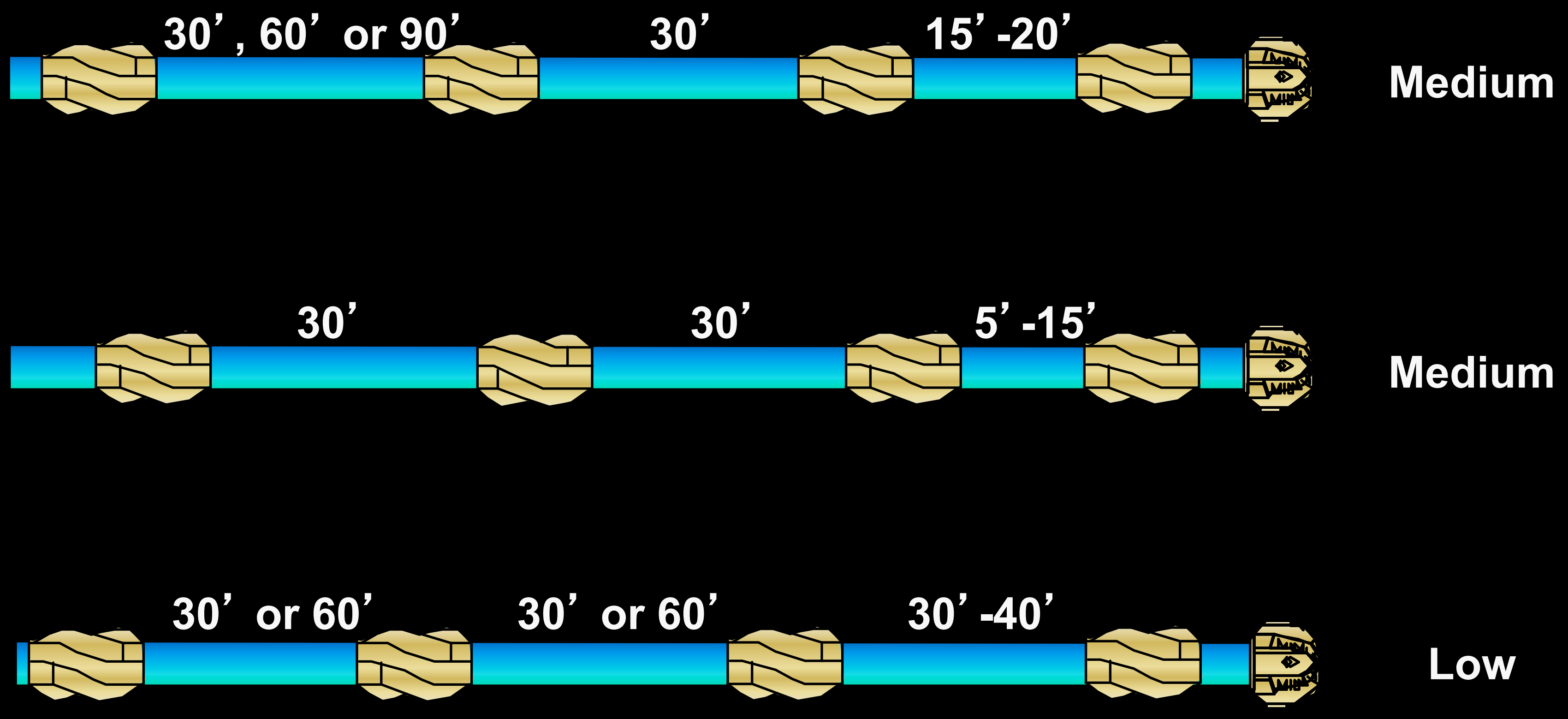
Methods of Deflection

Dropping Assemblies



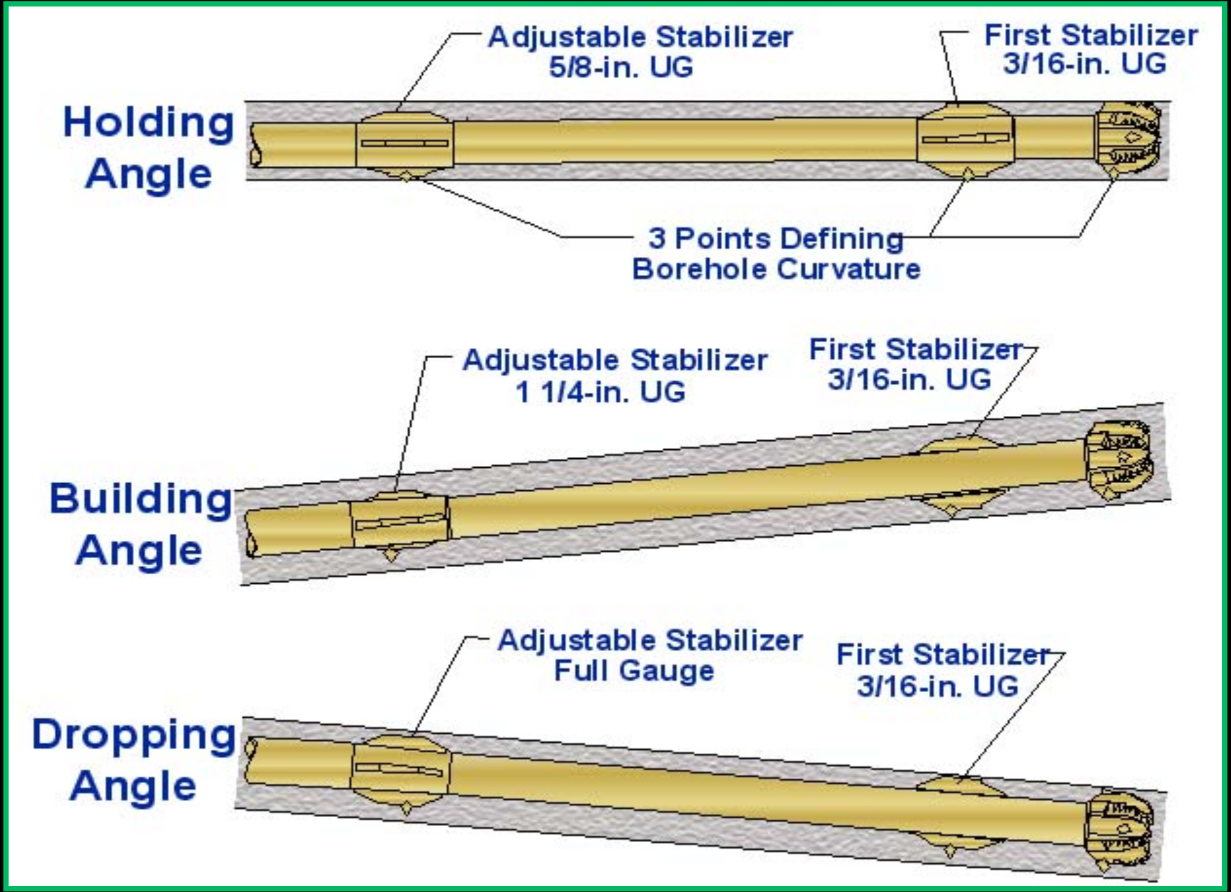
Methods of Deflection

Holding Assemblies

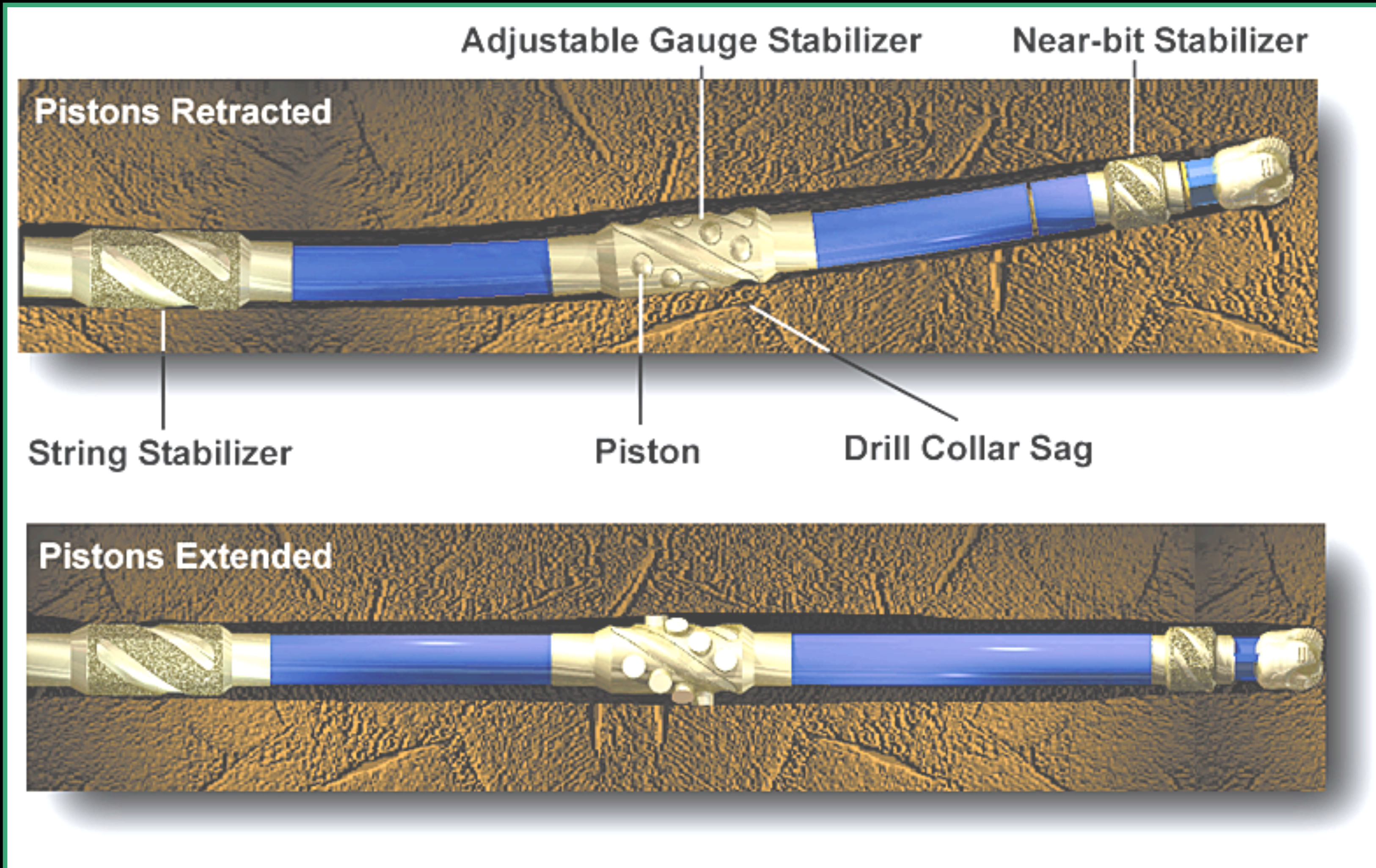


Methods of Deflection

Adjustable stabilizer

