Scientific Drilling

July 5th, 2017

Directional Drilling and Magnetic Ranging Services for Geothermal Energy Development

Clinton Moss – Scientific Drilling International

DD/MR Services for Geothermal Development

Agenda

- Introduction – About me
- What is the “Shale Revolution” and what made it possible
  - Directional Drilling
  - Hydraulic Fracturing
- Directional Drilling Fundamentals
  - What is it and why we do it
  - How we do it
    - Deviating the wellbore
    - Surveying
    - Well placement uncertainty
- Magnetic Ranging Fundamentals
  - Source and receiver
  - Eliminating uncertainly
- Putting it all together – a case study from Western Canada
  - Intersecting geothermal Wellbores - continuous completions
- Q&A

The Shale Revolution

What is the Shale Revolution?

- The “Shale Revolution” refers to the combination of hydraulic fracturing and horizontal drilling that enabled the United States to significantly increase its production of oil and natural gas, particularly from tight oil formations, which now account for 36% of total U.S. crude oil production

- This new production capacity has reduced the United States’ dependence on oil imports from overseas and continues to provide an important economic boost as the country recovers from the 2008 recession

https://www.strausscenter.org/energy-and-security/the-u-s-shale-revolution.html

The Shale Revolution

What is the Shale Revolution?

- Advances in two technologies in the late 1990s and early 2000s changed all that, although at first only for gas. Hydraulic fracturing — injecting a mixture of water, sand and chemicals underground at high pressure — cracks the rock to release the gas. Horizontal drilling — sinking a well a mile or more straight down, then a mile or more sideways — made it possible to expose a much greater area of resource-bearing rock. Neither practice was entirely new but refining the techniques and combining them transformed the commercial viability of shale gas.

https://www.strausscenter.org/energy-and-security/the-u-s-shale-revolution.html

The Shale Revolution

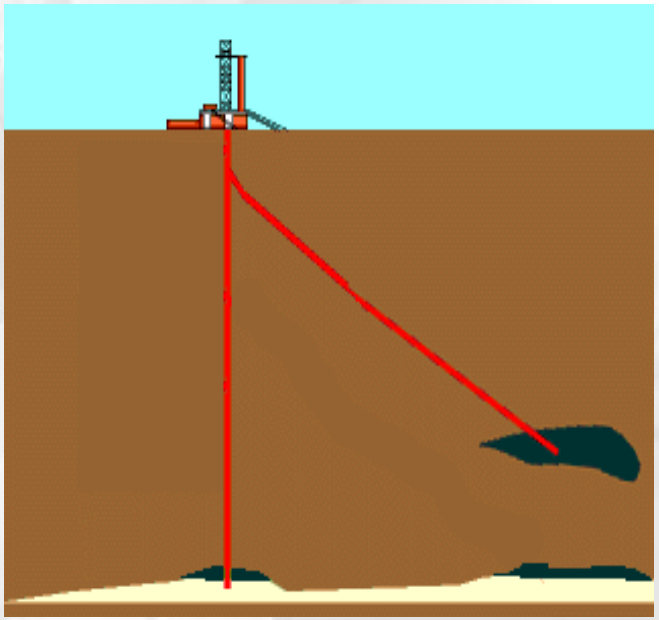
What is the Shale Revolution?

Directional Drilling

An Introduction to Directional Drilling

What is it?

Directional Drilling is the science of deviating a well bore along a planned course to a subsurface target whose location is a given lateral distance and direction from the vertical



Directional Drilling

Scientific Drilling

An Introduction to Directional Drilling

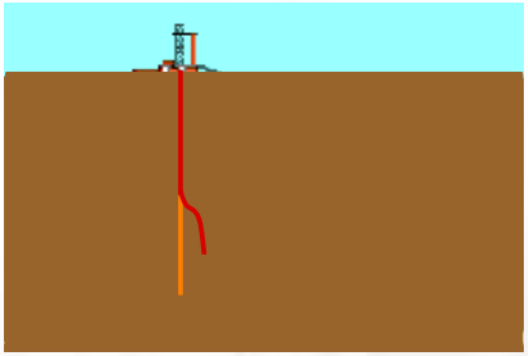
What is it?

Directional Drilling

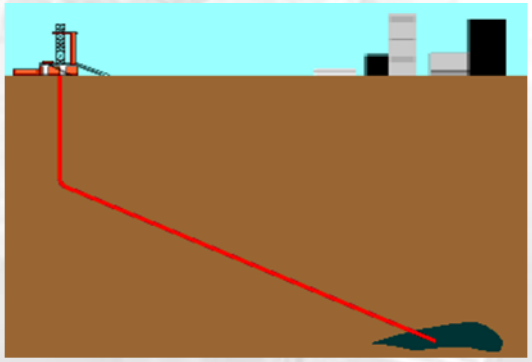
Scientific Drilling

An Introduction to Directional Drilling

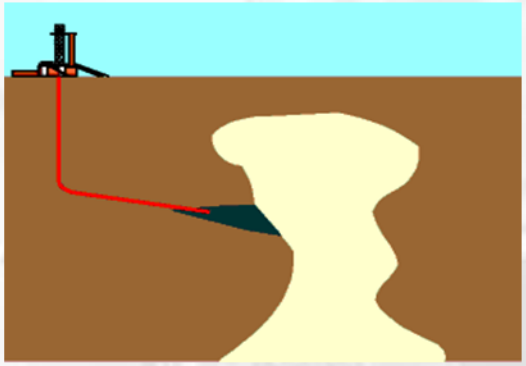
Why Use Directional Drilling?



