Geothermal Well Drilling, the differences between Geothermal Drilling and Oil and Gas Drilling. The challenges of drilling and producing hot, volcanic resources from fractured formations.

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November 21, 2014

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Different types of Geothermal Resources

Resource Type

- Liquid-dominated.
- Vapor-dominated
- Geopressured - Geothermal
- Engineered Geothermal System (EGS)

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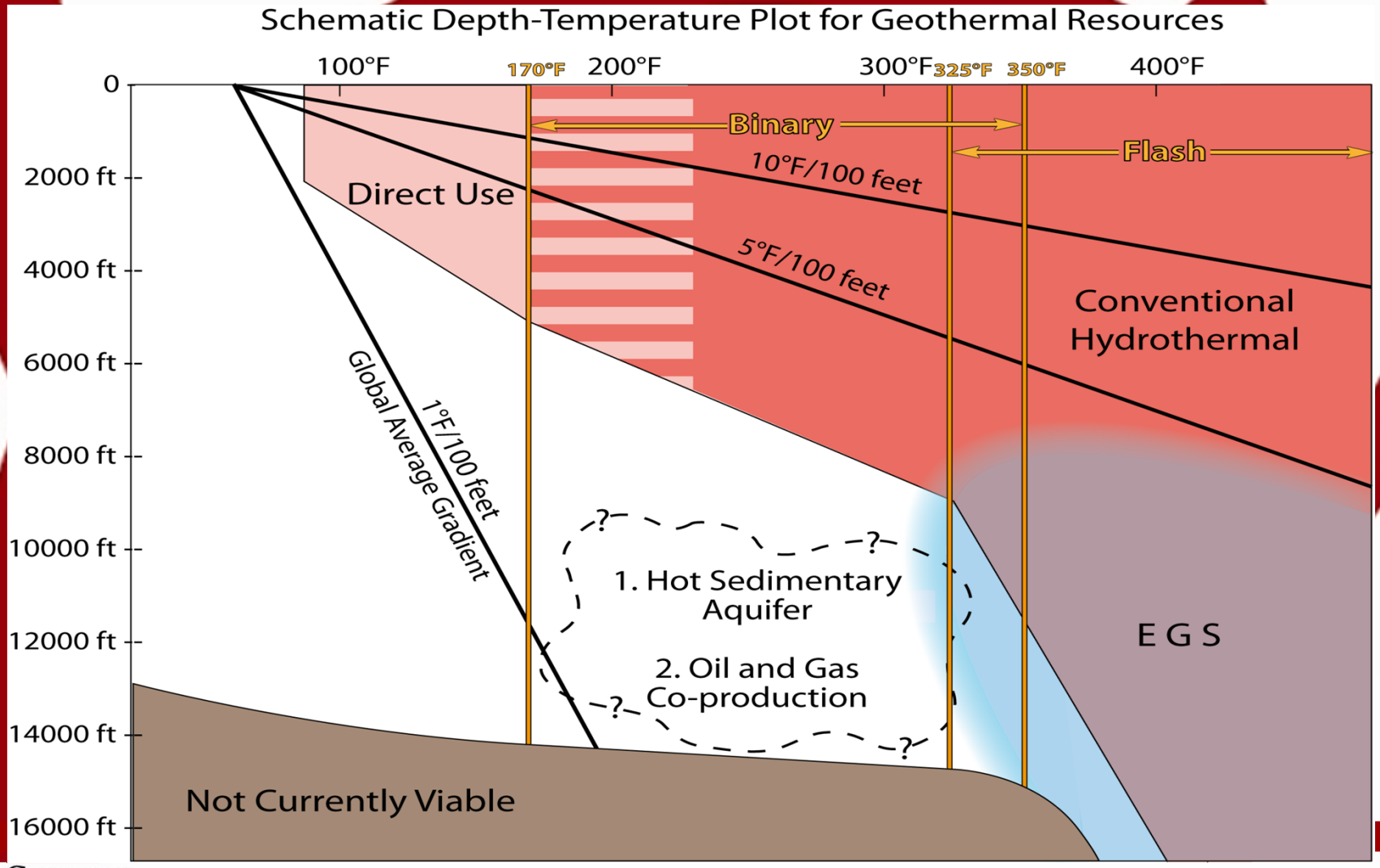
Field and Lithology Information



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Differences between Oil/Gas and Geothermal Drilling

- Temperature
- Hard-Rock Formations
- Large Wellbore
- Low Reservoir Pressure
- Completion Methods

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Temperature

- Normal Geothermal Gradient is 1˚ to 1.5˚ per 100’. Geothermal Gradient can be as high as 10˚ per 100’
- Reservoir Temperatures can be as low as 280˚ to 300˚ F to as high as 700˚ F plus.
- Changes will have to be made to all conventional drilling tools, materials and equipment to withstand temperature in the Reservoir.

Temperature

- Mud coolers
- High temperature electronics
- High temperature cements
- High temperature mud additives

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Mud Coolers

- Needed to keep fluid cool to maintain mud properties.
  - Wall Cake
  - Gel Yield
  - Carrying Capacity
- High Temperatures can damage electronic drilling tools.
- Mud must be changed out prior to entering the productive reservoir.

