



**July 5<sup>th</sup>, 2017**

**Directional Drilling and Magnetic Ranging  
Services for Geothermal Energy Development  
Clinton Moss – Scientific Drilling International**



## 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 uncertainty
- 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?

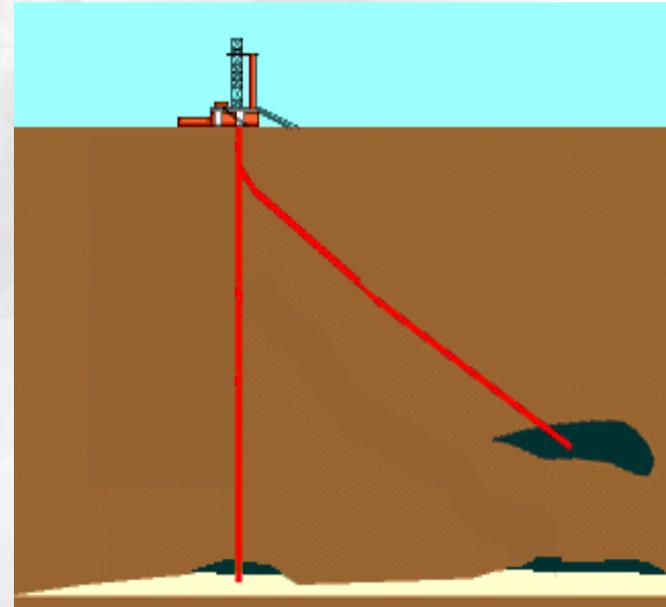


# Directional Drilling

## 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

## An Introduction to Directional Drilling

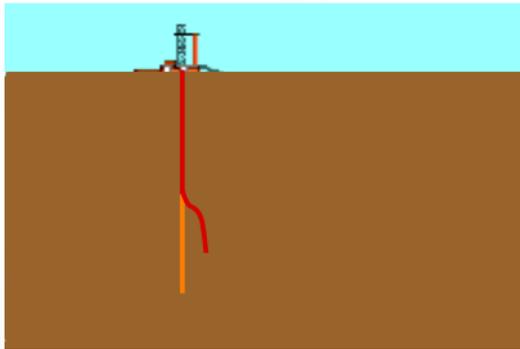
What is it?



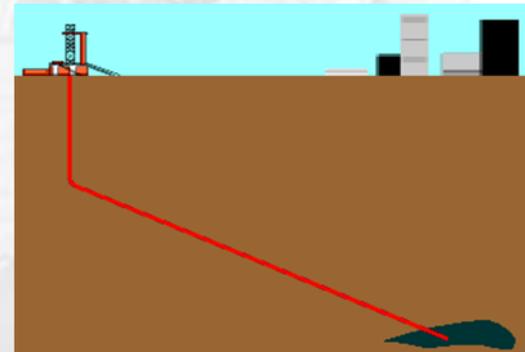
# Directional Drilling

## An Introduction to Directional Drilling

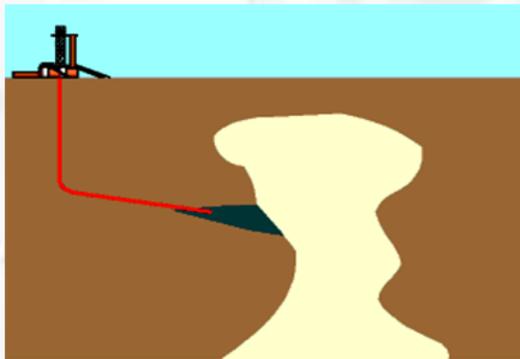
Why Use Directional Drilling?



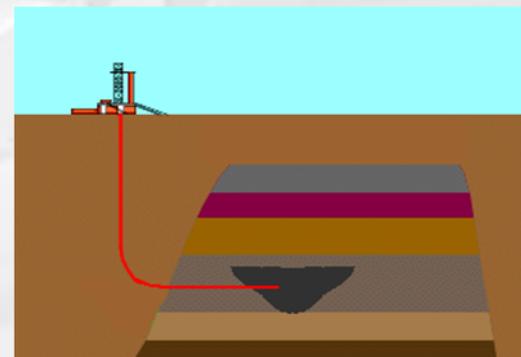
Sidetracking



Inaccessible Locations



Salt Dome Drilling



Fault Controlling

# Directional Drilling

## An Introduction to Directional Drilling

### Why Use Directional Drilling?

### GEOTHERMAL SOLUTIONS

**DRILLING SYSTEMS**

SDI offers a full range of fit-for-purpose motors to meet your drilling needs. Our Titan series has been designed as a one trip solution, ideal for geothermal applications. Its innovative design allows it to be fully rotatable in all hole sections, record higher than expected build rates and is rated at 347°F (175°C).