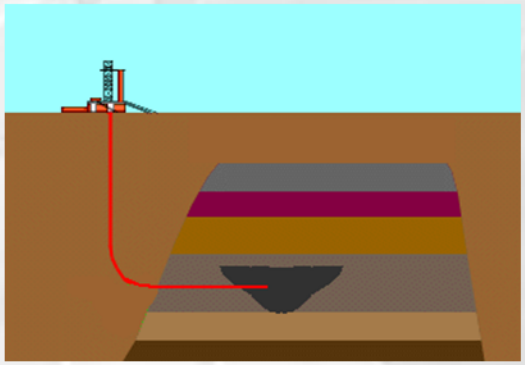
Sidetracking



Inaccessible Locations



Salt Dome Drilling

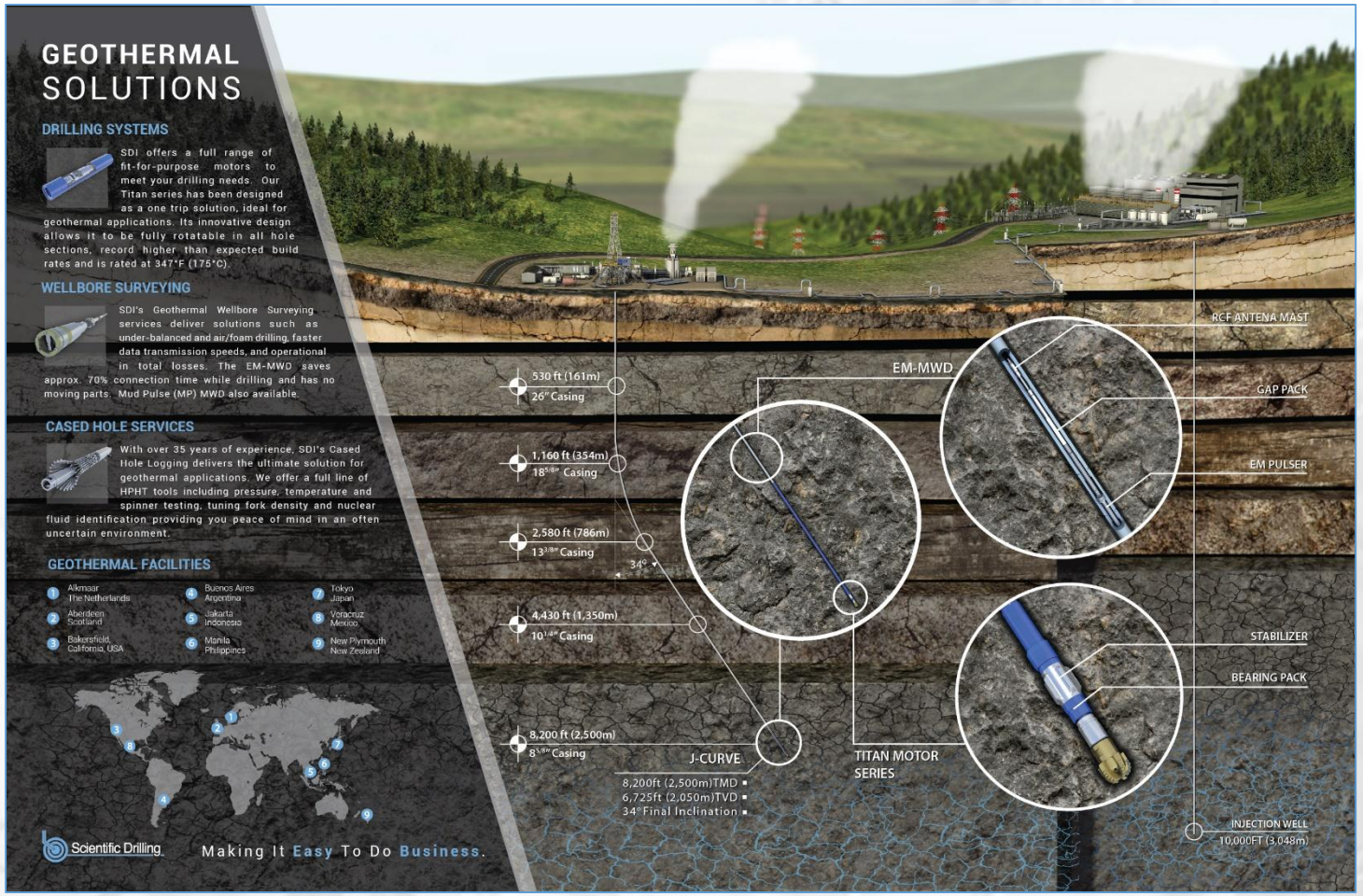


Fault Controlling

Directional Drilling

An Introduction to Directional Drilling

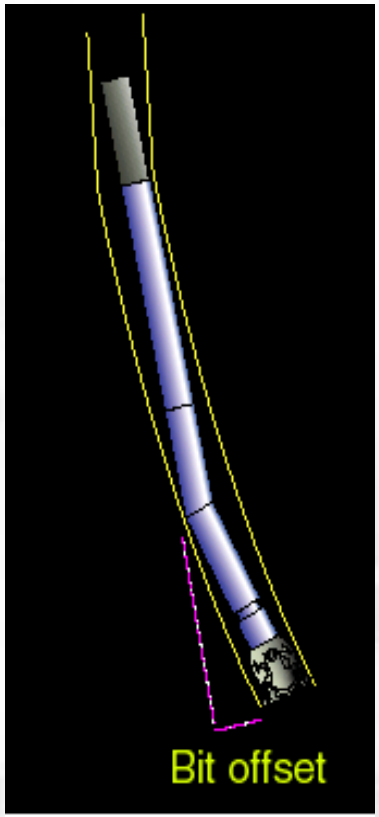
Why Use Directional Drilling?

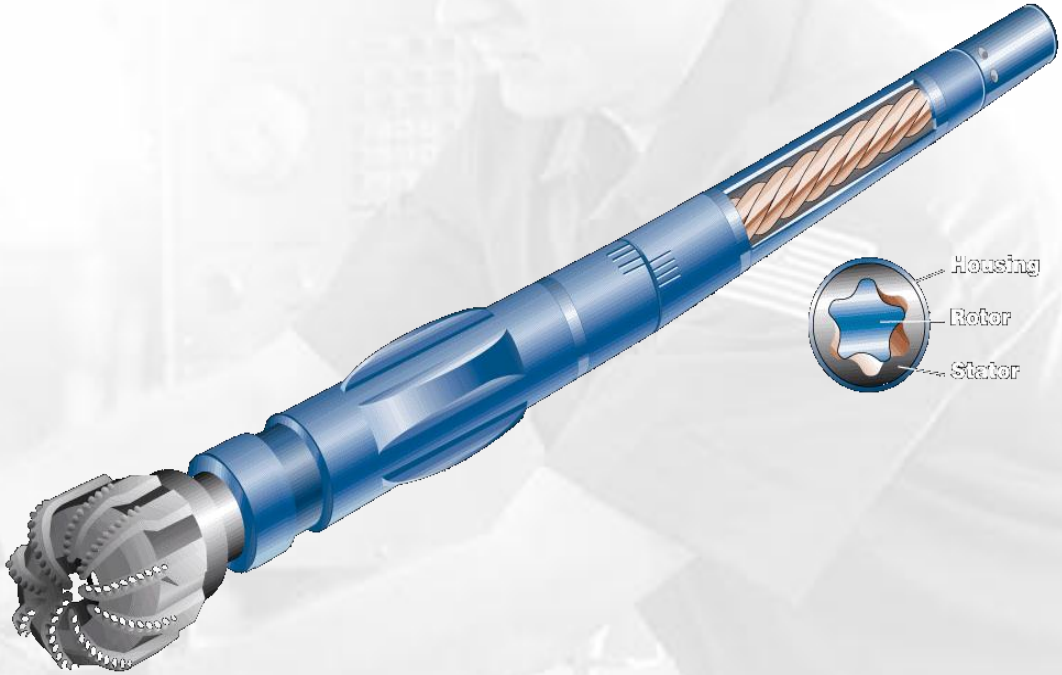


Directional Drilling

An Introduction to Directional Drilling

How do we deviate the wellbore?





