

# Geothermal Energy Lab

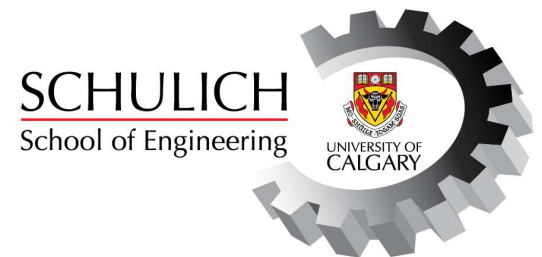
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## Drilling and Completions

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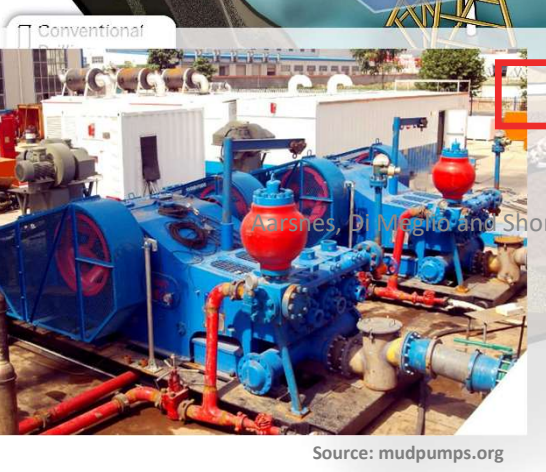
# What is Drilling?