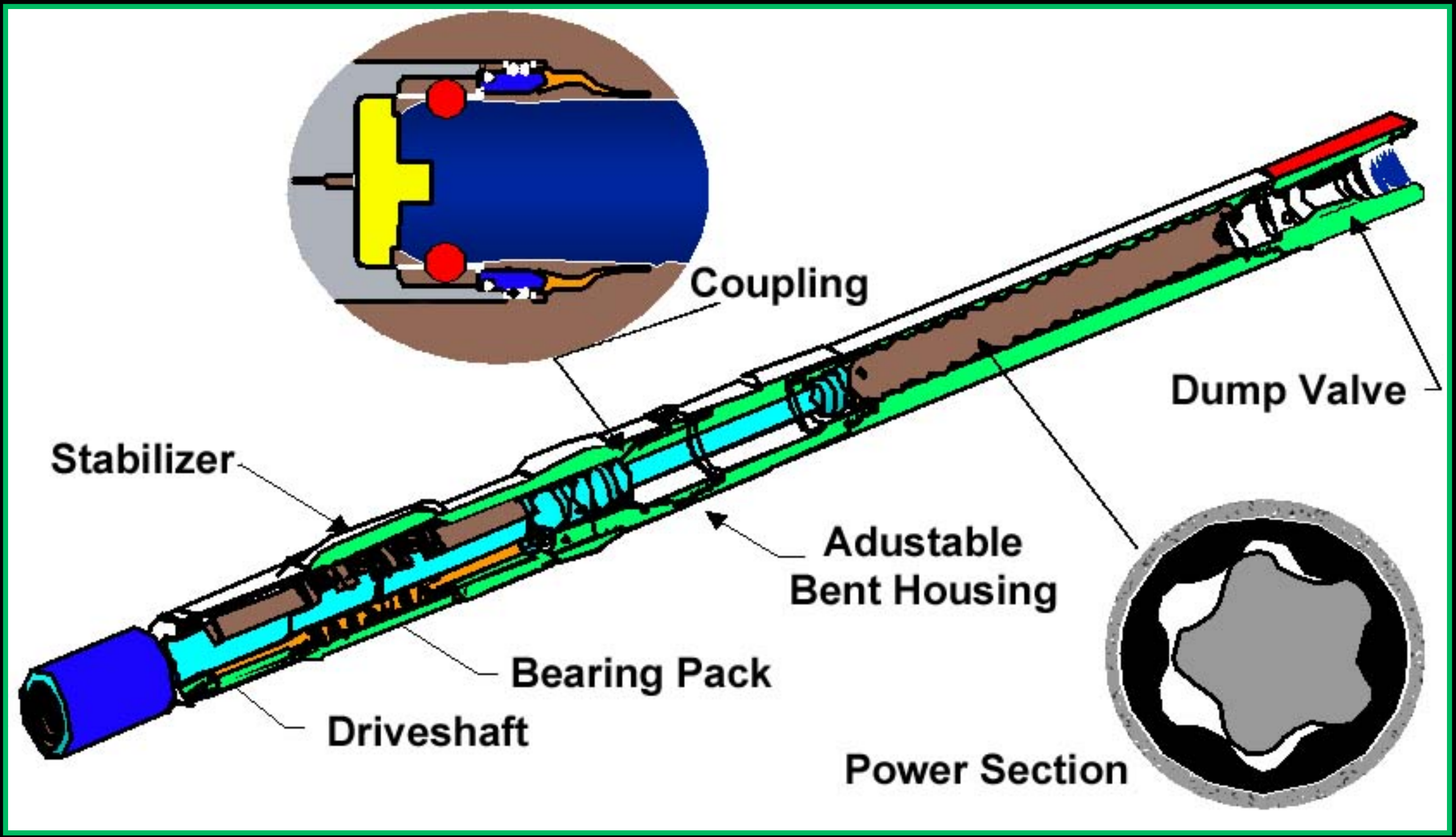


Methods of Deflection



Methods of Deflection

Mud (positive displacement) motors

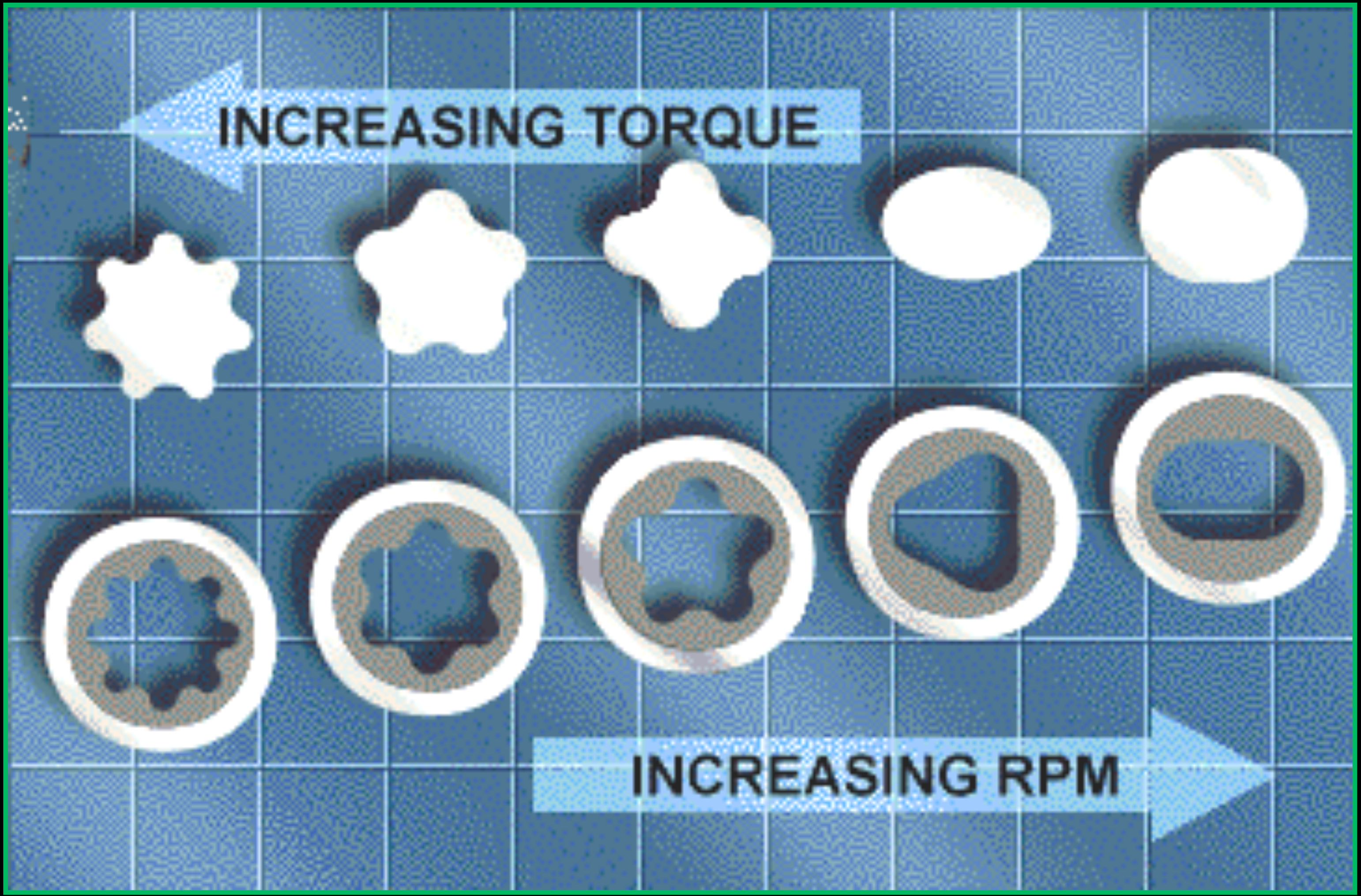


Methods of Deflection

Speed (RPM) / Torque (Ft-Lbs.)

For best performance, the power section should be matched to the bit and formation being drilled. The speed and torque of a power section is directly linked to the number of lobes on the rotor and stator. The higher the number of lobes, the higher the torque and the lower the RPM.