**WELLBORE SURVEYING**

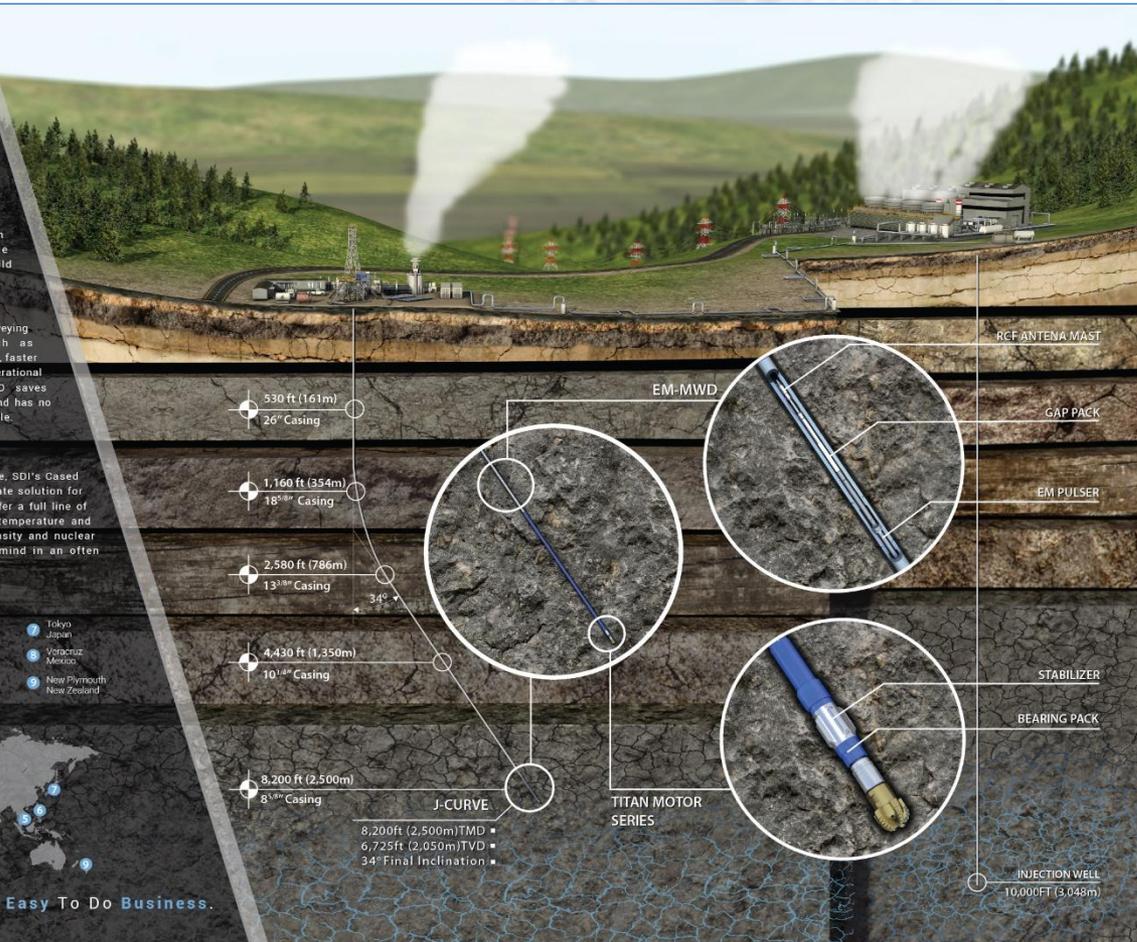
SDI's Geothermal Wellbore Surveying services deliver solutions such as under-balanced and air/foam drilling, faster data transmission speeds, and operational in total losses. The EM-MWD saves approx. 70% connection time while drilling and has no moving parts. Mud Pulse (MP) MWD also available.

**CASED HOLE SERVICES**

With over 35 years of experience, SDI's Cased Hole Logging delivers the ultimate solution for geothermal applications. We offer a full line of HPHT tools including pressure, temperature and spinner testing, tuning fork density and nuclear fluid identification providing you peace of mind in an often uncertain environment.

**GEOTHERMAL FACILITIES**

- 1 Alkmaar, The Netherlands
- 2 Aberdeen, Scotland
- 3 Bakersfield, California, USA
- 4 Buenos Aires, Argentina
- 5 Jakarta, Indonesia
- 6 Manila, Philippines
- 7 Tokyo, Japan
- 8 Veracruz, Mexico
- 9 New Plymouth, New Zealand



The diagram illustrates a wellbore with the following specifications:

- 530 ft (161m) 26" Casing
- 1,160 ft (354m) 18" Casing
- 2,580 ft (786m) 13" Casing
- 4,430 ft (1,350m) 10" Casing
- 8,200 ft (2,500m) 8" Casing
- Final Incline: 34°
- Total Depth: 10,000 FT (3,048m)

Key components and services shown include:

- EM-MWD (Electromagnetic Measurement While Drilling)
- TITAN MOTOR SERIES
- J-CURVE
- RCF ANTENNA MAST
- GAP PACK
- EM PULSER
- STABILIZER
- BEARING PACK
- INJECTION WELL