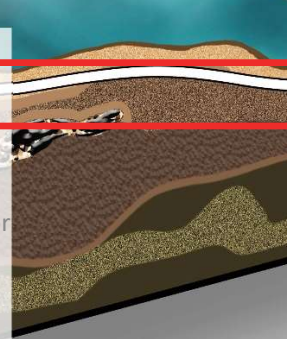
Source: bridgat.com



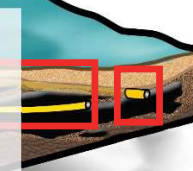
Source: everypart.com



Source: mudpumps.org



Source: eaglefordshale.com



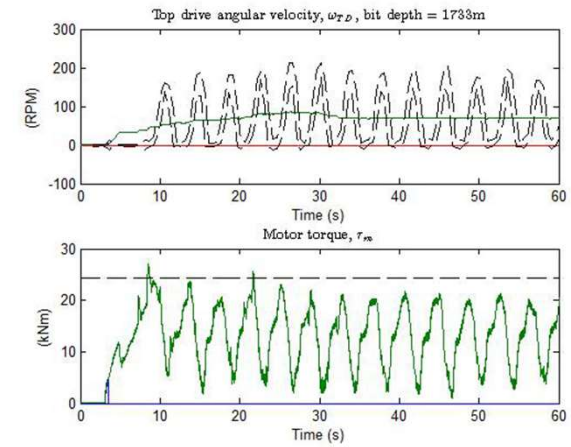
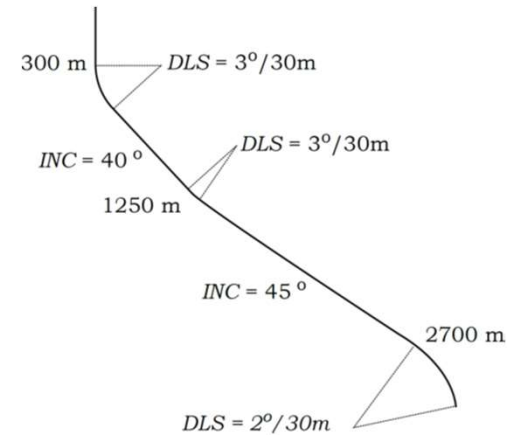
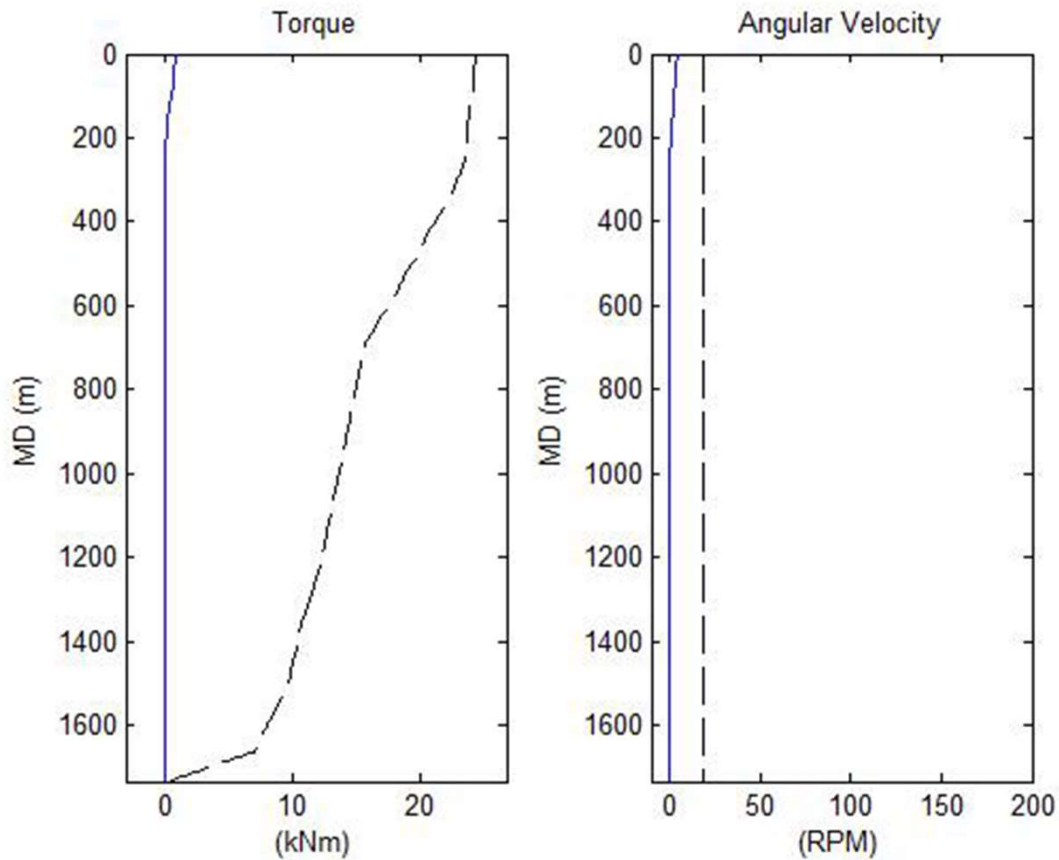
Source: newoilrigs.com

