GEOTHERMAL MANUFACTURING PRIZE

AMERICAN MADE
GEOTHERMAL PRIZE

U.S. DEPARTMENT OF ENERGY

Drilling 101: Basics

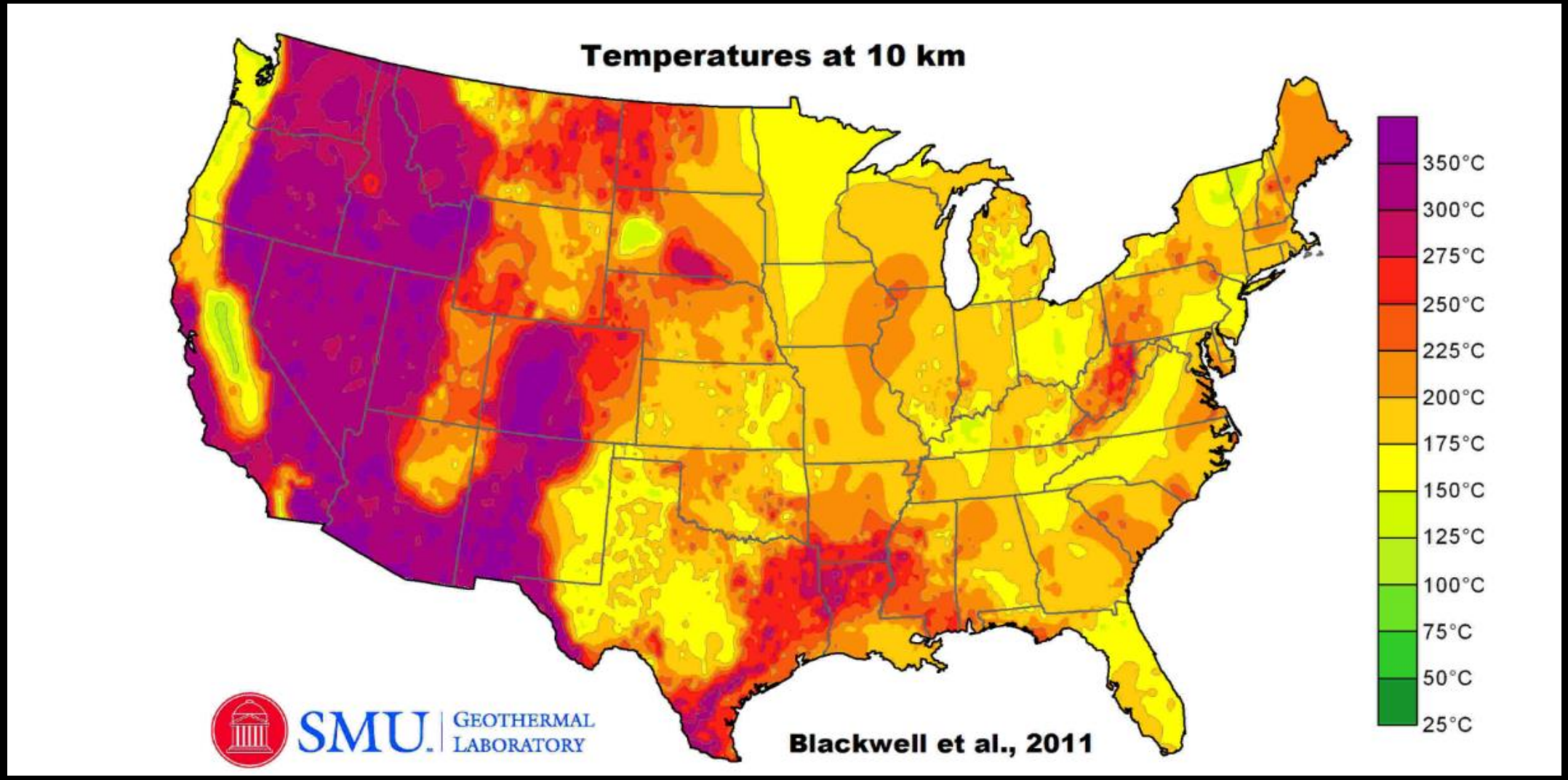
Drilling Faster Saves Time. Rig Time is Expensive, and Less Drilling Time Saves Money. *We Want Cost Reduction. Faster is better.*