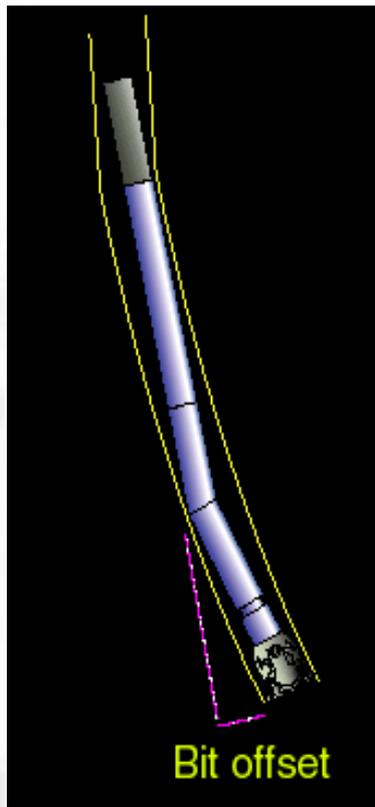
Wellbore Details:

- 8,200ft (2,500m) TMD
- 6,725ft (2,050m) TVD
- 34° Final Inclination

# Directional Drilling

## An Introduction to Directional Drilling

How do we deviate the wellbore?

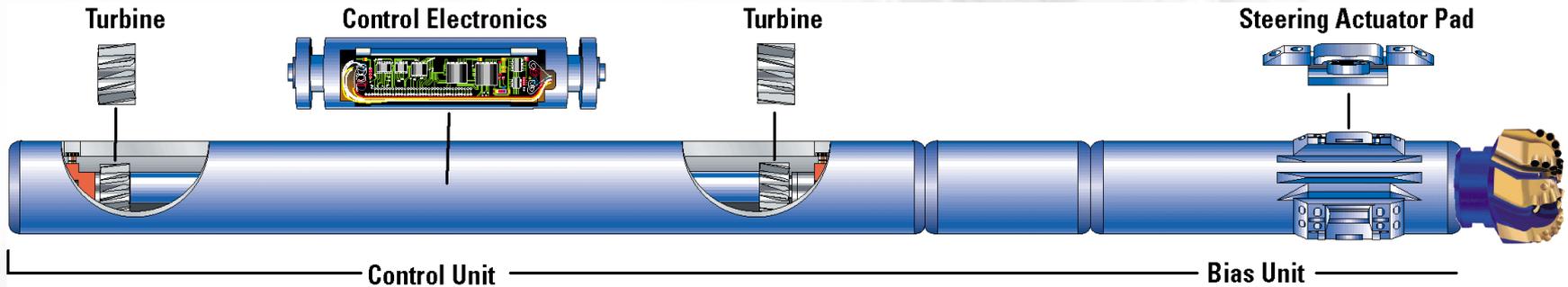


PDM motors have a bent housing (~1-3 degrees) and allow the bit to turn independently of the drillstring

# Directional Drilling

## An Introduction to Directional Drilling

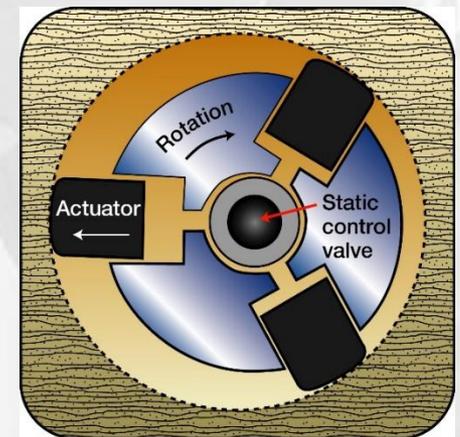
How do we deviate the wellbore?