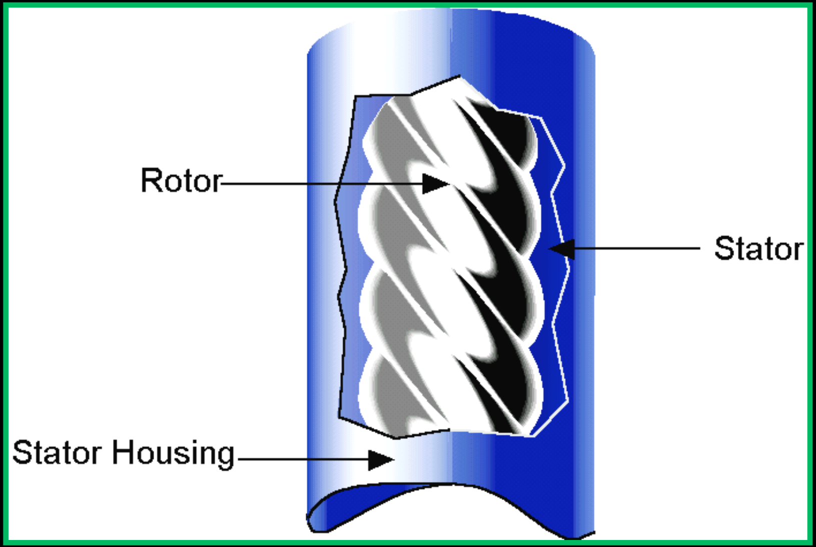
Methods of Deflection



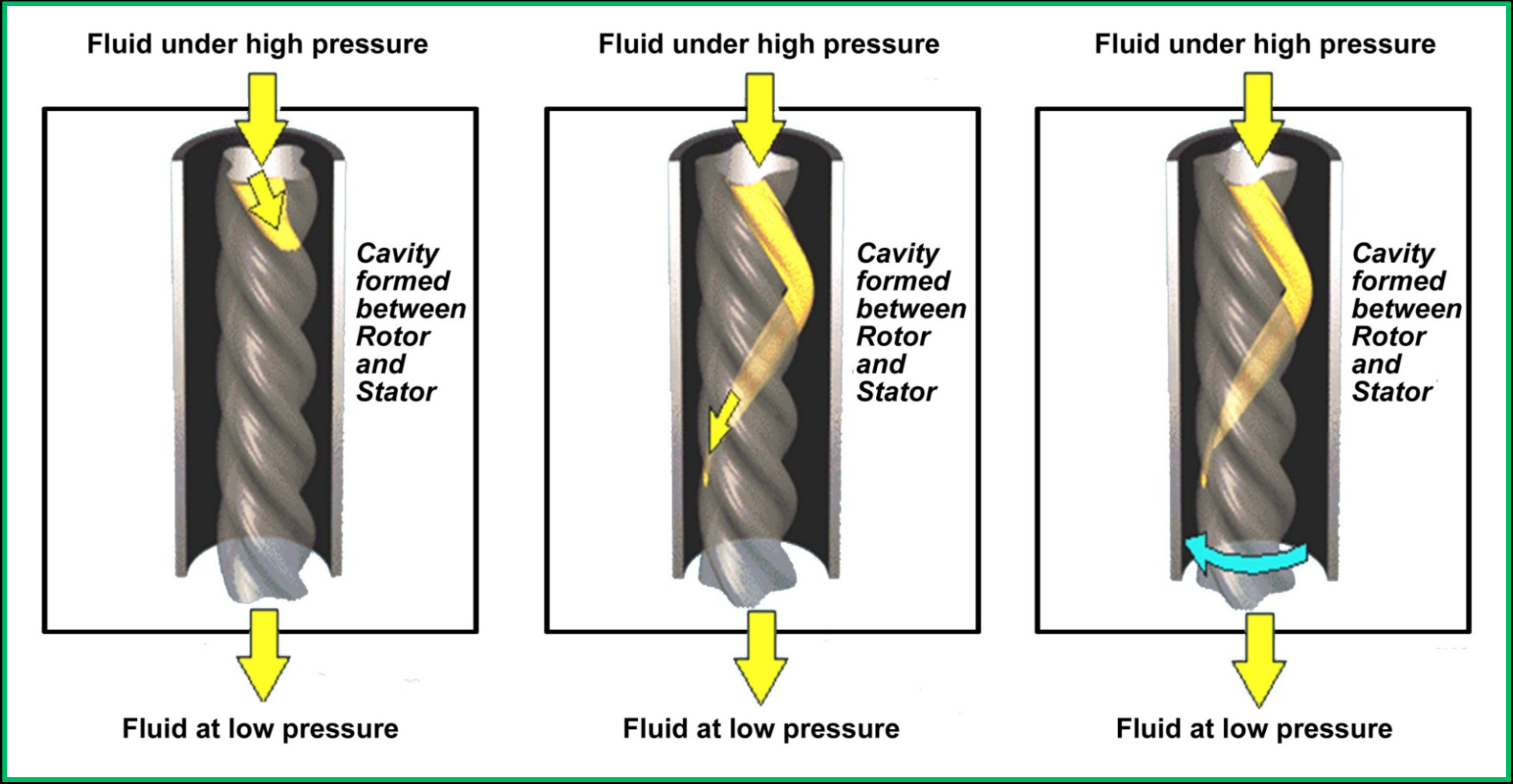
Methods of Deflection

Power pack section

- Rotor is hard
- Stator is flexible
- Stator housing is thin
- PDM is not a drill collar