High Temperature Electronics

- Directional tools are very temperature sensitive
- Wireline electronic logging tools are also very temperature sensitive
- Bit program design must take temperature and circulating media into consideration

High Temperature Cement and Cementing Procedures

- Cements will need to be retarded to withstand reservoir conditions.
- Unlike Oil and Gas wells, casing in Geothermal wells need to be cemented across entire length.
- Uncemented voids in casing annuli will result in casing failures (One of the primary important factor of a good geothermal well is a good cement job on all casing strings).

High Temperature Mud Additives

- Gel (Bentonite) Muds can cause formation damage in production sections.
- High temperature polymers are needed to clean the hole and stabilize the wellbore.
- Air or Aerated Fluids can be used due to low pressure formations.
- Air / Aerated Drilling can cause hole integrity problems.

Hard Rock Formation

- Volcanic hard rock may exist from spud to total depth.
- Permeability exists primarily in fracture systems.
- Fractures may exist throughout the entire wellbore.
- Lost Circulation due to fractures and low reservoir pressures is very common.
- PDC bits do not perform well due to air/aerated drilling, fractures and increased temperatures.
- Lost circulation zones make casing cementing difficult

Large Diameter Well Completions

- Production rates are directly proportional to the diameter of the well
- Large diameter “hard-rock” bits are expensive and drill slow due to available weight on bit.
- Large diameter casing and hole sizes require large amounts of cement and the placement methods become critical

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Low Reservoir Pressures

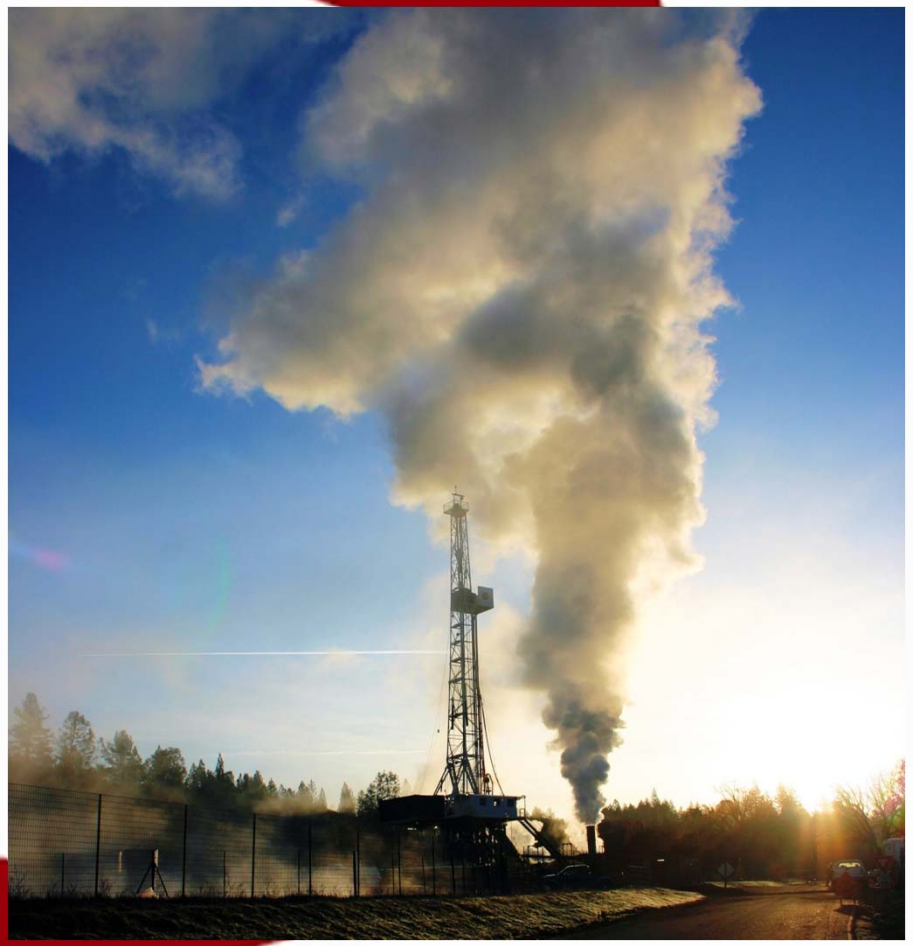
- High potential of loss circulation in drilling and cementing.
- Low pressure may require the wells to be pumped requiring large diameter down-hole pumps, therefore large diameter wells.
- Drilling media, mud, air or aerated water or mist must be used to penetrate reservoir

Completion Methods

- Many geothermal wells are completed open hole and resource is produced through casing.
- Slotted or Perforated casing is utilized to filter large formation debris from entering flow stream.
- Wellhead completion are large diameter master valve through which the well was drilled

Major problems in Drilling Geothermal Wells

- Temperature
- Hard-Rock Formations
- Large Wellbore
- Low Reservoir Pressures
- Completion Methods



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