# What is the current state of the art?

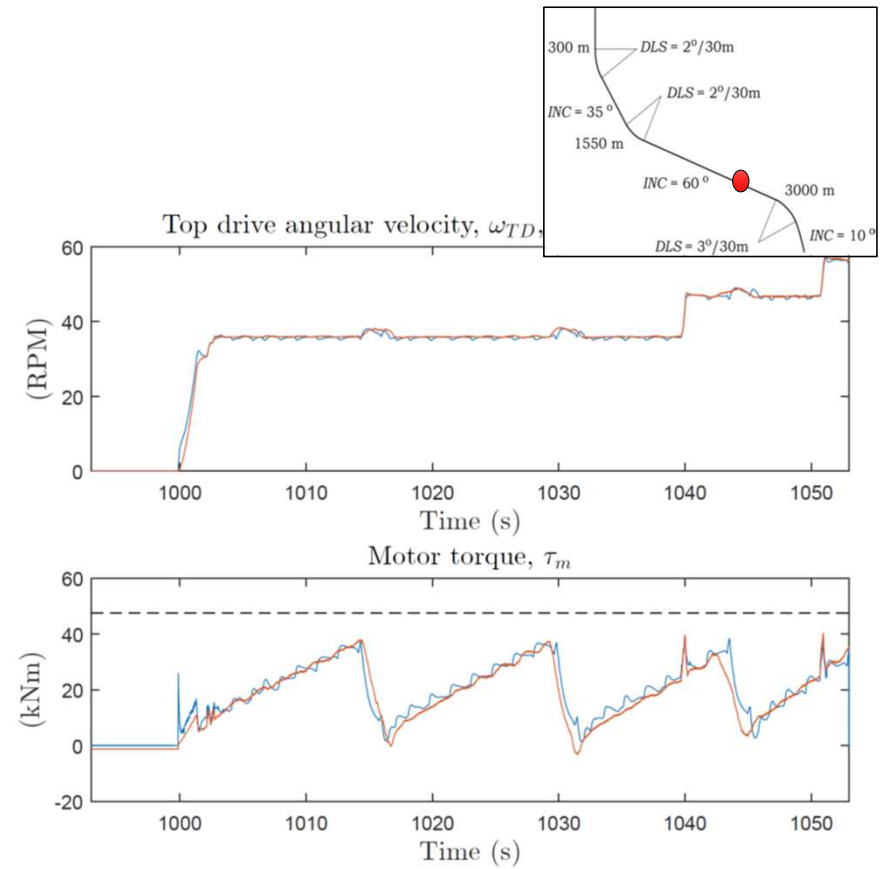
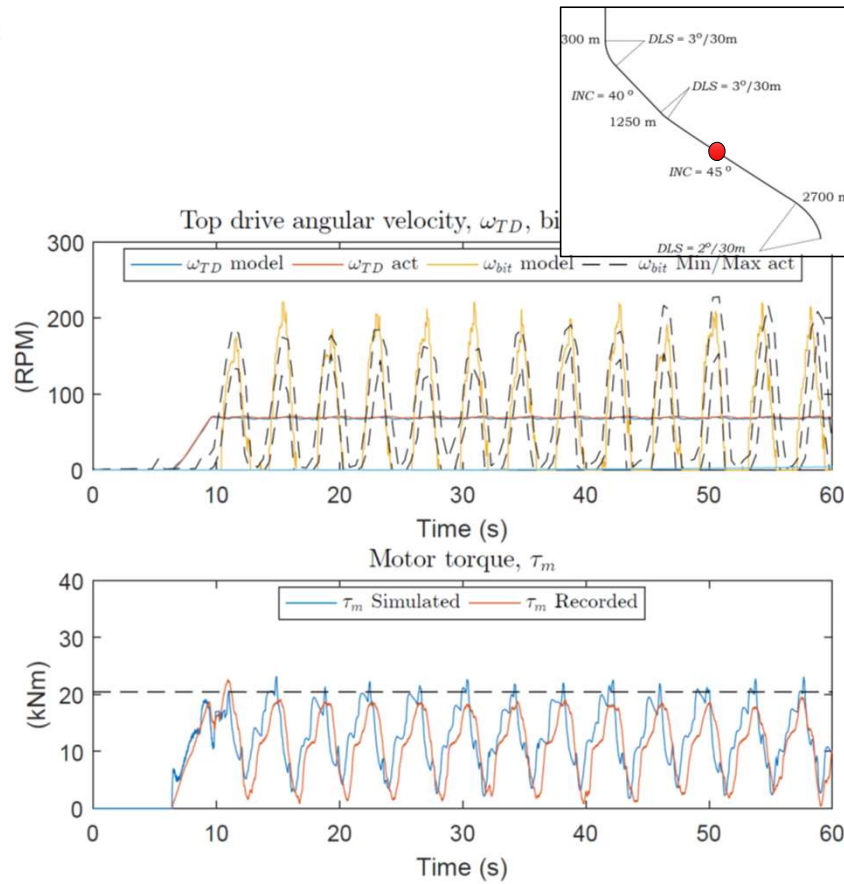
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- Inexpensive and fast wells in sedimentary basins: 5km long wells in two weeks
- High pressure and high temperature (HPHT) wells with surface pressures over 15 ksi (100 Mpa) and flowing surface temperatures above 350°F (177°C)
- Autodrillers with energy based (MSE, in wide use) or optimum seeking controllers (experimental)
- Automated vibration mitigation systems
- Real-time estimation of bottom hole conditions (experimental)
- Real-time automated drilling fluid rheology
- Automated formation detection and bit wear estimation (experimental)
- Wellbore intersection and ranging technologies
- Well plans to optimize reservoir contact and minimize wellbore stresses