Pad out



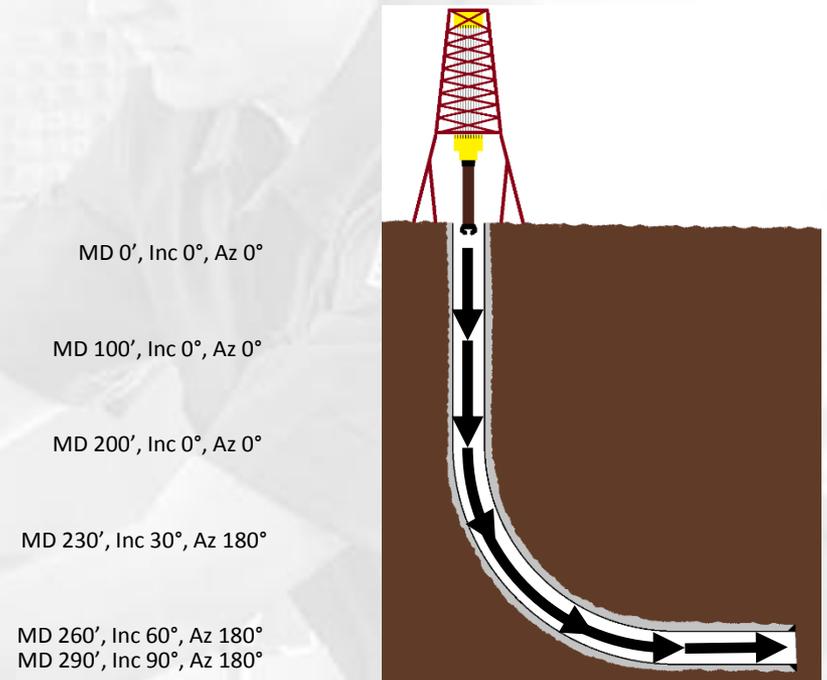
Pad in



## An Introduction to Surveying

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

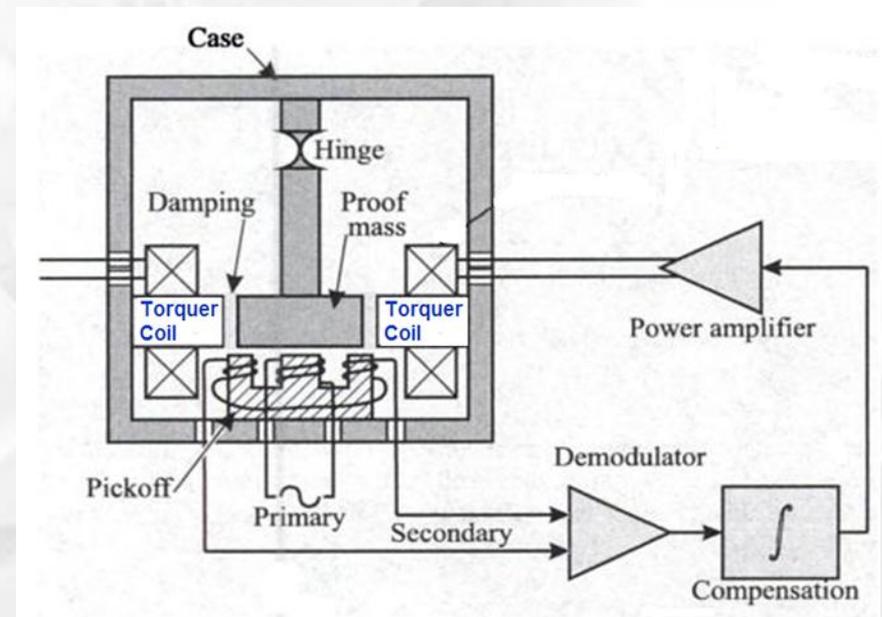
- Measured Depth
  - Acquired from Drill Pipe Tally or Wireline Depth
- Inclination
  - Angle from Gravity Vector (Vertical)
- Azimuth
  - Angle from North on a Horizontal Plane
    - True North
    - Grid North
    - Magnetic North



## 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

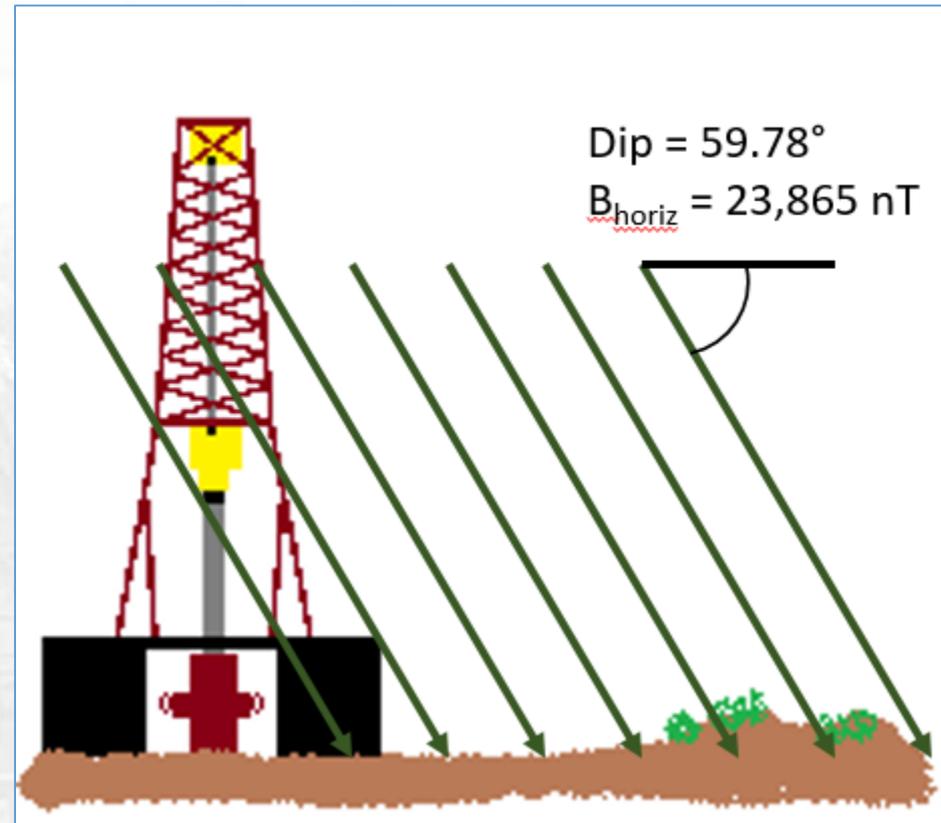
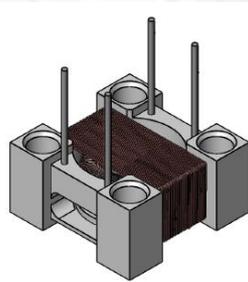