Reducing Tool Failure Rates Reduces “Tripping” Which Saves Time

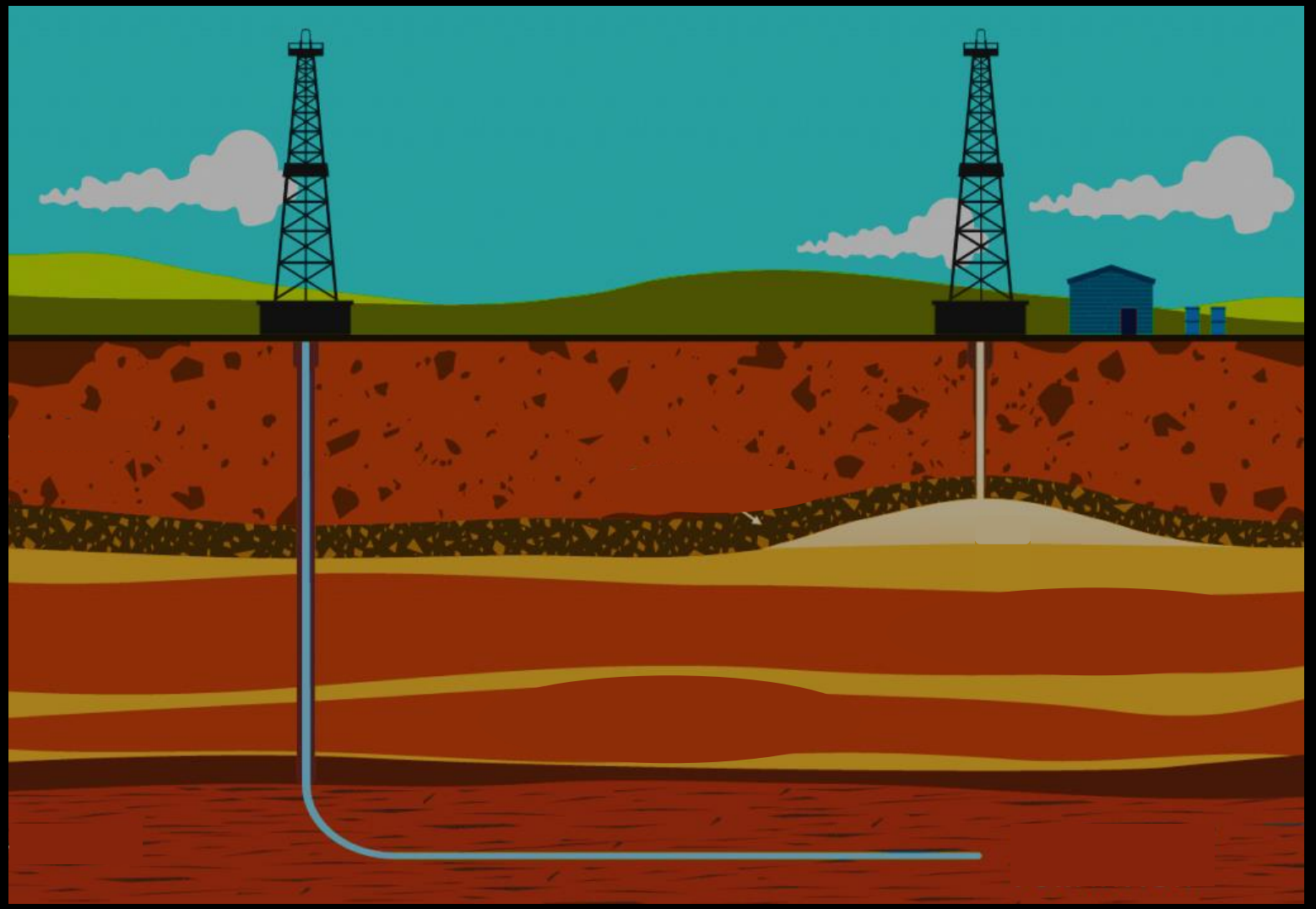
Increasing Tool Capabilities Opens Up New Frontiers for Development

- Hotter (at least 200C – the higher the better – 350C)
- Extreme Shock and Vibration
- High Pressure
- Resists Corrosion

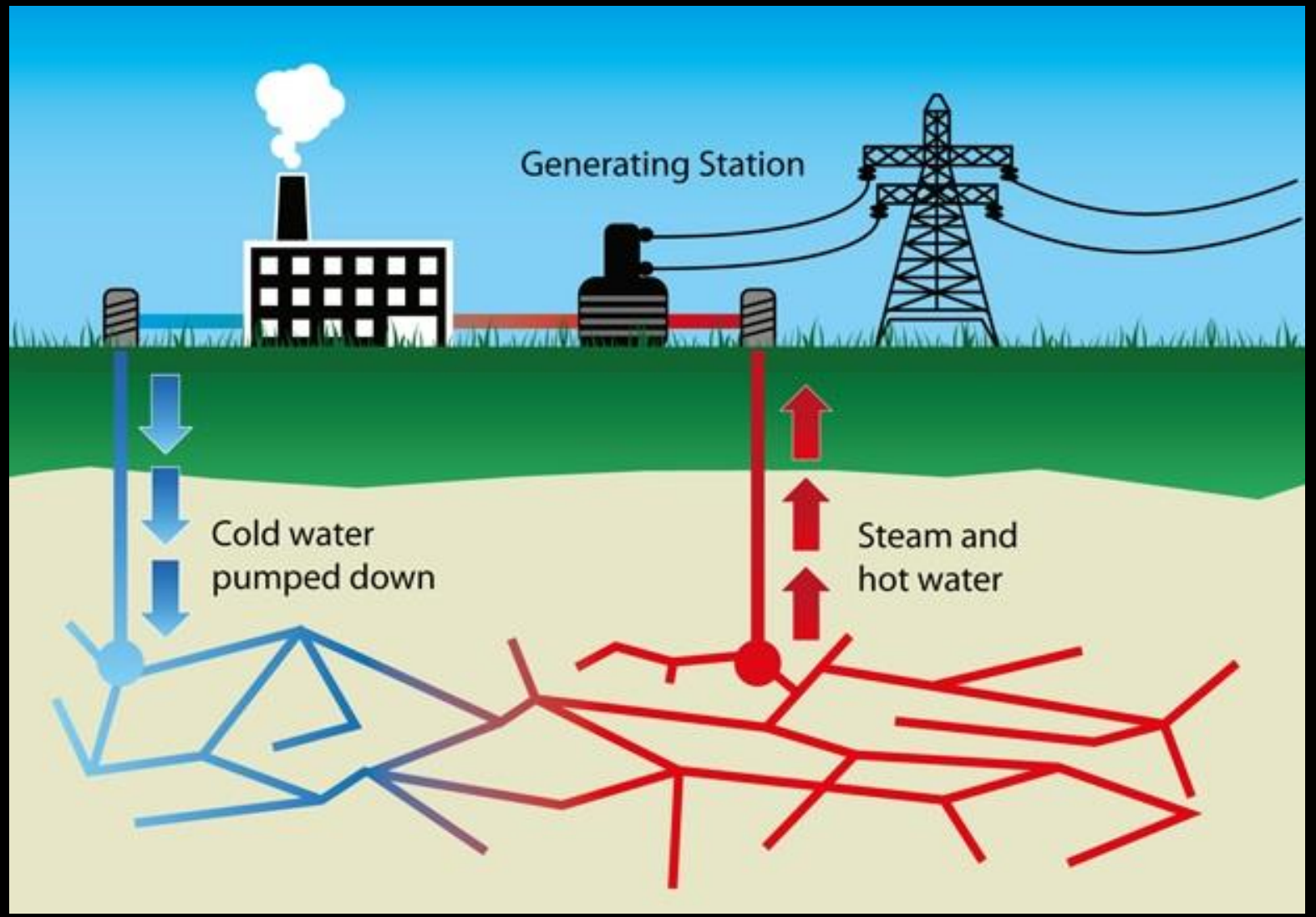
Drilling 101: Why Those Capabilities?