# Drilling Dysfunction – Stick-Slip



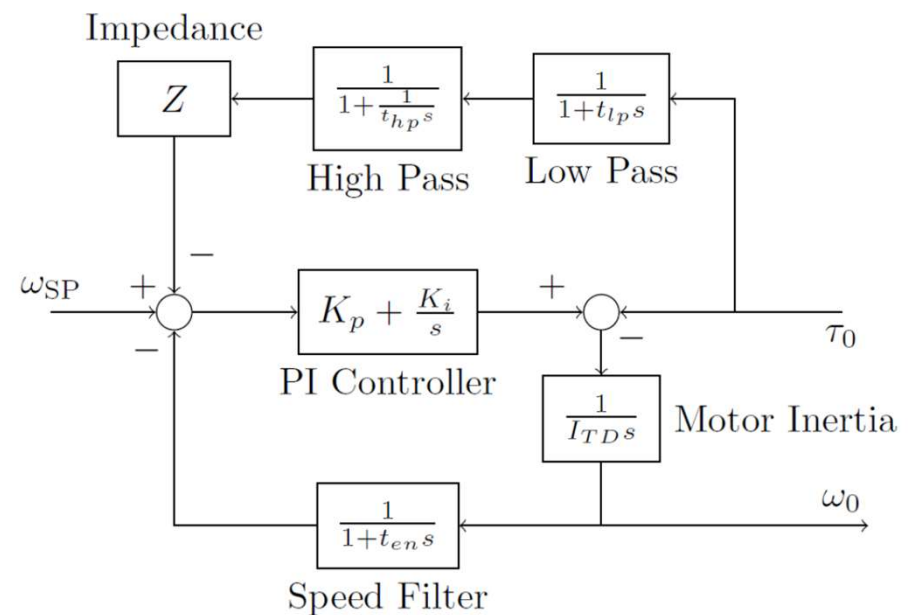
# Drilling Dysfunction – Stick-Slip



# Stick-slip Mitigation Control

Top Drive Speed Control:

1. Stiff speed control
2. Tuned PI control
3. Impedance Matching control
4. Feedforward control (*experimental*)
5. Model Predictive / Machine Learning Based control (*experimental*)