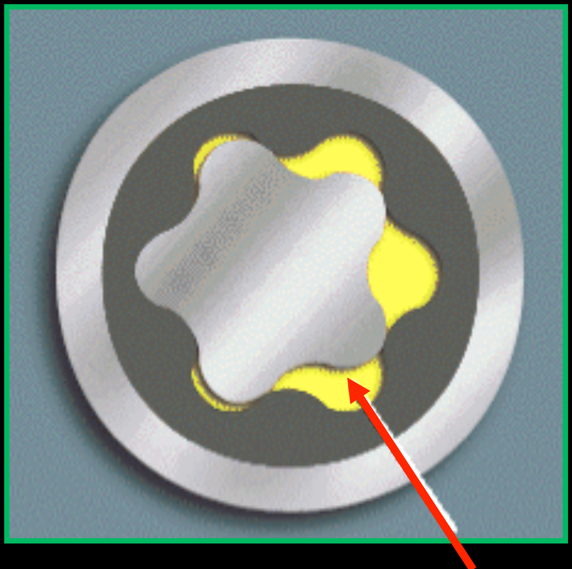


Methods of Deflection



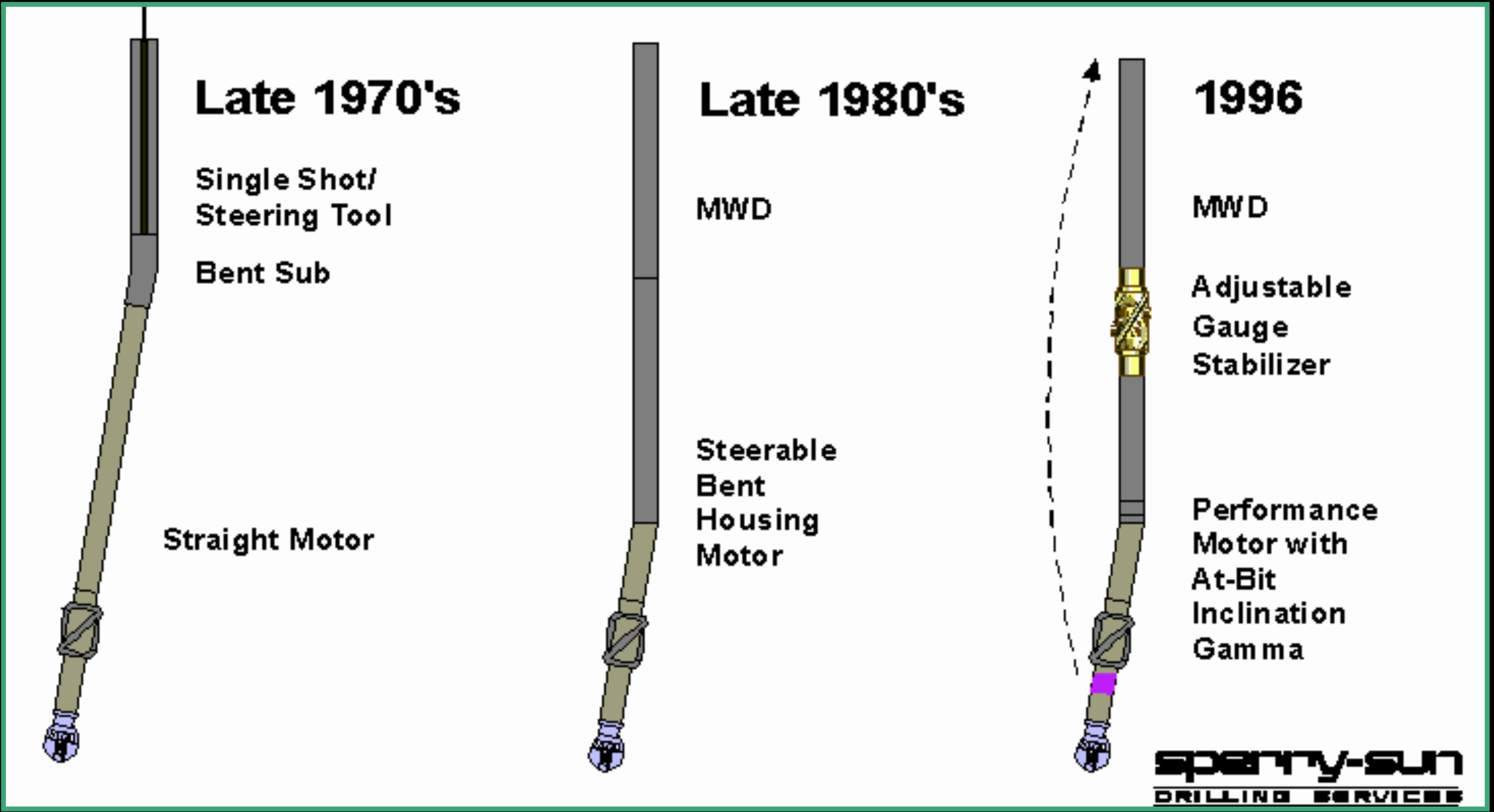
Methods of Deflection

The sum of the cross-sectional areas of any plane is a constant. As a result, the speed of the motor is constant for a given flow rate.



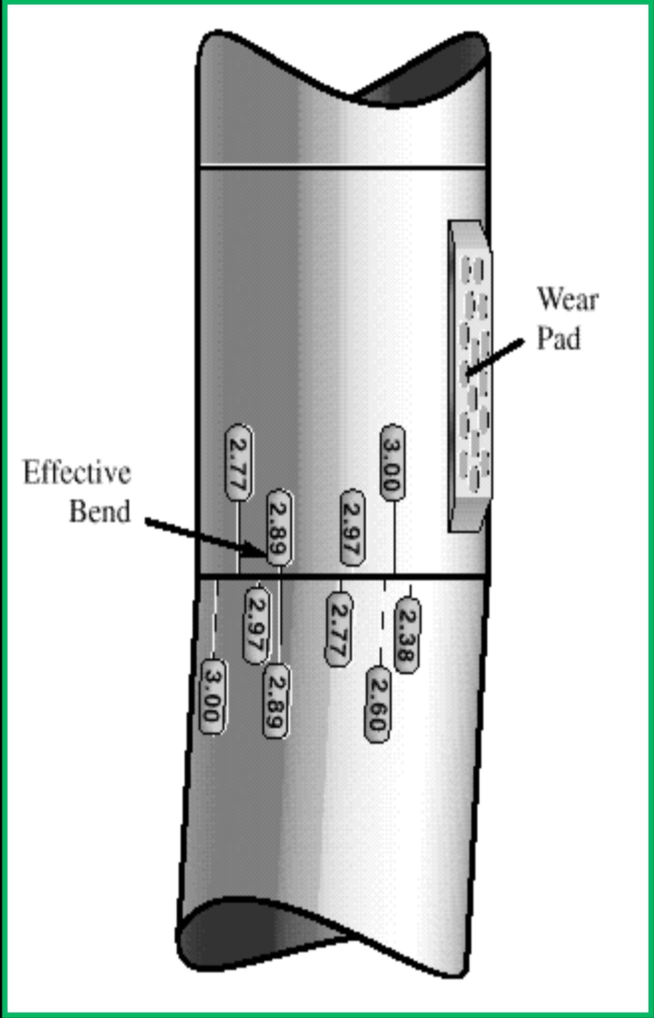
Methods of Deflection

Changes in Directional Drilling Practices



Methods of Deflection

- Works on offset pin and box concept
- Typically adjust from 1 to 3 degrees
- Four main Components: Offset Housing, Splined Mandrel, Stator Adapter Housing, and Adjusting Ring