PDM motors have a bent housing (~1-3 degrees) and allow the bit to turn independently of the drillstring

Directional Drilling

An Introduction to Directional Drilling

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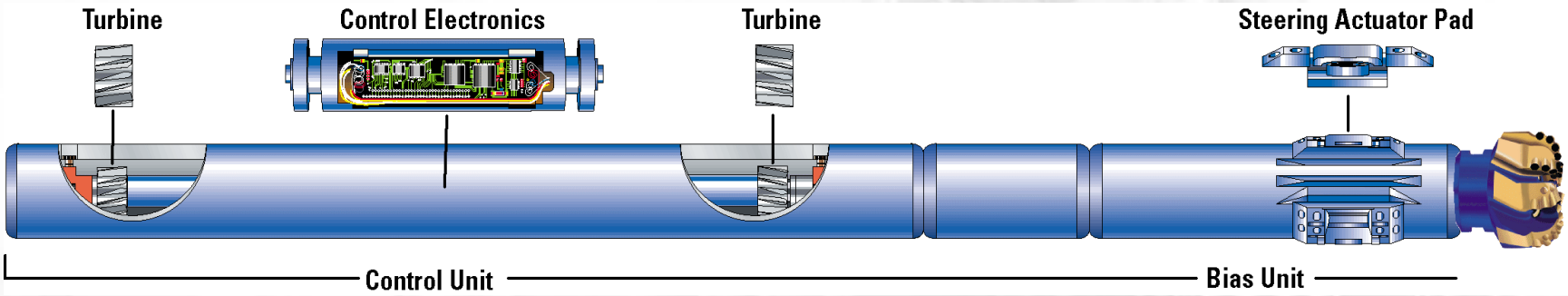
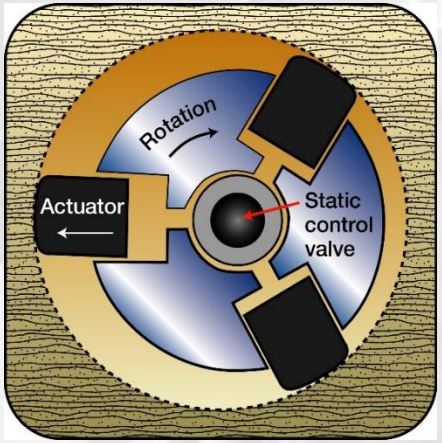


Pad out

Pad in



Surveying

Scientific Drilling

An Introduction to Surveying

How do we measure the deviation and know “where we are”?

- Measured Depth
  - Acquired from Drill Pipe Tally or Wireline Depth
- Inclination
  - Angle from Gravity Vector (Vertical)
- Azimuth
  - Angle from North on a Horizontal Plane
    - True North
    - Grid North
    - Magnetic North

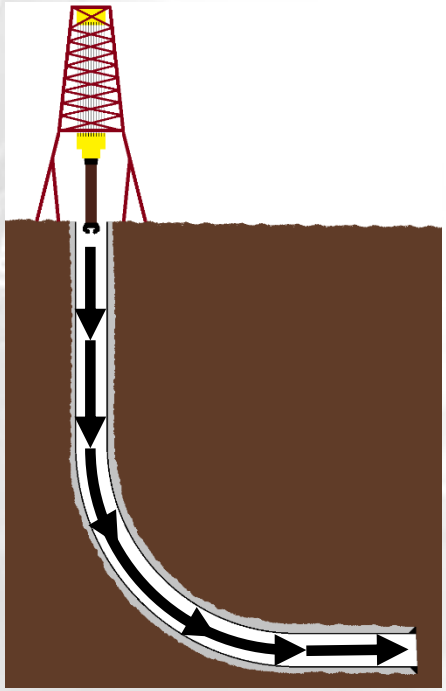
MD 0’, Inc 0°, Az 0°

MD 100’, Inc 0°, Az 0°

MD 200’, Inc 0°, Az 0°

MD 230’, Inc 30°, Az 180°

MD 260’, Inc 60°, Az 180°
MD 290’, Inc 90°, Az 180°



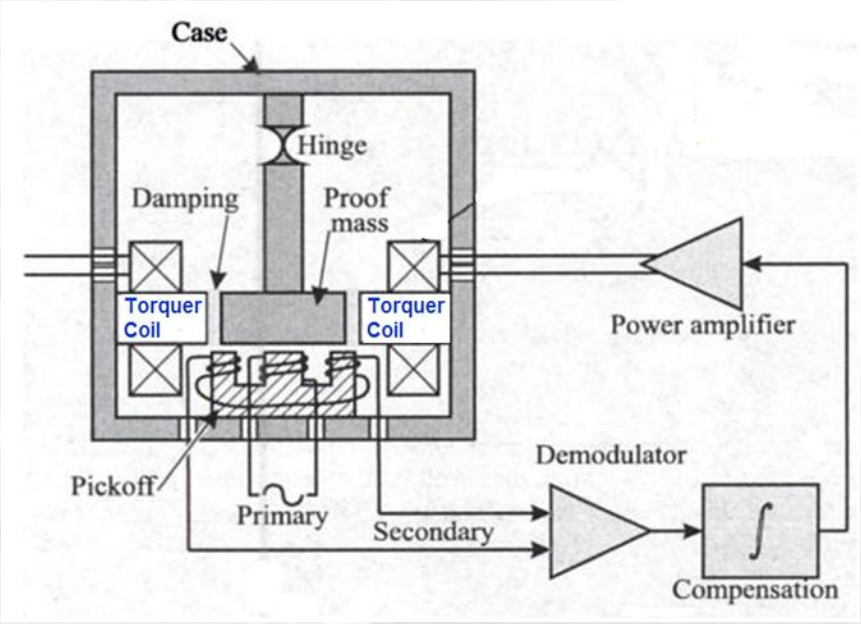
Surveying

Scientific Drilling

An Introduction to Surveying

How do we measure the deviation and know “where we are”? - Inclination

- Measure Earth’s gravity vector
- Tri-Axis Accelerometers
  - X, Y, & Z
- Pendulous Mass Accelerometers



How Do We Measure a Survey?