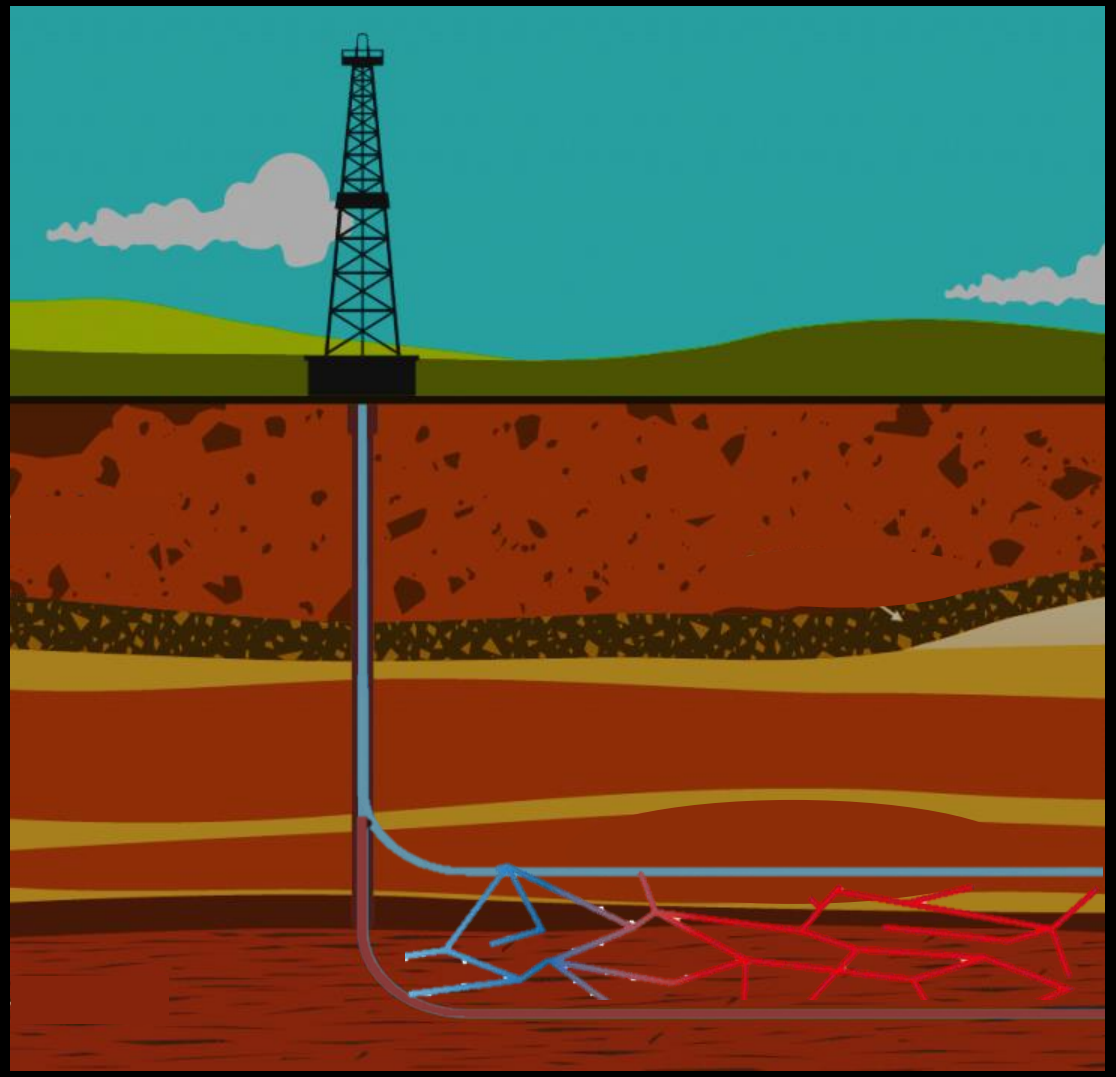
Drilling 101: Vertical vs. Directional



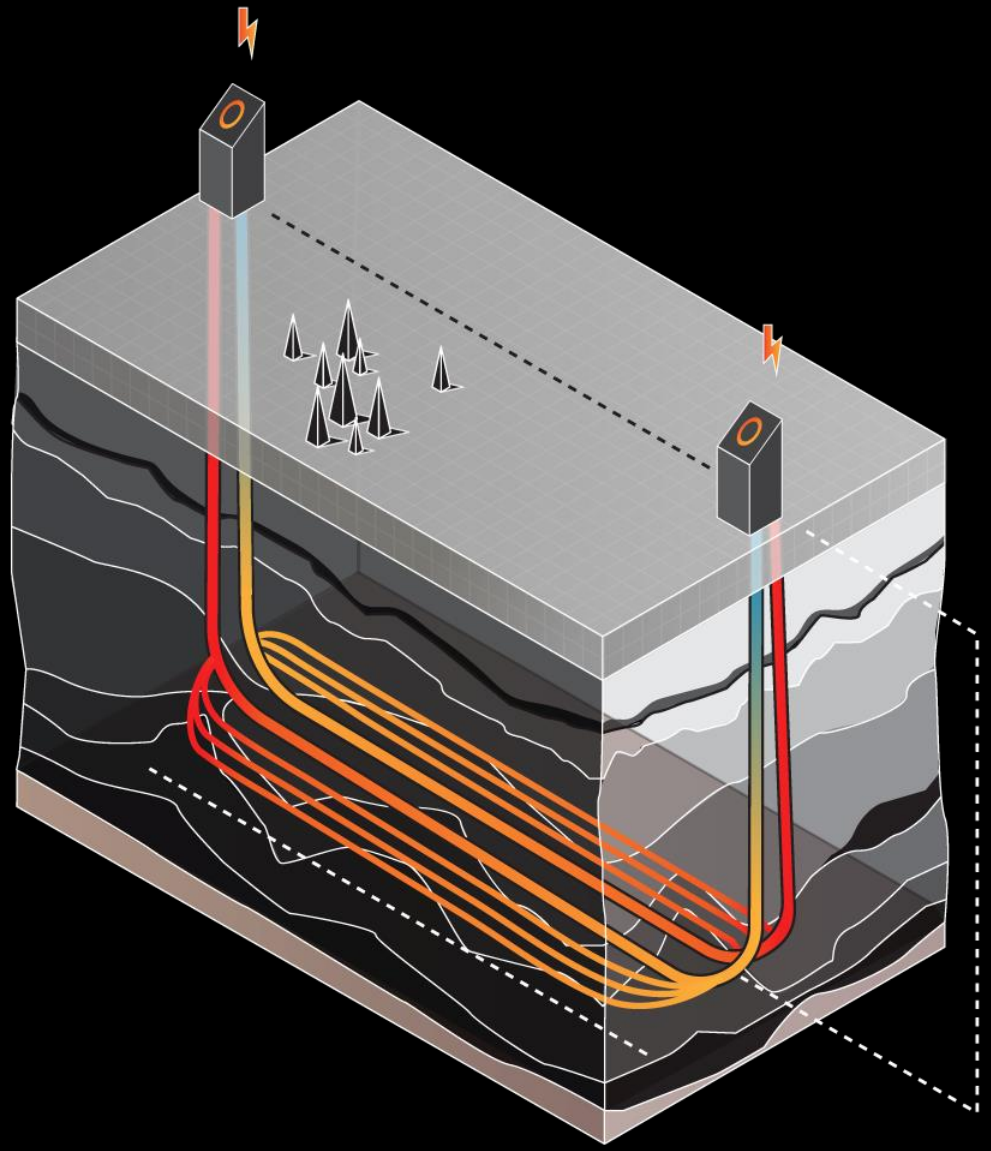
Drilling 101: Vertical vs. Directional



Drilling 101: Vertical vs. Directional



Drilling 101: Vertical vs. Directional

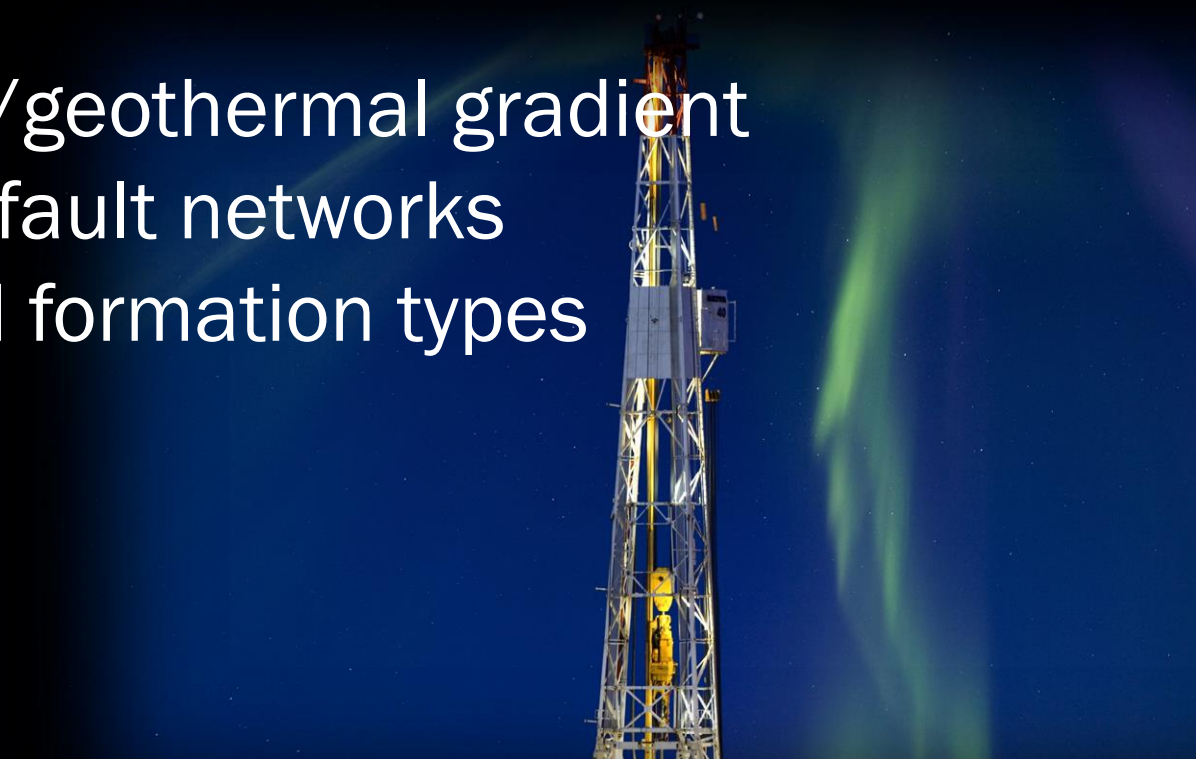


Courtesy of Eavor

Drilling 101: Capabilities We Need