# How Do We Measure a Survey?

## An Introduction to Surveying

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

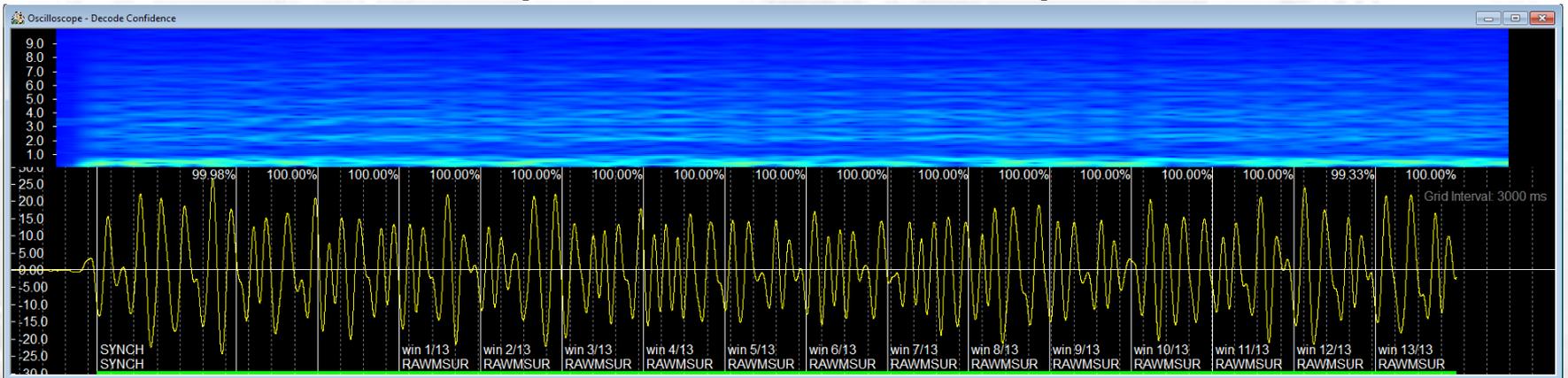
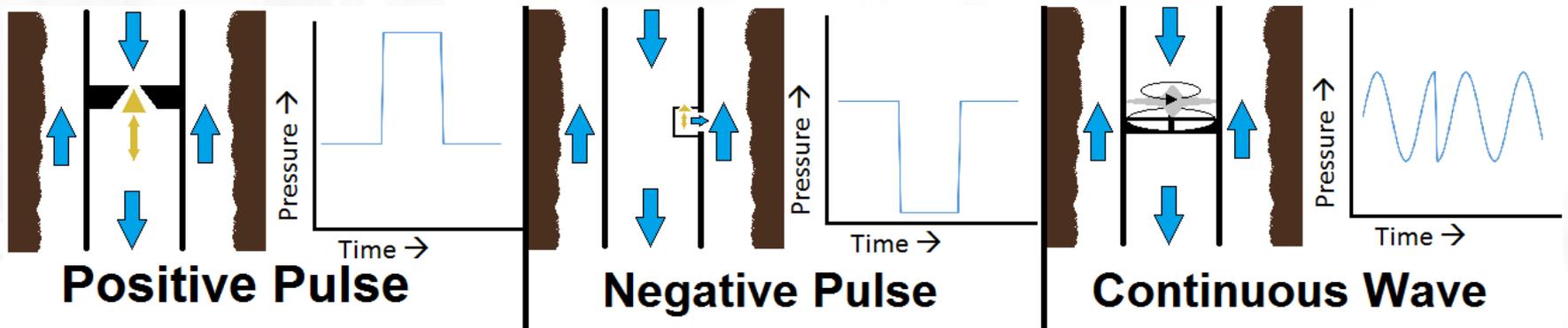
- Measure direction of Earth’s Magnetic Field
  - Declination
  - Dip
  - BTotal
- Tri-Axis Magnetom
  - X, Y, & Z
- Fluxgate Magnetor



# How Do We Obtain Our Measurement?

## An Introduction to Surveying

How do we collect the data as we drill?

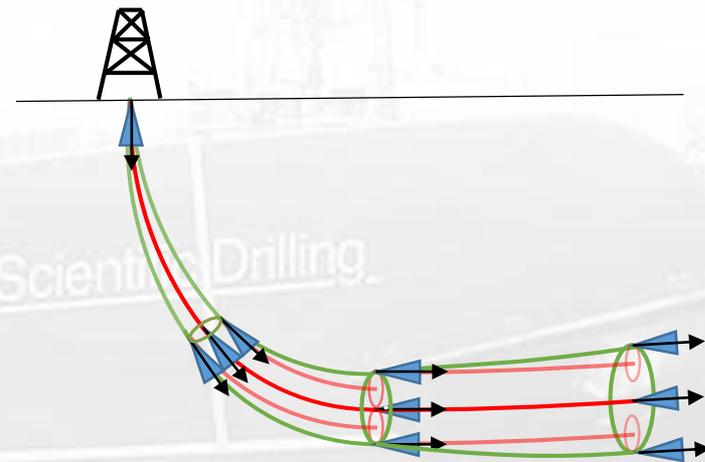




## An Introduction to Surveying

Do we know we were have drilled?