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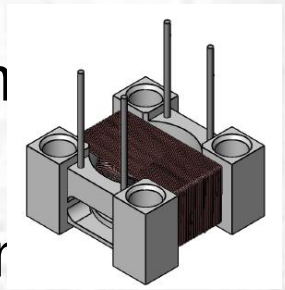
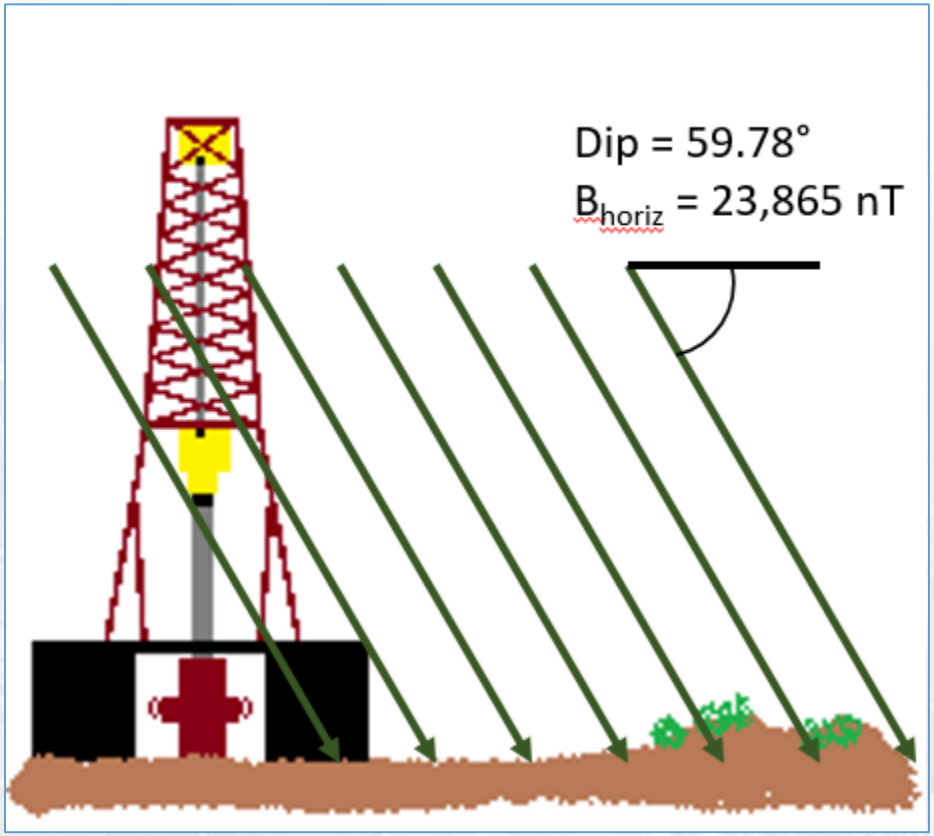
An Introduction to Surveying

How do we measure the deviation and know “where we are”? - Azimuth

- Measure direction of Earth’s Magnetic Field
  - Declination
  - Dip
  - BTotal
- Tri-Axis Magnetom
  - X, Y, & Z
- Fluxgate Magnetor

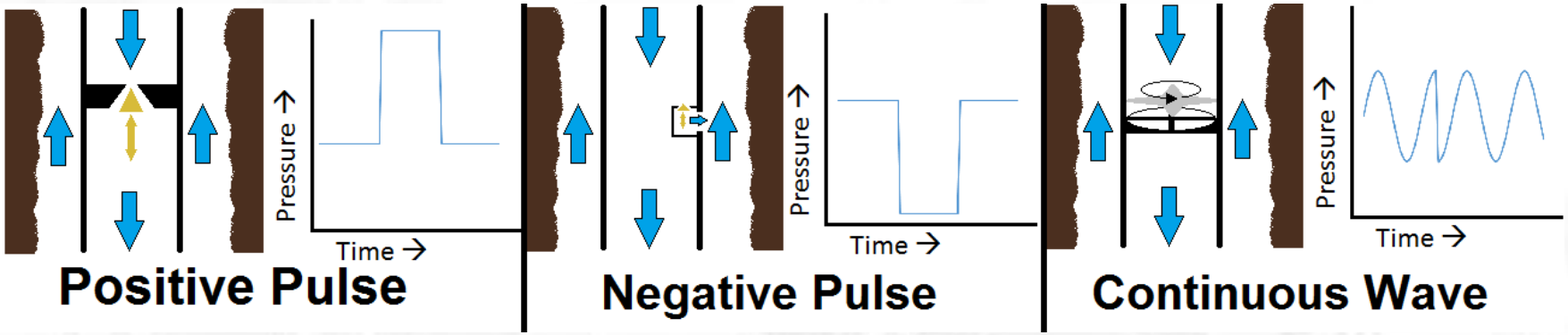


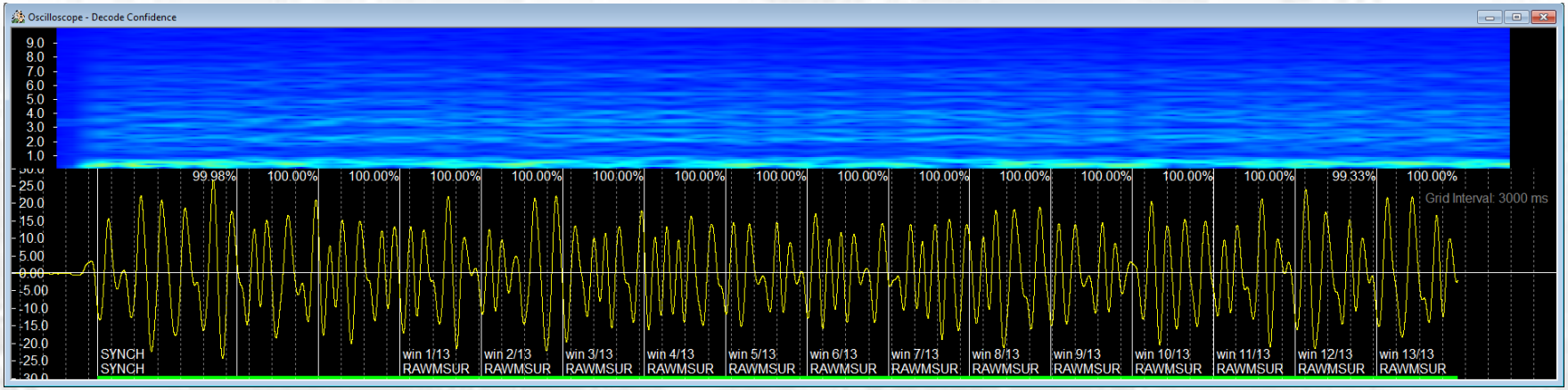


How Do We Obtain Our Measurement?