Exploration/Characterization:

- We need to be able to see inside formations to understand:
  - Temperature at depth/geothermal gradient
  - Natural fractures and fault networks
  - Presence of water and formation types
  - Stress and pressure



Drilling 101: Capabilities We Need

Drilling:

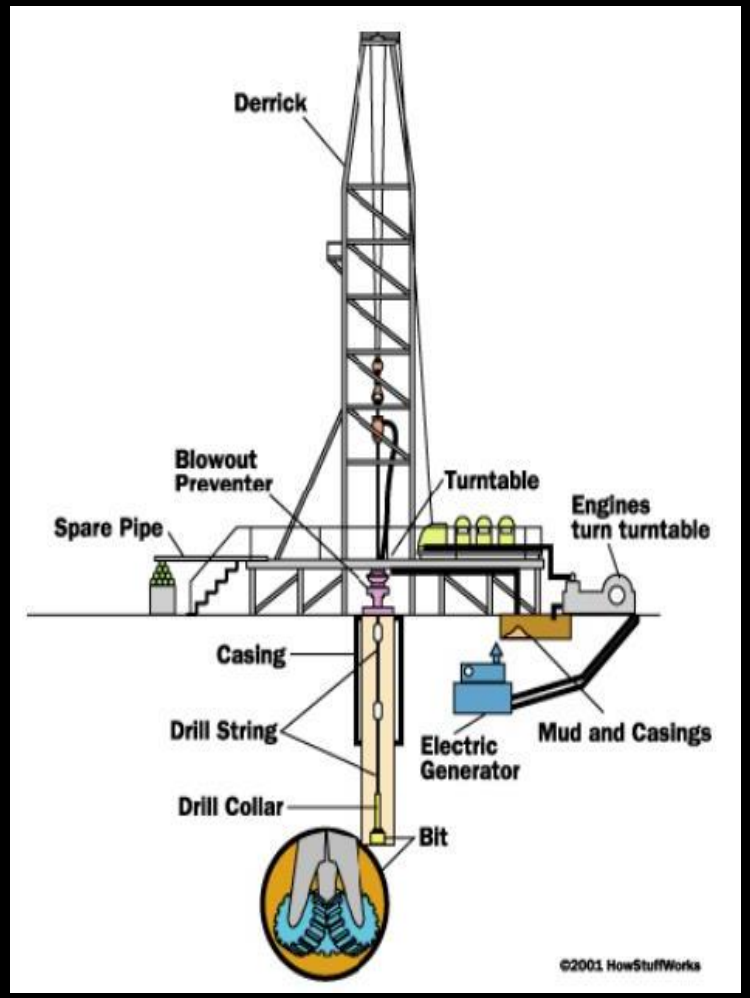
- We need to be able to detect bit location, and conditions it is encountering (temperature, pressure, vibration, shock);
- We need to be able to get that data to the surface quickly, ideally in real time;
- We need to be able to make turns with the drill bit
- We need power downhole to drive these components