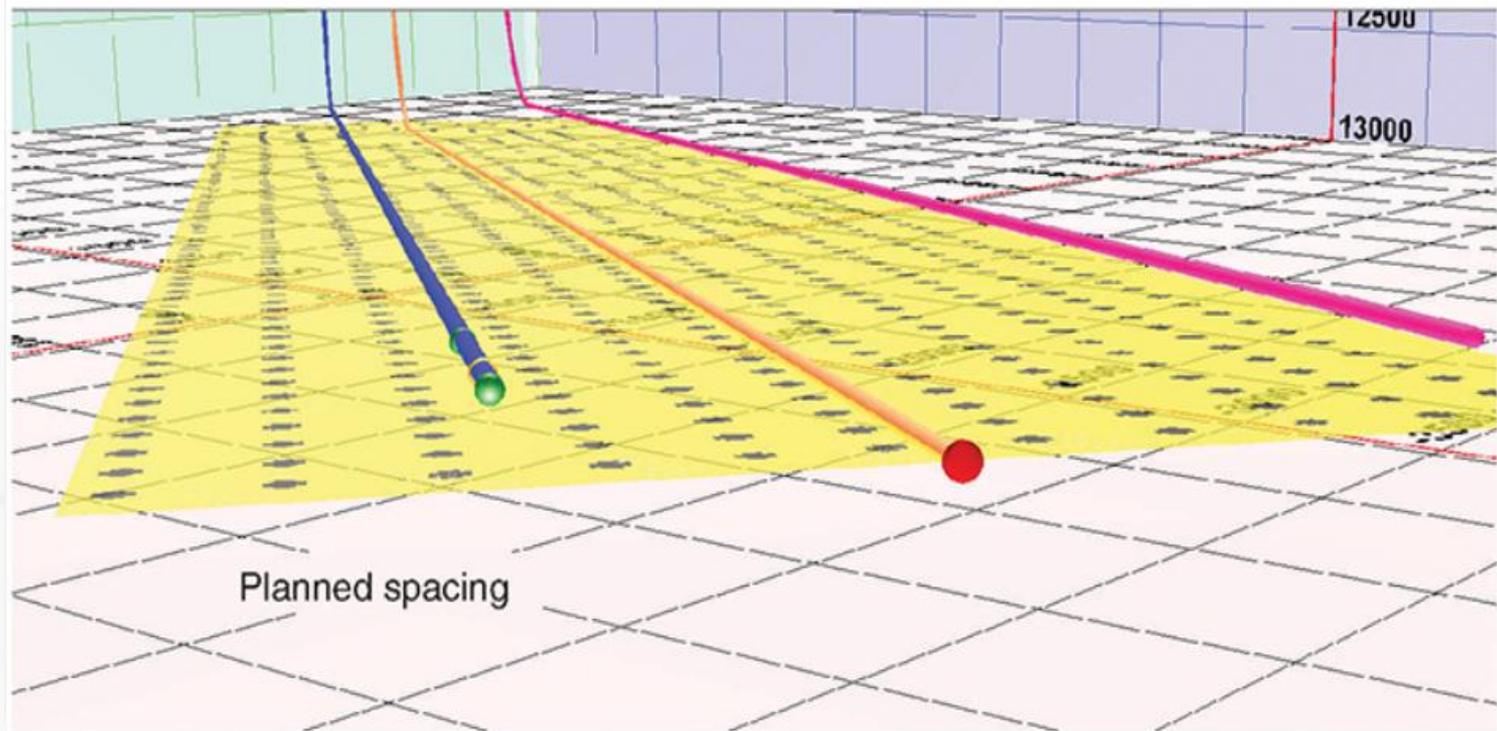
- Short Answer: No
- Propagation of Error
  - Measurement Uncertainty
  - Positional Uncertainty
  - Accumulates Along the Wellbore
  - Ellipse of Uncertainty