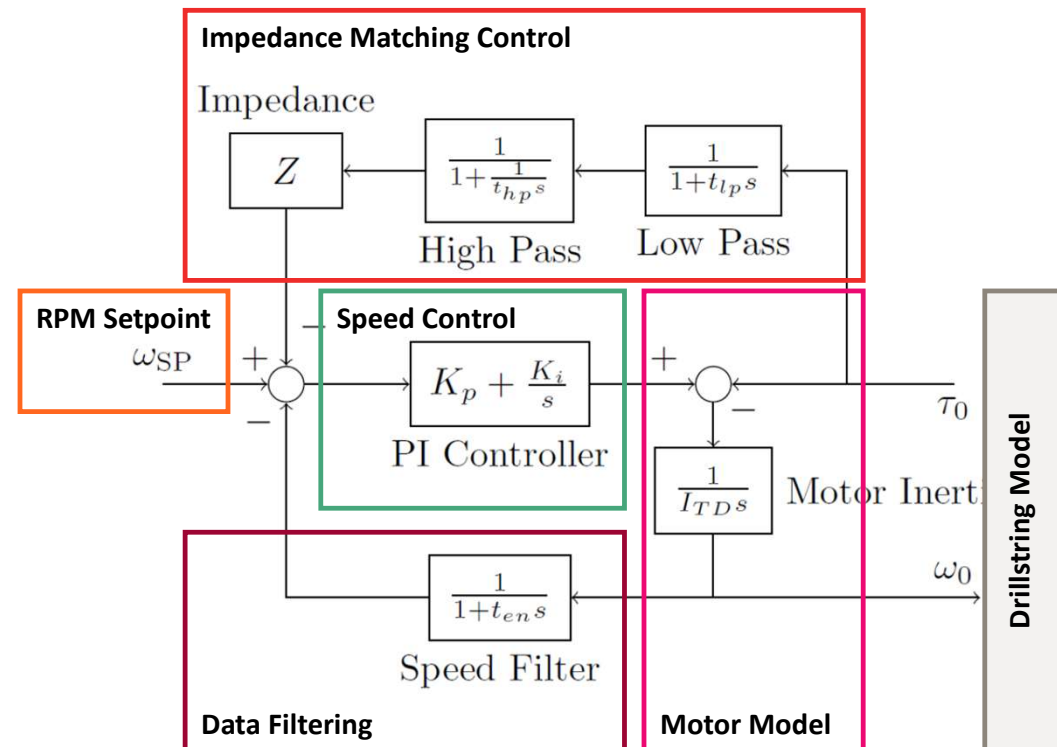




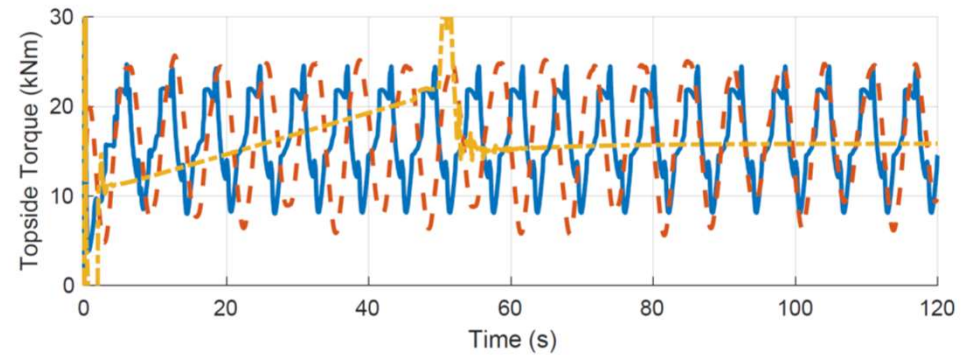
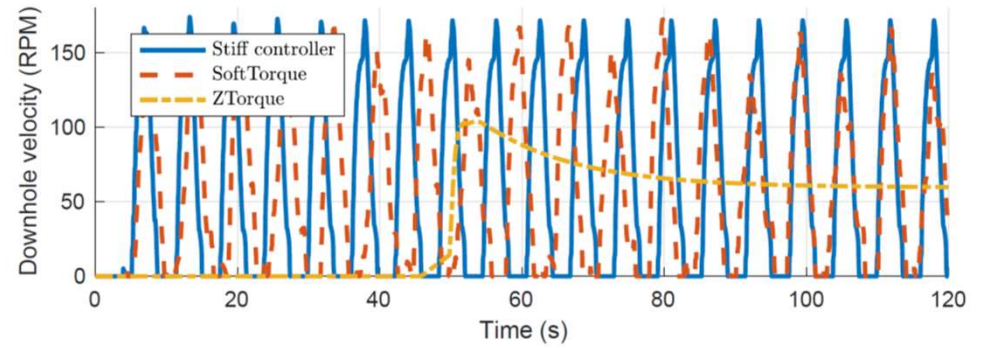
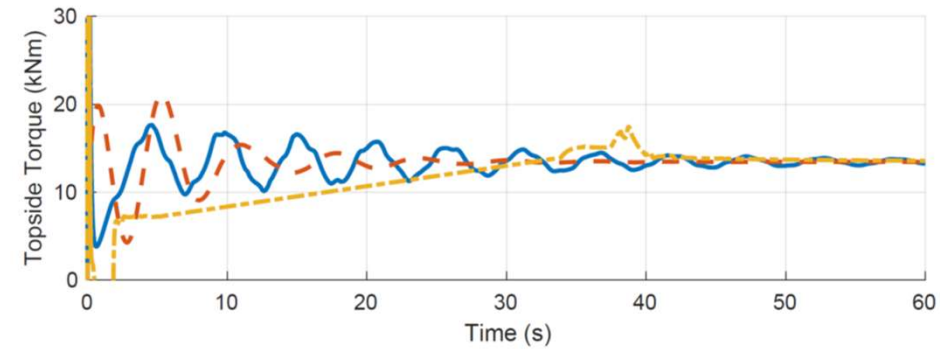
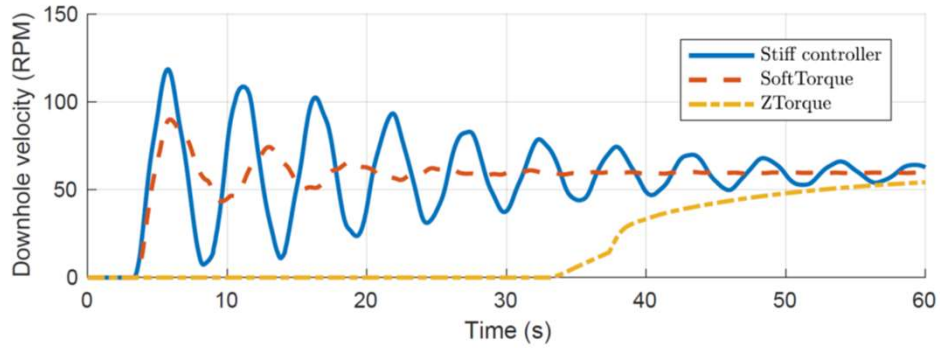
# Stick-slip Mitigation Control