Drilling 101: Capabilities We Need

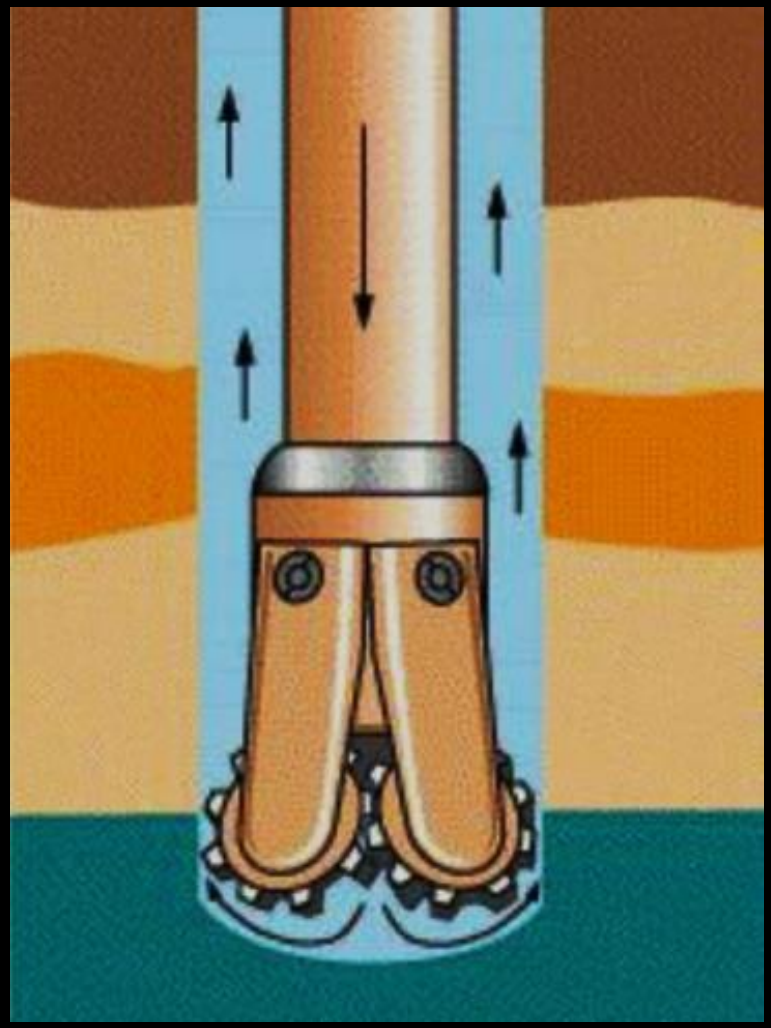
Production/Monitoring/Maintenance

- We need sensors that can survive long term in extreme conditions embedded into the casing to tell us things like temperature and pressure;
- We need to be able to monitor how fractures in the system are evolving over time;
- We need to be able to pinpoint problems areas in the reservoir and repair them (short circuit example)

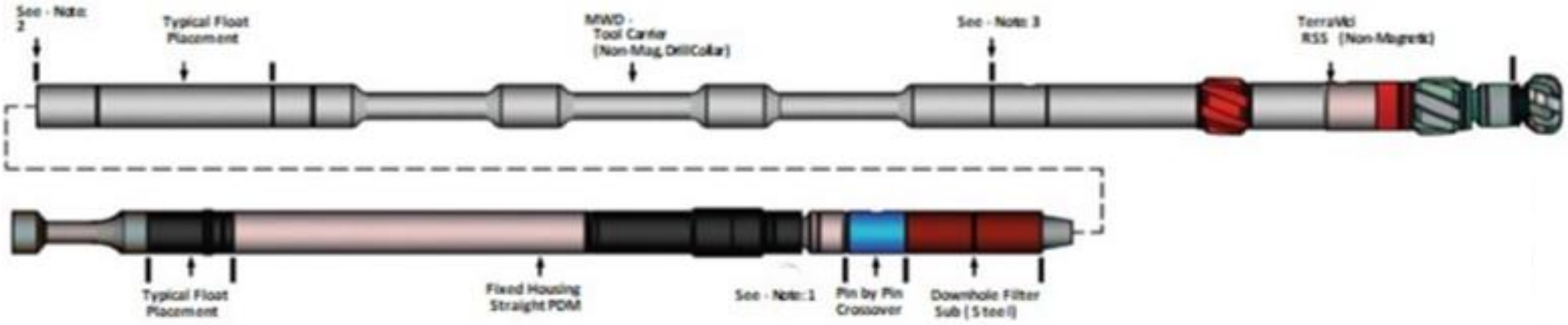
Drilling 101: The Drill String



- The “drill string” includes the bit, BHA, collar and pipe
- Drill bit crushes and cuts rock as it rotates
- Cuttings are flushed out of the hole with a mud circulation system through the bit and out of the annulus
- Mud is cleaned and pumped by downhole
- Drill pipe is layed in 30 foot sections – this is why we need the derrick
- Casing and cementing are performed in increments to isolate well from formation



Drilling 101: Bottom Hole Assembly



Drilling 101: LWD/MWD/Steerables

Typical tools in a drill string:

- Drill bit – basic or intelligent
- Motor to drive bit
- Monitoring while drilling (MWD)
  - Includes a mud pulser or EM telemetry to get data to surface
- Logging while drilling (LWD)
- Batteries or a turbine generator to power tools