# Surveying Errors

## A Review of Wellbore Uncertainty

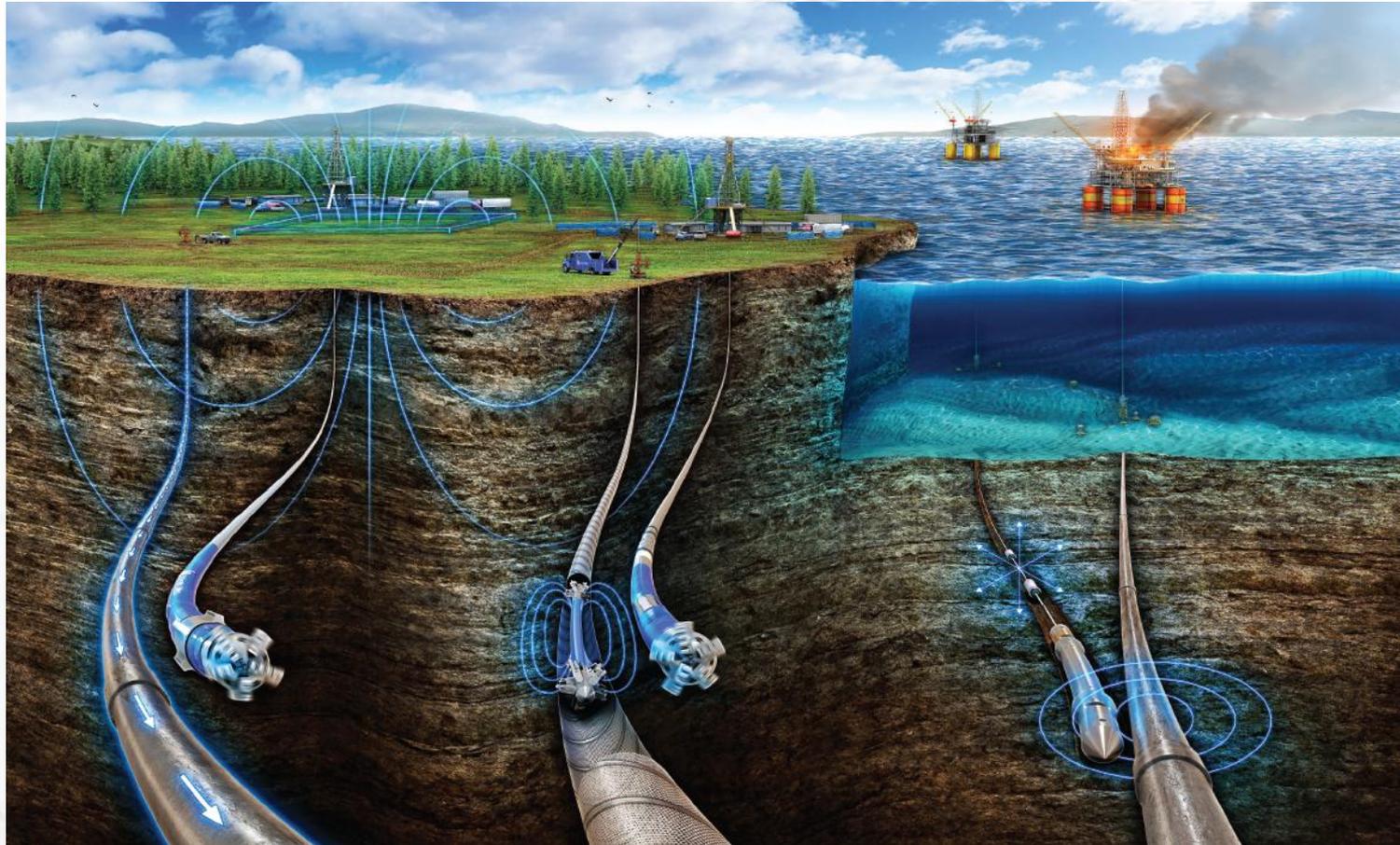
What the reservoir engineer asked for



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

# Magnetic Ranging

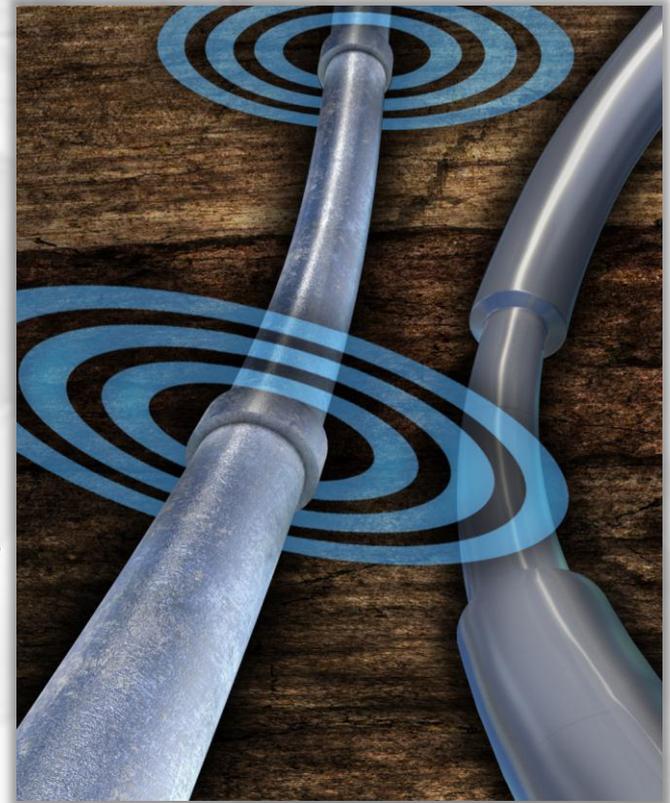
A Suite of Tools for Determine Relative Proximity



