Outline

› Background
› Geothermal drilling challenges
› Drilling and rock breaking
› Paths to drilling improvements
About IRIS

› Client-oriented research institute – Energy, Environment and Social Science
› Clients from trade, industry and public sector – nationally and internationally
› Ca. 200 employees, from 23 different countries, 92 PhDs
› Main office in Stavanger, Norway

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IRIS Energy – main areas

- Drilling & well technology
- Reservoir technology
- Research facilities
- Green technologies
Geothermal energy resources

› Geothermal gradients
  • 5-70 °C/km in the earth’s crust (typically ~30 °C/km)
  • Anomalies occur (volcanic regions)

› ‘Unlimited’ energy resource base
  • A matter of well depth
  • MIT report (2006): potential for 100 GWₑ in the US

› How to harvest the thermal energy resources?
Geothermal energy today

1. Low temperature systems
   - With heat pump systems
   - Seasonal storage
   - Shallow wells (some 100 meters)
   - Relatively “easy” drilling (hammer/percussive)
   - Cost-effective heat and increasingly popular

2. High temperature systems
   - Limited to “hydrothermal” sites – typically volcanic regions
   - Up to ~4 km depth
   - Sufficient water and high natural permeability
   - Suitable for power production – typically ~200 °C steam
   - Limited resource base (few regions in the world)
Unconventional geothermal well types

› “Hot dry rock” or EGS (engineered/enhanced geothermal systems)
  › Possibility of “universal” geothermal solution
  › Need to drill sufficiently deep (hot enough)
  › Understanding the reservoir
  › Necessary to circulate through a large fracture network (subsurface heat exchanger)
› Future: Extreme temperatures (supercritical fluids)
  › 400-500 °C, high pressure
  › Hot research topic

› A vast resource base is available
Deep geothermal vs. oil & gas

› Geothermal wells are similar to oil & gas:
  1. Drilling
  2. Completion
  3. Maintenance/ intervention (production)
  4. Plugging and abandonment

› Technology transfer (oil & gas vs. geothermal)?
  • Different incentives for cost reduction
  • Shared markets yield high costs (compete for rigs, crew etc.)
  • Geothermal as first mover?
Cost of geothermal drilling

› Literature: 30-70 % of plant cost on well construction
› IEA (2011): Key R&D priority on cost-effective drilling technology
› EGEC (2016): Target of 25 % well construction cost reduction


(Augustine et al., 2006)
Some geothermal drilling cost drivers

› “Uniqueness”/learning curve effect
› Materials (casing/cement)
› Large hole diameters
› High temperatures
› Downhole environment
› Fractured rock
› Hard rock
Drilling cases and applications

- Shallow
  - Mining
  - Tunnel construction
  - Shallow geothermal
- Deep
  - Deep geothermal
- Soft rock
- Hard rock
- Petroleum
Technology development – deep hard rock (geothermal) drilling

› Rock breaking is the single most important factor
  • Low penetration rates
  • Equipment wear and failure

› Fundamental concerns of rock breaking process:
  • How energy is transferred to the rock (breaking the rock)
  • Controlling secondary effects (bit wear, drillstring dynamics)
  • Cuttings removal
Technologies for breaking rock

**Thermal**
- Flame
- Electric spark/arc
- Laser
- Electromagnetic
- ...

**Fluid-based**
- Jetting
- Cavitation

**Chemical**
- Reactive acids, fluorine etc.
- Explosives
- ...

**Mechanical**
- Impact (axial)
- Shearing (torsional)
Mechanical drilling improvements

- Percussive drilling
- Rotary drilling
- Drilling process control
Percussive drilling

› Effective for hard rock
  • High rock breaking efficiency

› Limited depth
  • Air drilling for shallow wells
  • Unconventional for deep wells

› Development for deep drilling
  • Operation
  • Hammer
  • Drillbit
  • Drilling fluids
  • Rotary/percussive action

(Axis Copco hammer/drillbit)
Rotary drilling

› Today’s method for deep wells
  • Efficient shearing mechanism

› Hard rock challenges
  • Drillbit wear
  • Dysfunctional vibrations

› Development areas
  • Drillbits
  • Other tools in the string
  • Control/operation
Geothermal drilling: Short term improvements

› Percussive drilling for deeper wells
  • Increased applicability (depth)
  • Potential for step changes

› Rotary drilling for increasingly harder rocks
  • Shearing (PDC) bits for geothermal
  • Increased applicability (control, materials...)
  • Gradual improvements
Geothermal drilling: Longer term improvements

› Electrical power from surface to downhole
  • Efficiency and robustness
  • Powering and direct control of drilling tool
  • Traction
  • High bandwidth communication (wired pipe)

› Development of “unproven” methods
  • High rock breaking potential: Laser, microwaves, plasma, electric sparks etc.
  • Performance at depth, e.g. power supply, high pressure
Summary and conclusions

- Accessing the geothermal energy is a major challenge (cost issue)
- The Norwegian oil & gas drilling expertise gives us a benefit
  - Close collaboration with drilling industry
  - From petroleum to geothermal well construction – similarities and differences
- IRIS wants to contribute to the geothermal community
Thank you for your attention!

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