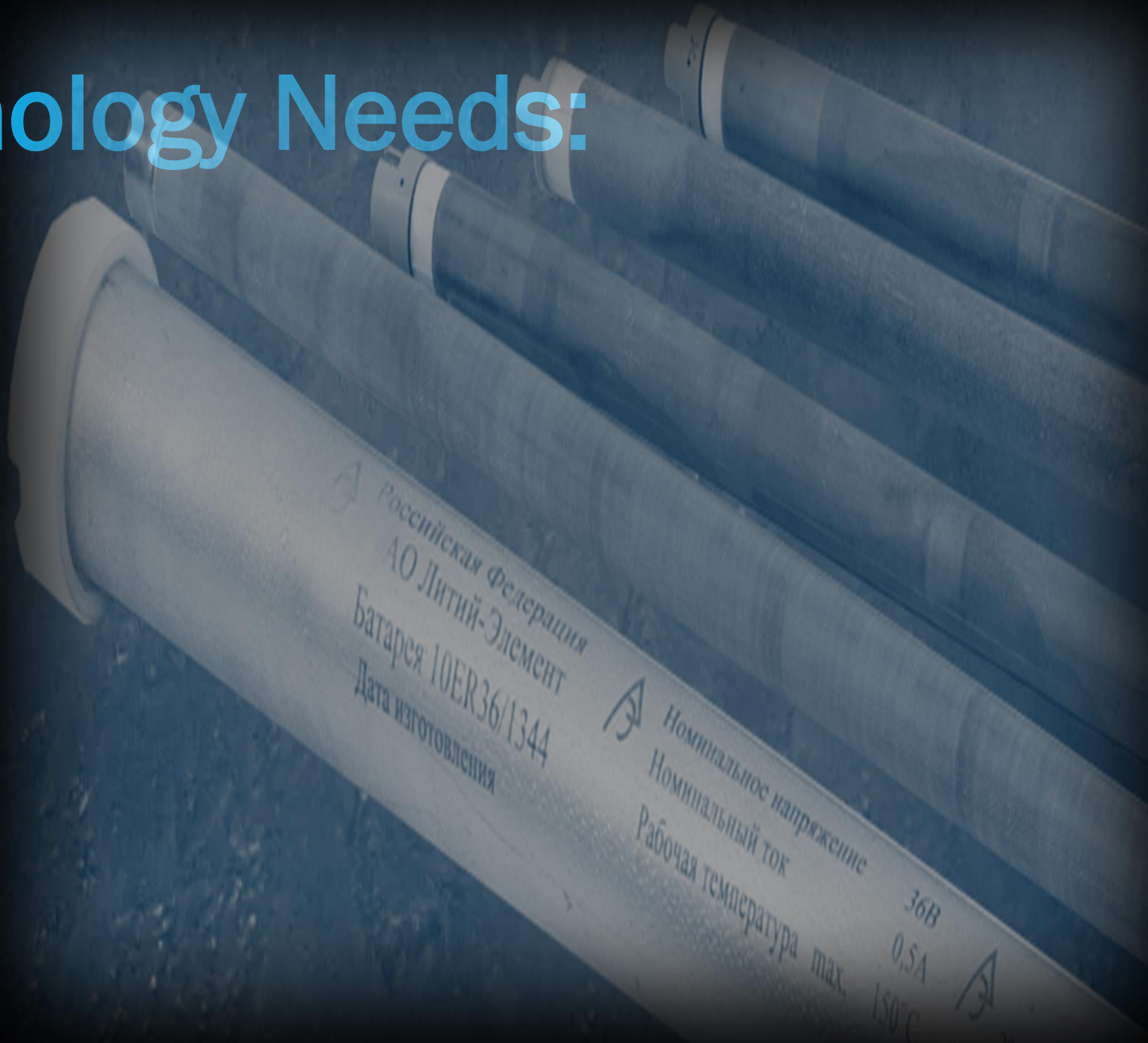
Each tool type adds a new capability, but they all have challenges in high temps – 180C is max for most

What do we need to make it happen? Harden the Tools.

- Resource Characterization
- Drilling and Completion
- Operation, Monitoring and Maintenance

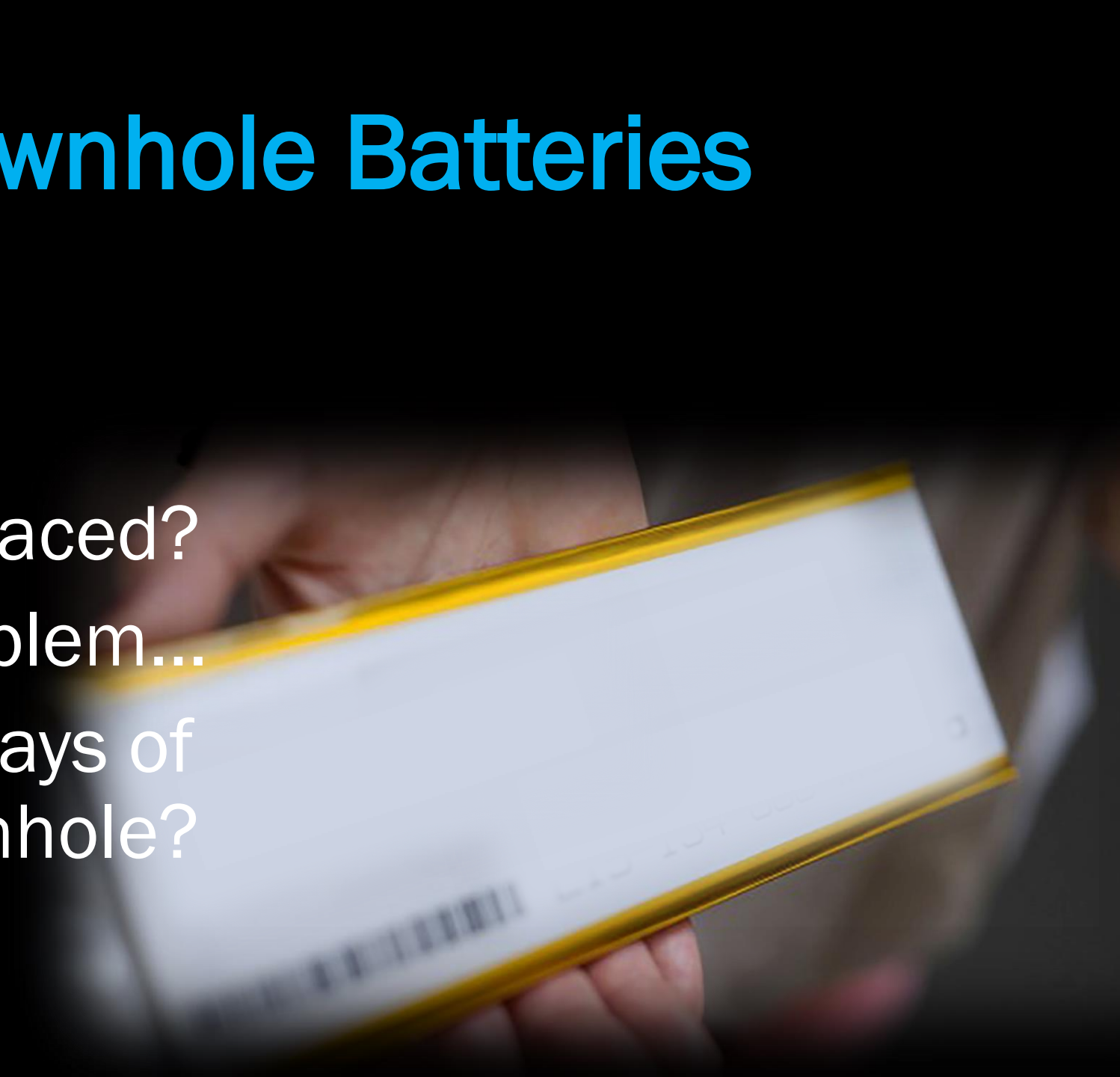
Example Technology Needs:

- Ultra high temperature energy storage devices or other downhole power sources



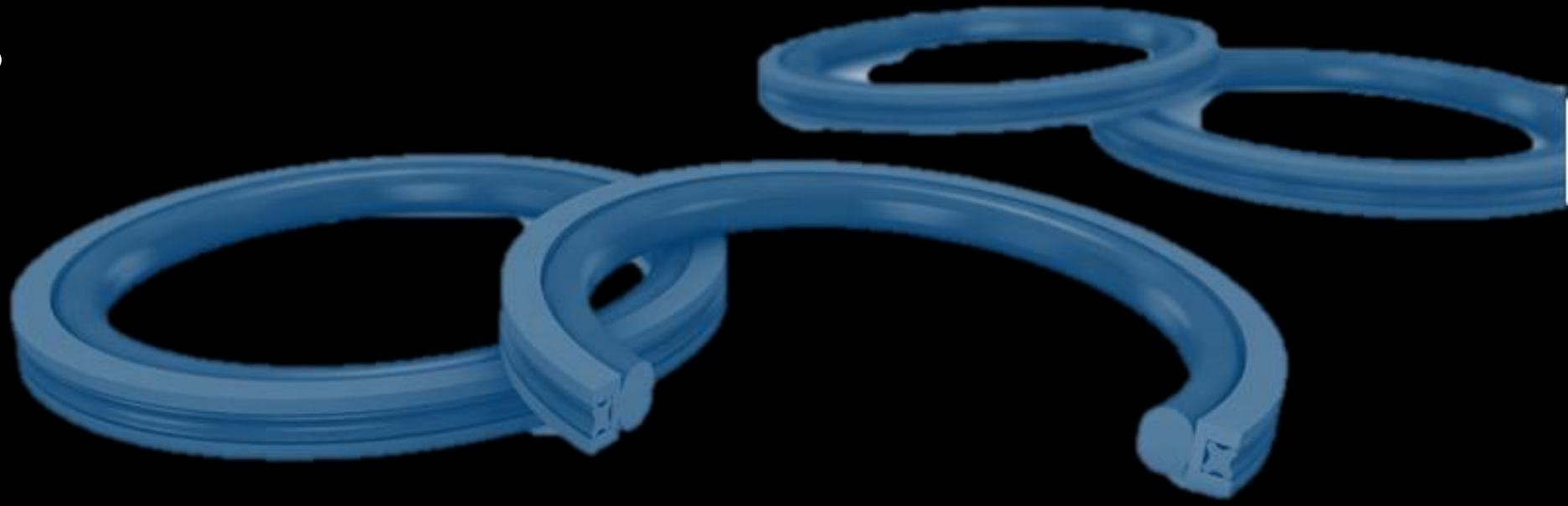
Case Study: Downhole Batteries

- Insulation?
- What about shock?
- Can Lithium be replaced?
- The form factor problem…
- What about other ways of getting energy downhole?



Example Technology Needs:

- High temperature seals or new technologies that eliminate seals



Case Study: Downhole Motors

https://www.osti.gov/servlets/purl/1496969

Sealing Technology

- Current design elastomers would not survive 300°C

Normal

After 50 hours @ 300°C

- Solutions
  - Metallic Bellows used in drill bit pressure compen
  - FFKM O-rings used in mud motor

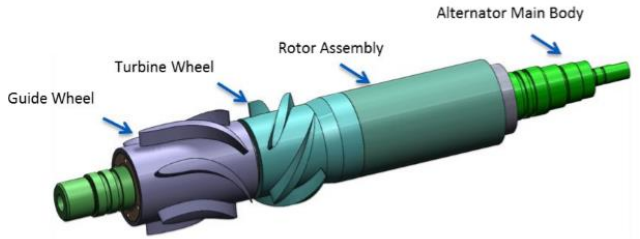


Figure 11 Alternator with guide- and turbine wheel

Alternator guide- and turbine wheel for concept testing on a water flow line

For Each Tool, Ask the Following:

- What causes this tool to fail at high vibration, pressure, shock or temperature?
- Can this mode of failure be eliminated by a design that leverages additive?
- Where is the ‘low hanging fruit’

GEOTHERMAL MANUFACTURING PRIZE

AMERICAN MADE
GEOTHERMAL PRIZE

U.S. DEPARTMENT OF ENERGY