An Introduction to Surveying

How do we collect the data as we drill?





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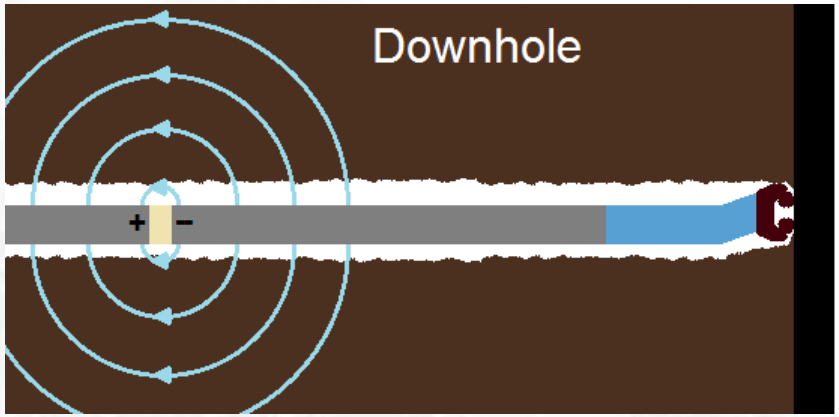
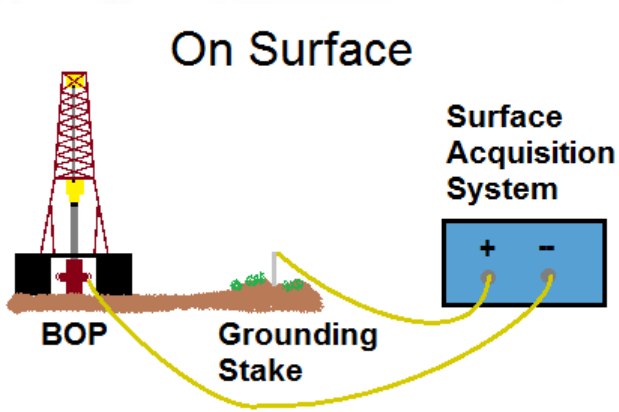
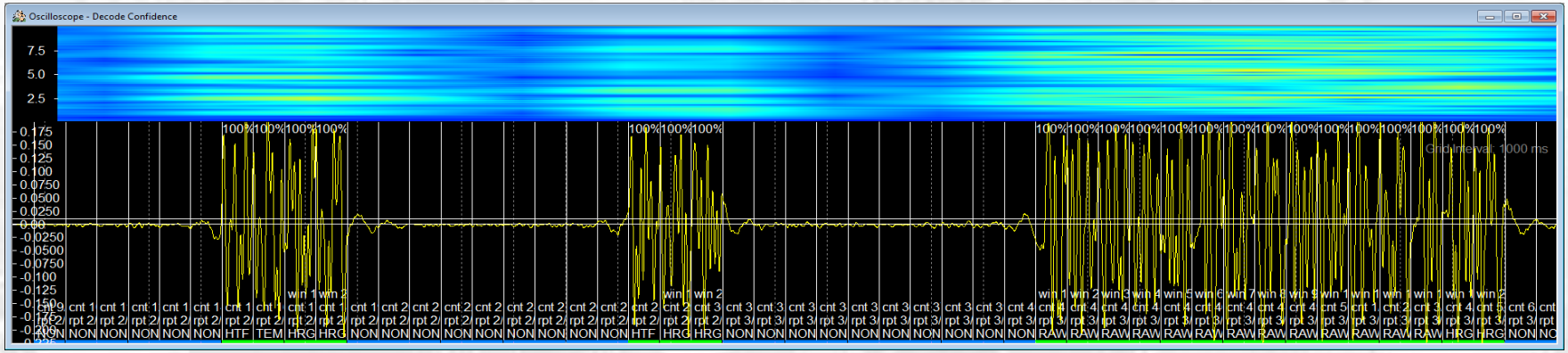