Top Drive Speed Control:

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# Stick-slip Mitigation Control





# Gaps in Knowledge & Technology

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- High Pressure / High Temperature electronics
  - Standard oilfield electronics are only rated to 175°C
- Thermal stresses on borehole equipment
- Thermal effects on hoop stress and rock strength
- Thermal cycling of equipment, casing and cementing
- Hard-rock drilling & optimization
  - Equipment
  - Drilling tools
- Hydraulic and fluid designs

# Sensing and Estimation



## Surface Data Collection

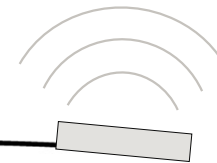
RPM, Torque, Hookload, Pump rate, Pressure, Flow, etc

**Real time** – typically recorded at 1-10Hz  
**Often Asynchronous**

**Real time** – technologies exist, but are often cost prohibitive

**Latent data** – widespread use of mud pulse telemetry (seconds to transmit data with typical bit rates of up to 1kbps)

**Stored data** – stored memory tools can record days worth of high frequency data

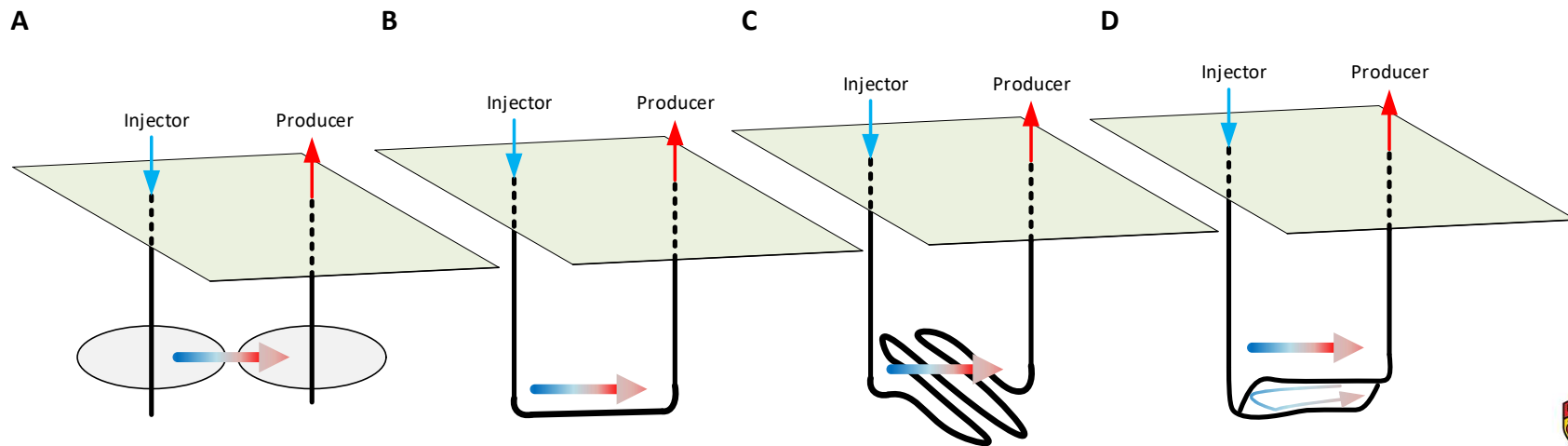


## Downhole Data Collection

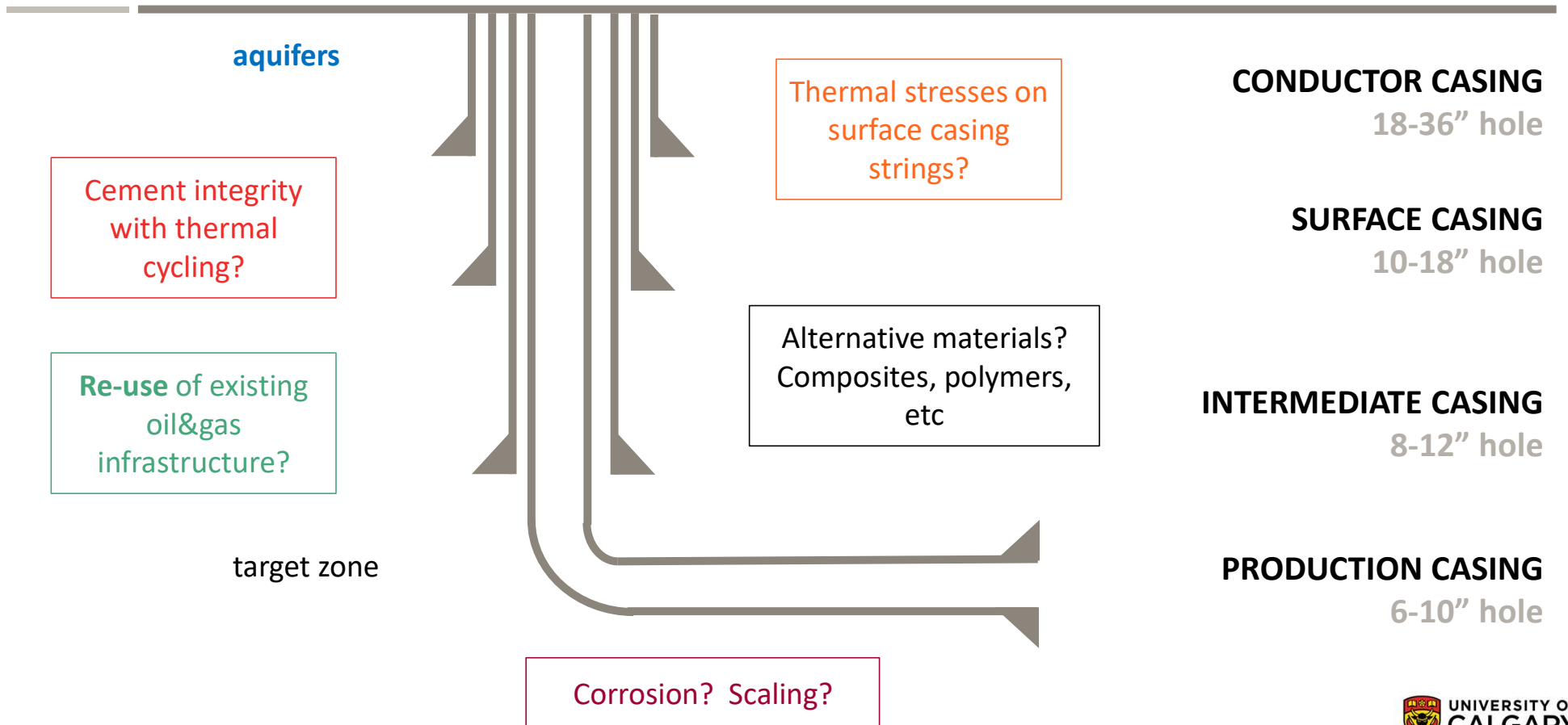
RPM, Torque, Weight-on-bit, Pressure, Vibration, etc

# Well Designs

- Open vs. Closed Loop Geothermal
  - Thermal reservoir as a battery
- Well steering and intersection
- Thermal efficiency & thermal energy recovery factors



# Casing Programs



# Thank you

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