# Magnetic Ranging Services

## What is Magnetic Ranging?

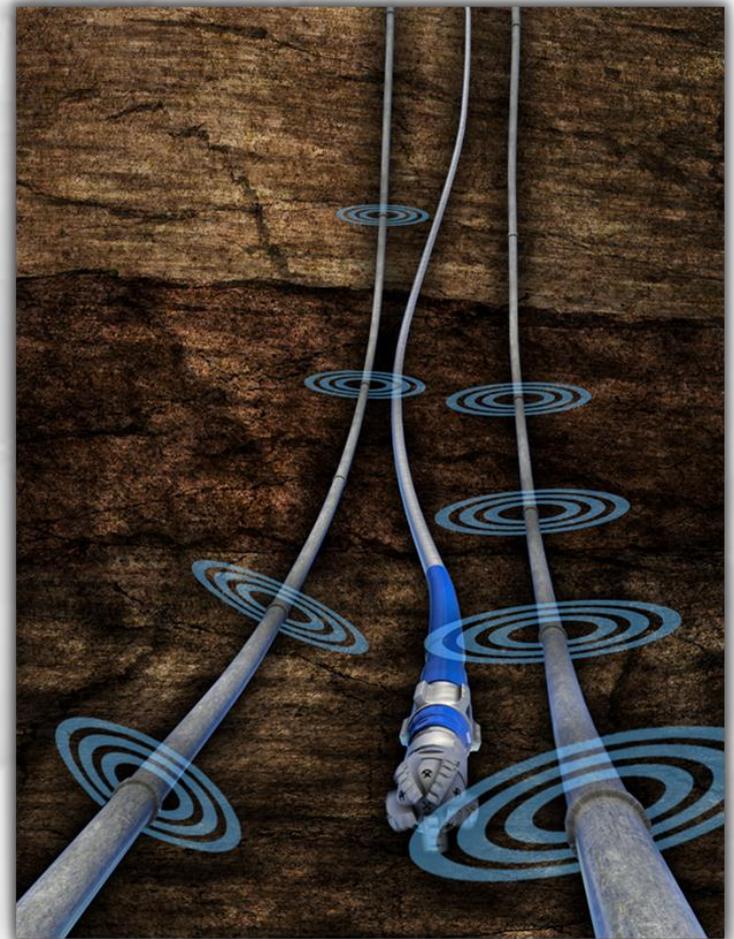
- Using a magnetic field (other than the Earth's field) to determine the distance and direction between wellbores
- A relative downhole vector quantity
  - Distance and direction
- Source
  - A magnetic field generator (solenoid, rare earth magnet, current on a wire or casing)
- Receiver
  - MWD magnetometer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

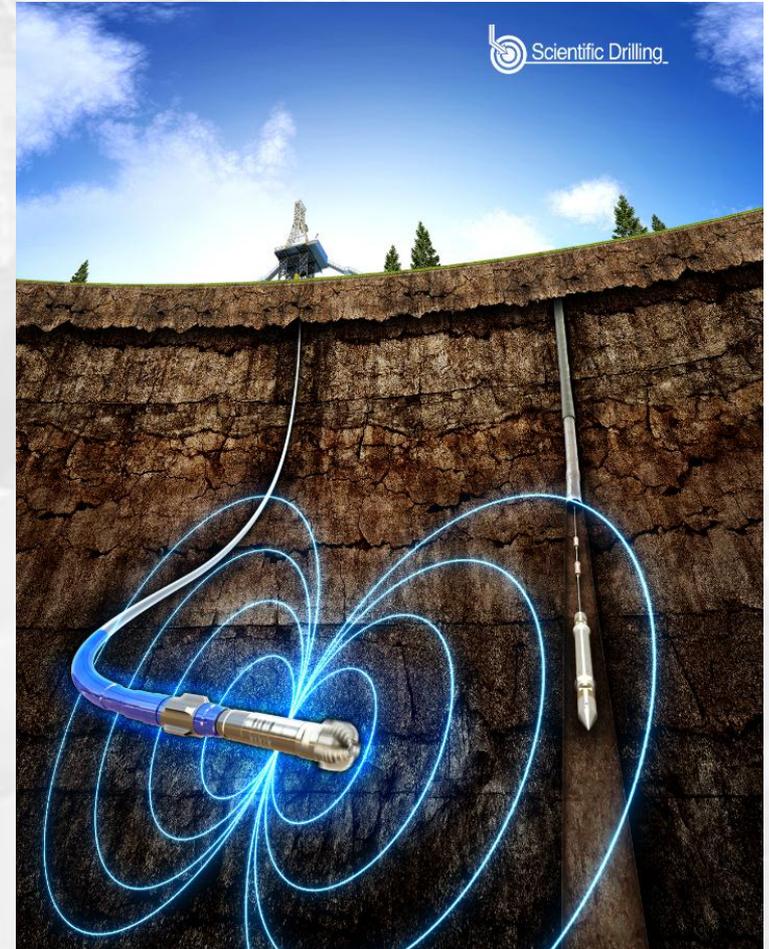


# Magnetic Ranging Services

## 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

## 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

## Geothermal Case Study from Western Canada

A Continuous Geothermal Completion Requiring Directional Drilling and Magnetic Ranging



# Closing Thoughts

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?**