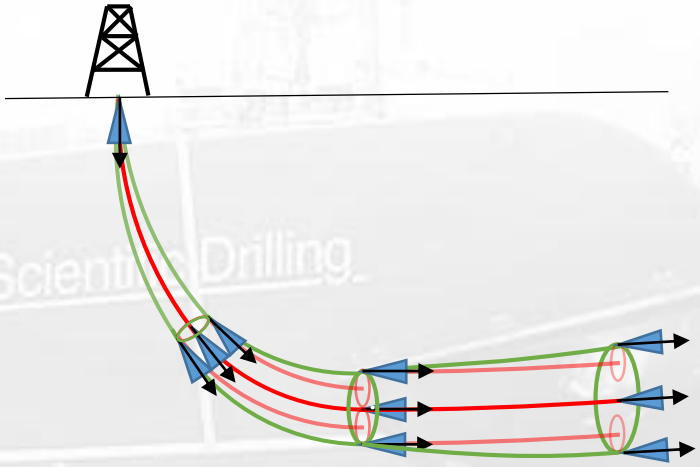


Surveying

An Introduction to Surveying

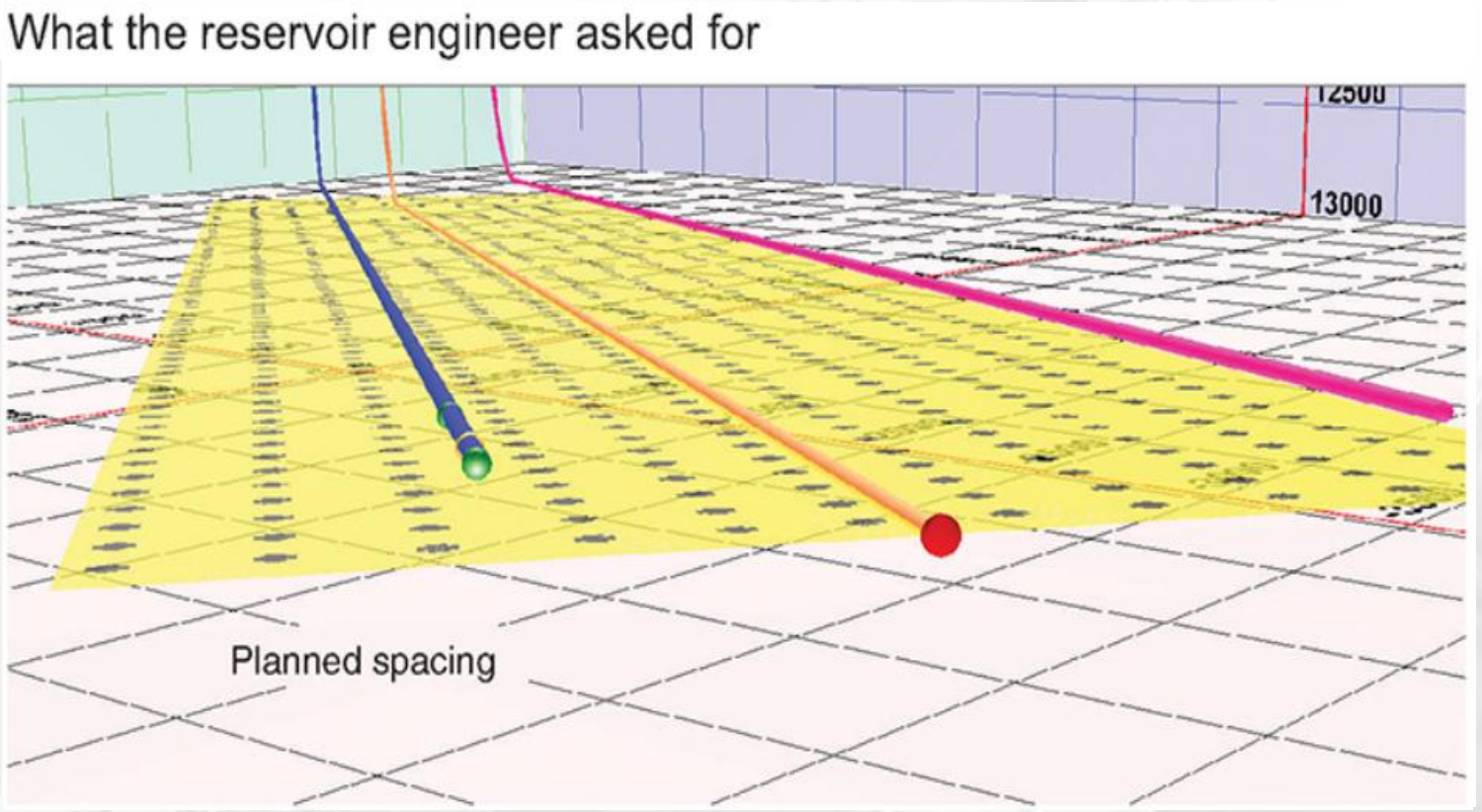
Do we know we were have drilled?

- Short Answer: No
- Propagation of Error
  - Measurement Uncertainty
  - Positional Uncertainty
  - Accumulates Along the Wellbore
  - Ellipse of Uncertainty



Surveying Errors

A Review of Wellbore Uncertainty

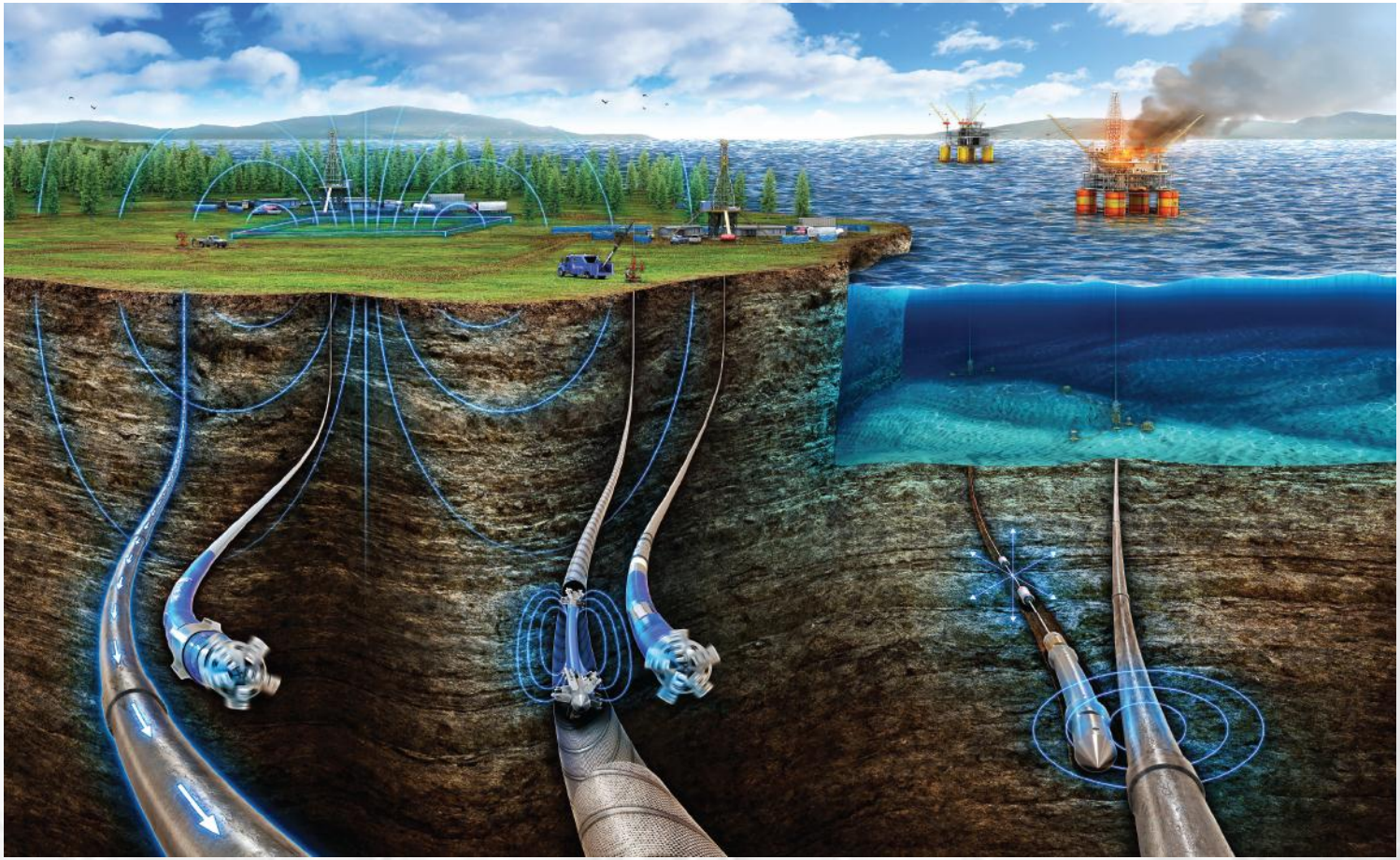


Parshall, J. (2015). Survey Management Makes Wells Safer and More Productive. Journal of Petroleum Technology, Volume 67 , Number 6. pp 66-69.