Methods of Deflection

Typical steerable motor configuration

Bent Housing for Changing Direction When Sliding the Drillstring

Stabilizers Define Directional Tendency When Rotating the Drillstring

Methods of Deflection

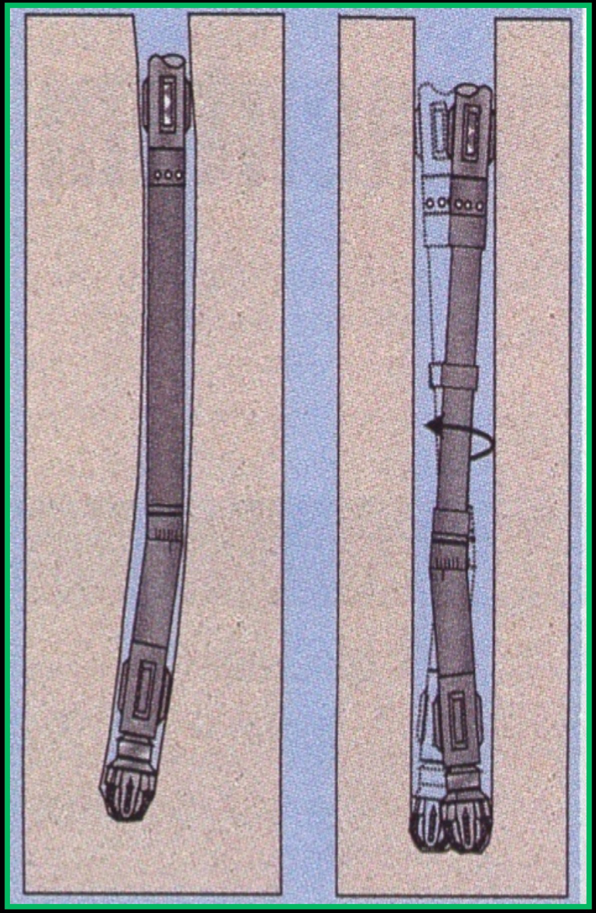
Rotary steerable

- Steerable without sliding (100% rotation)
- Can change both inclination and direction

Methods of Deflection

Steerable motor in the slide & rotate mode

Sliding



Rotating

Methods of Deflection

Limitations of steerable motors in the slide mode

- Sometimes difficult to slide
- Difficulty maintaining orientation
- Poor hole cleaning
- Lower effective penetration rate
- Higher wellbore tortuosity
- Differential pressure sticking
- Build rate is formation sensitive

Methods of Deflection

Limitations of steerable motors in the rotate mode

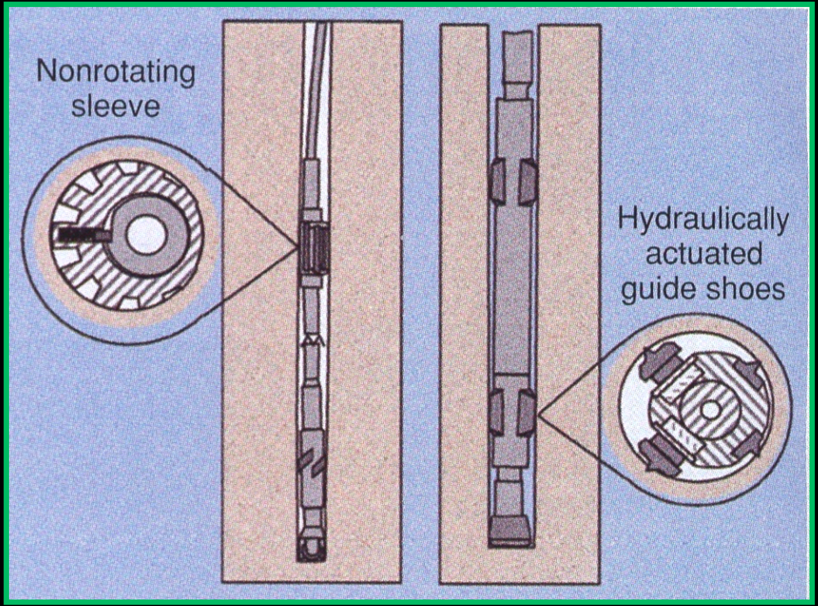
- Higher vibrations lead to motor and MWD failure
- Accelerated bit wear
- Poor hole quality for logs sometimes

The rotary steerable system address some but not all of the limitations

Methods of Deflection

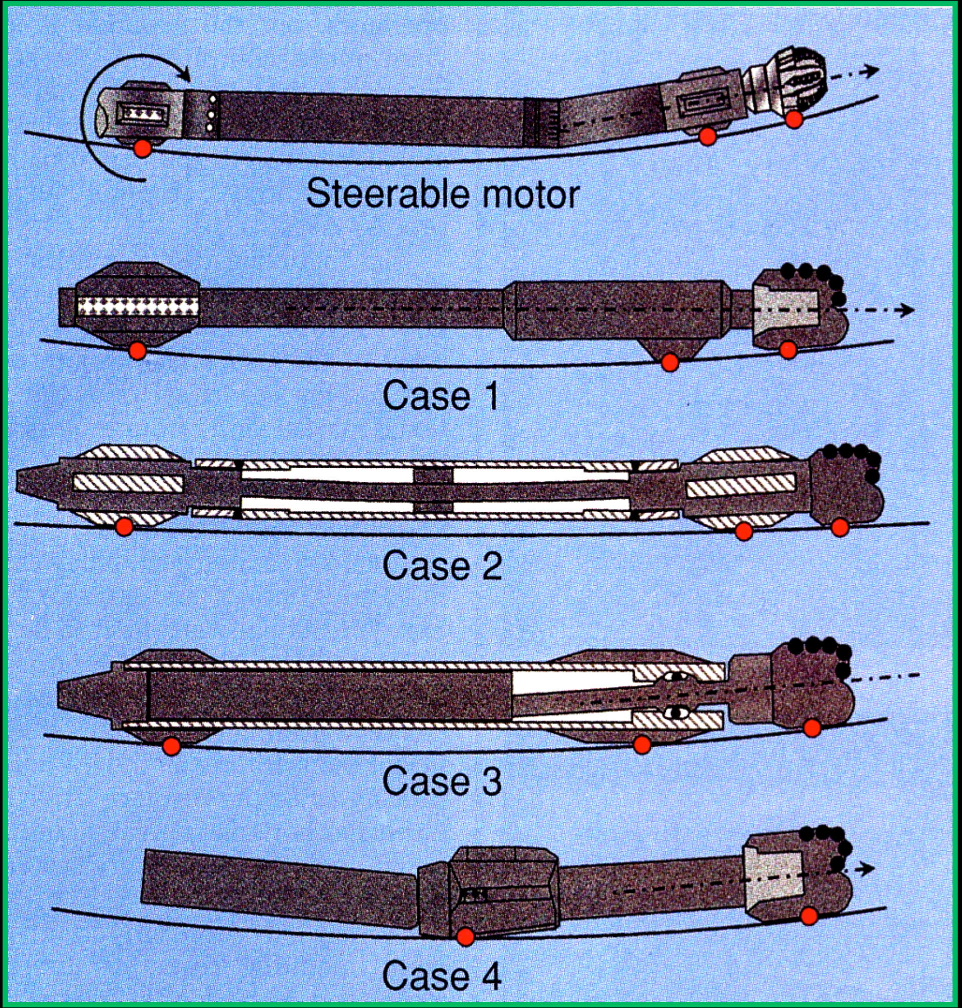
These rotary steerable concepts were patented in the 1950's, but the design is being used today

Guidance systems were required to make them work

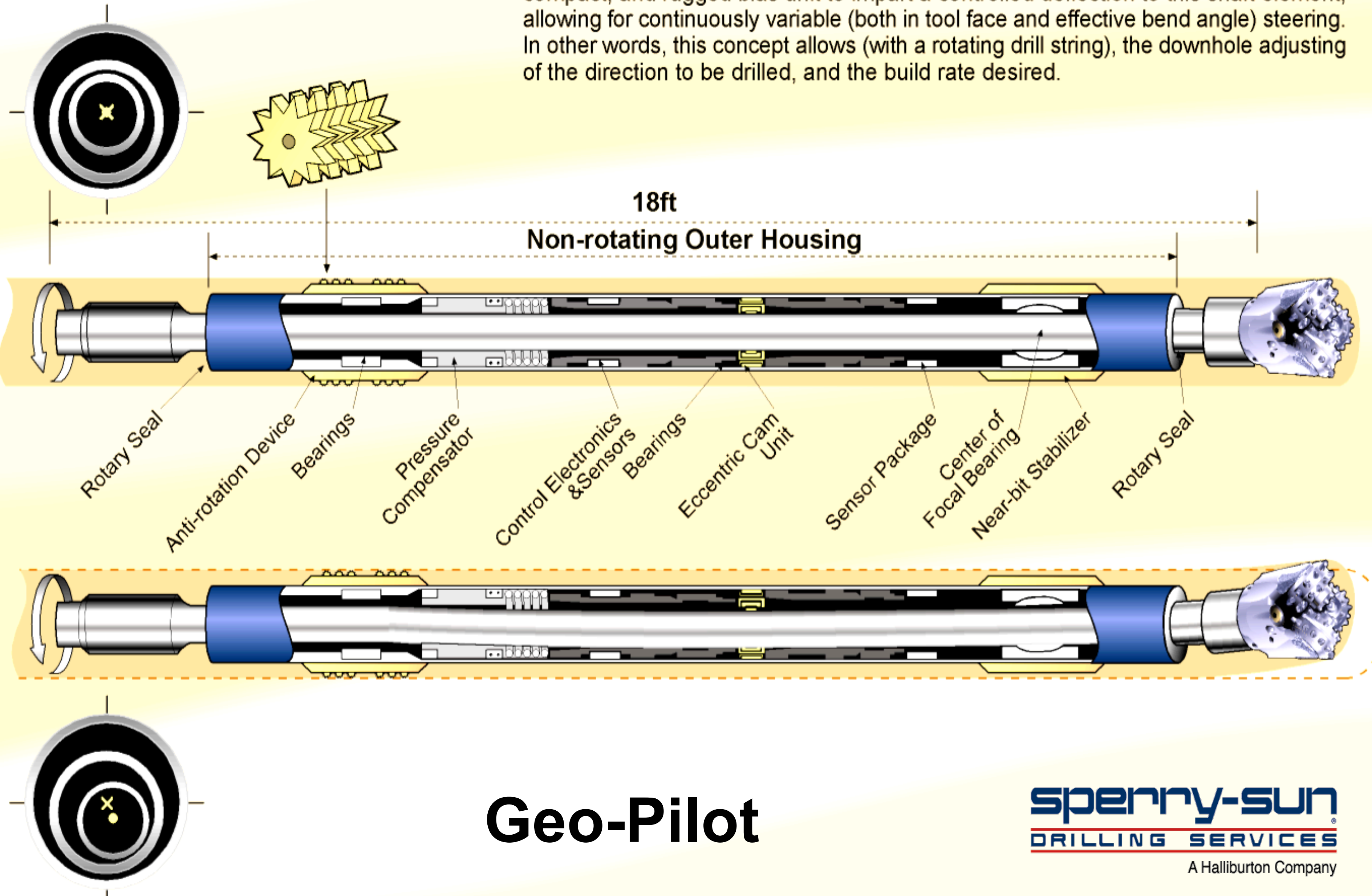


Methods of Deflection

Rotary steerable systems being designed and used today



The Geo-Pilot design concept involves deflection of a shaft between the bit and the drill string. A non-rotating and high-side reference housing contains an elegant, compact, and rugged bias unit to impart a controlled deflection to this shaft element, allowing for continuously variable (both in tool face and effective bend angle) steering. In other words, this concept allows (with a rotating drill string), the downhole adjusting of the direction to be drilled, and the build rate desired.