Magnetic Ranging

Scientific Drilling

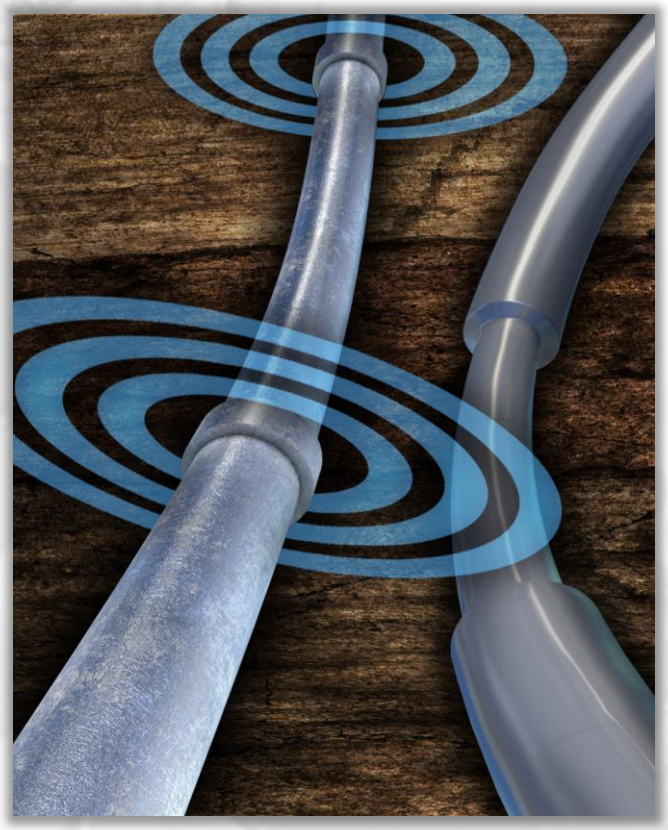
A Suite of Tools for Determine Relative Proximity



Magnetic Ranging Services

What is Magnetic Ranging?

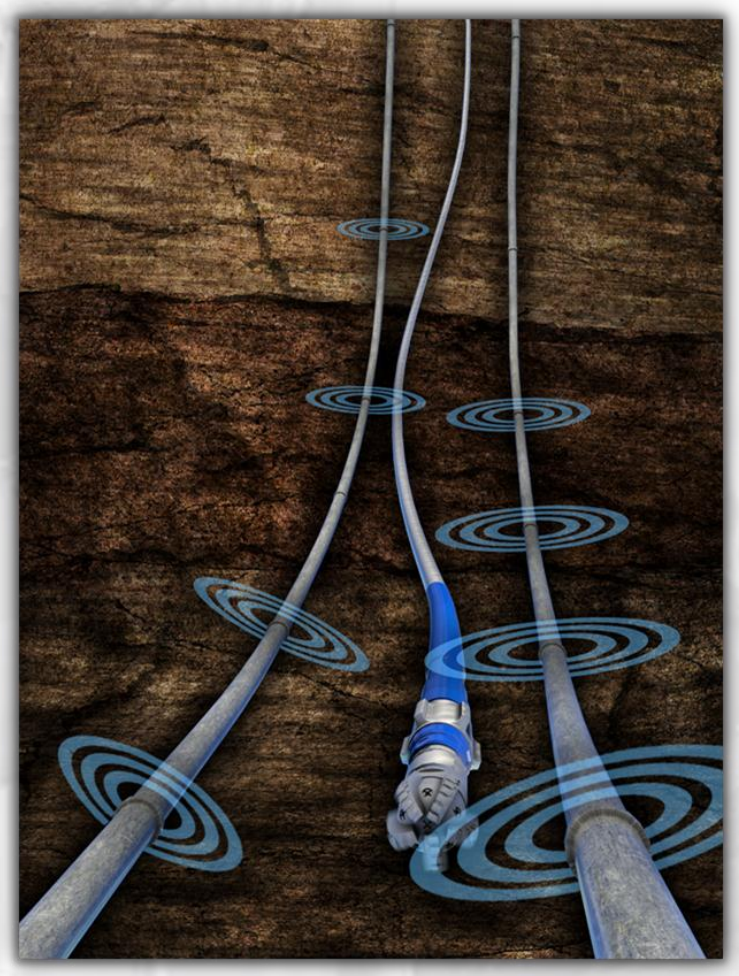
- Using a magnetic field (other than the Earth's field) to determine the distance and direction between wellbores
- A relative downhole vector quantity
  - Distance and direction
- Source
  - A magnetic field generator (solenoid, rare earth magnet, current on a wire or casing)
- Receiver
  - MWD magnetometer or wireline magnetometer package



Magnetic Ranging Services

What is Magnetic Ranging?

- Magnetic Ranging can be separated into two categories
  - **Active**
    Creating the magnetic field for each measurement that is collected
  - **Passive**
    Measuring the residual magnetic field of a nearby target well