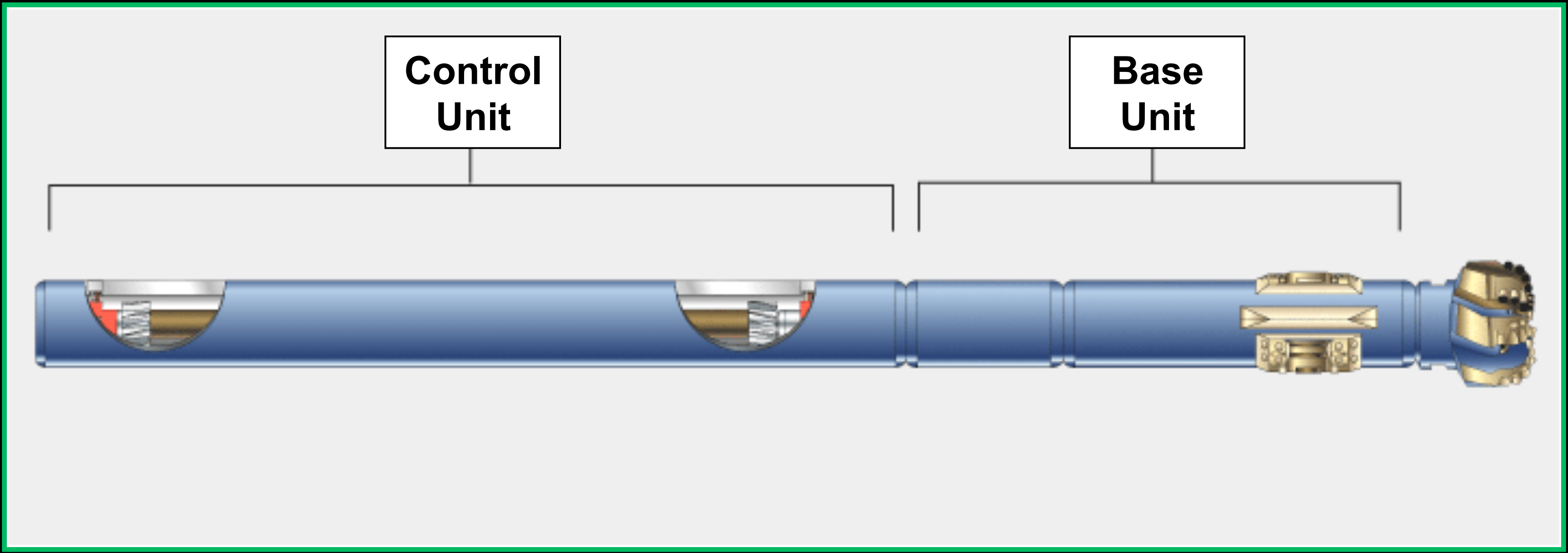


Geo-Pilot

sperry-sun
DRILLING SERVICES
A Halliburton Company

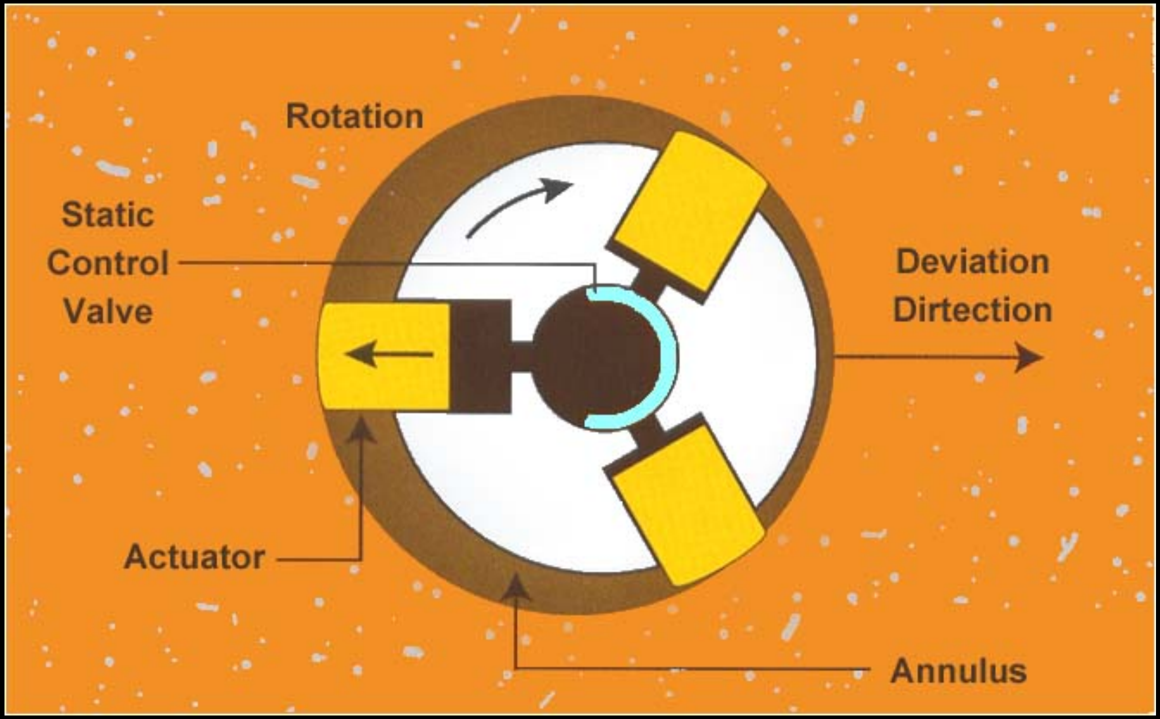
Methods of Deflection

Schlumberger Rotary Steerable Assembly



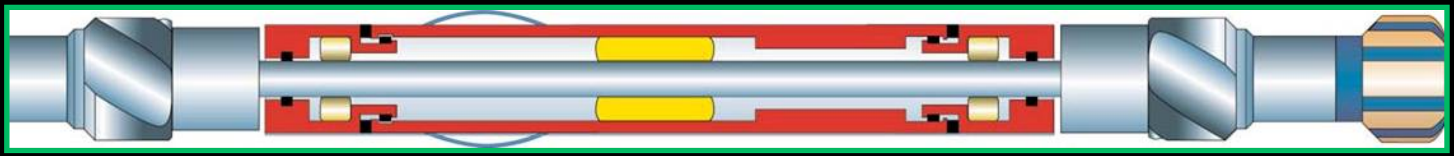
Methods of Deflection

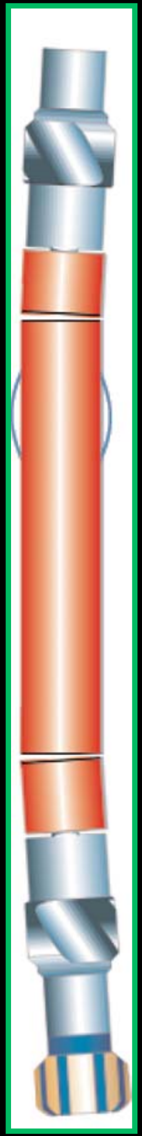
Schlumberger rotary steerable system has pistons near the bit that push against the side of the hole



Methods of Deflection

Gyrodata Rotary Steerable Assembly





Methods of Deflection

Baker Autotrak

Directional Drilling Conclusion

- Rapid development after MWDs in the 1970s
- Point and shoot = least expensive
- Geo-Steering = most expensive