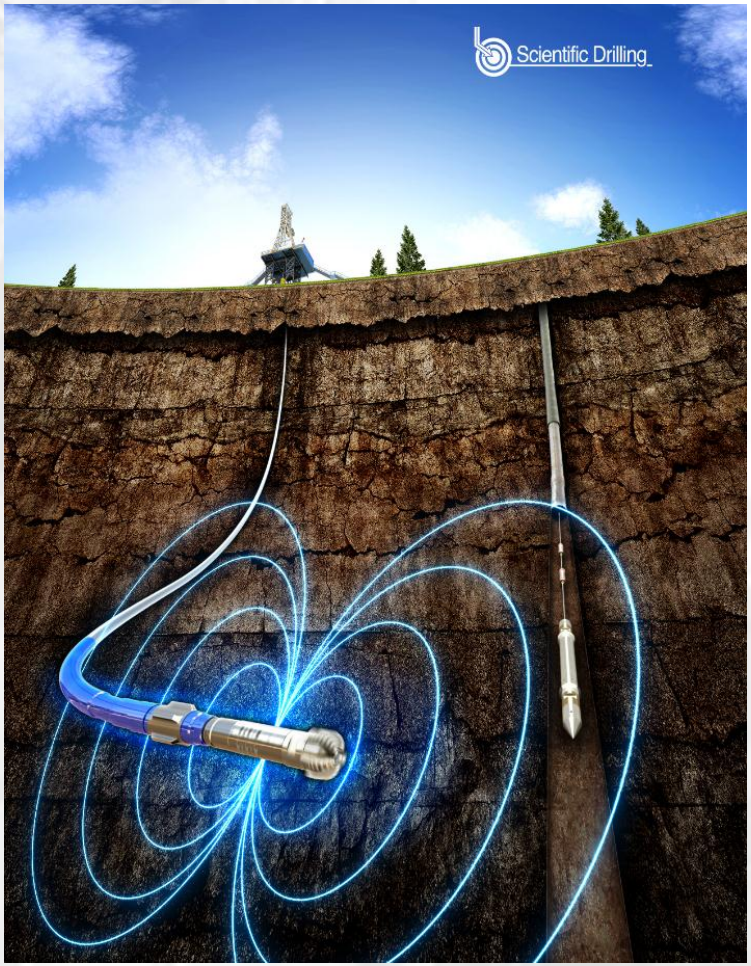


Magnetic Ranging Services

Lodestone™

At Bit Ranging System

- Overview
  - Rare earth magnets in a bit sub
  - When pumping, an alternating magnetic field is established
  - Detected by magnetometer package in the nearby well
  - Range measurement at the bit
  - Works on any drilling assembly



Magnetic Ranging Services

Scientific Drilling

Lodestone™

At Bit Ranging System

Specifications

- Detection up to 130m away
- Direction to target +/- 3°
- Distance to target +/- 5% of total separation

Uses

- Wellbore twinning
- Wellbore intersection
  - Plug and Abandonment
  - River crossings
  - Pipe line extension

Putting it all Together

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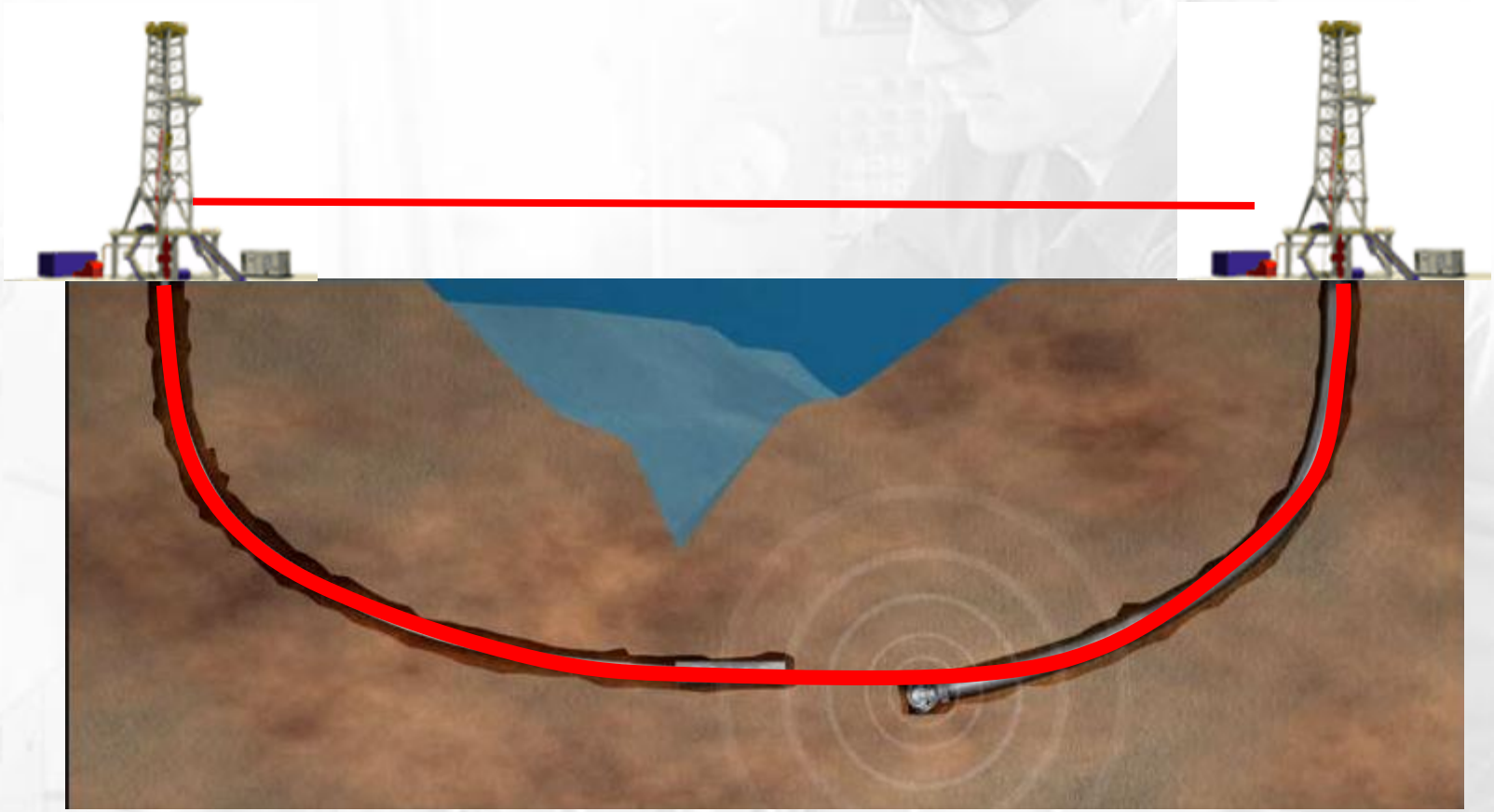
Geothermal Case Study from Western Canada

A Continuous Geothermal Completion Requiring Directional Drilling and Magnetic Ranging



Closing Thoughts

Scientific Drilling

Does Precision Wellbore Placement have a Place in Geothermal Drilling?

You tell me!

- Is the “Tiramisu” of geothermal drilling/energy lying just beneath our noses?
- Imagine ways of using advanced directional drilling and magnetic ranging techniques to realize efficiencies in geothermal projects
- Don’t tell me though…protect your IP
- I will see you in the field when we execute your novel geothermal energy extraction technique!

Thank You

Questions?