

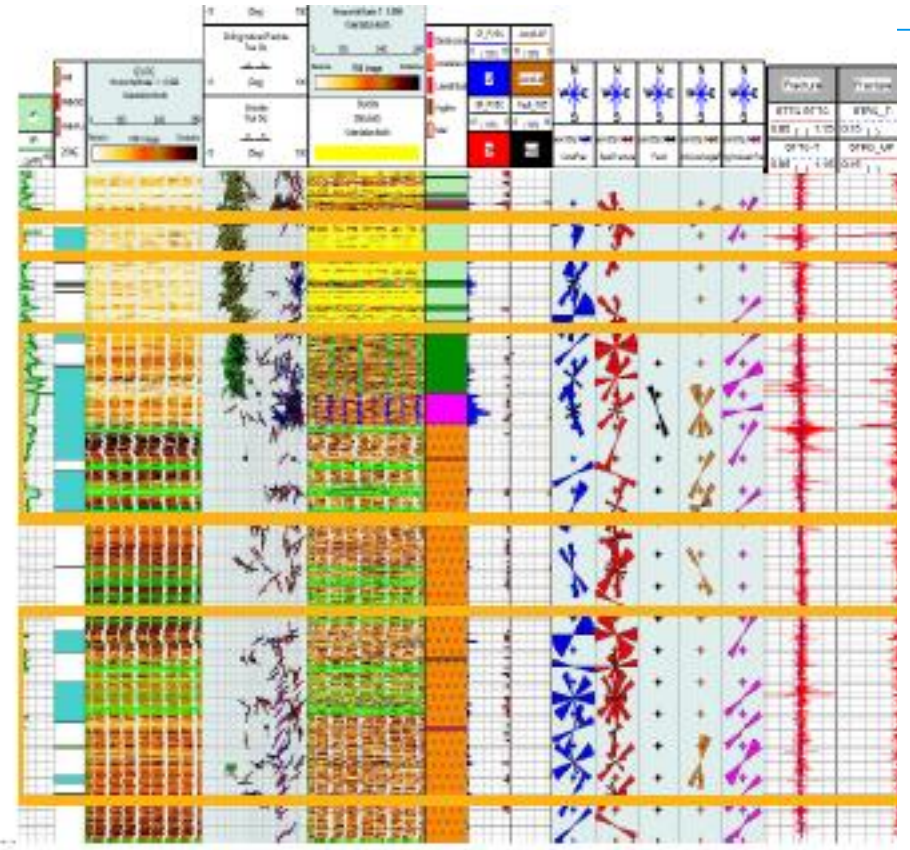
Geothermal Well Logging Opportunities & Challenges

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GeothermEx
A Schlumberger Company



Topics

- Objectives
- Geothermal environments
- Opportunities
- Limitations & challenges

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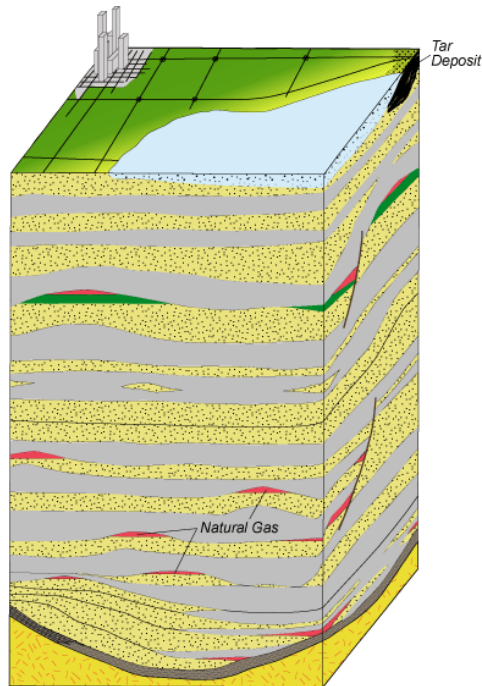
Objectives

Geothermal exploration and development are fundamentally a search for subsurface **temperature** and **permeability**, adequate to support **productive wells** for heat-energy extraction

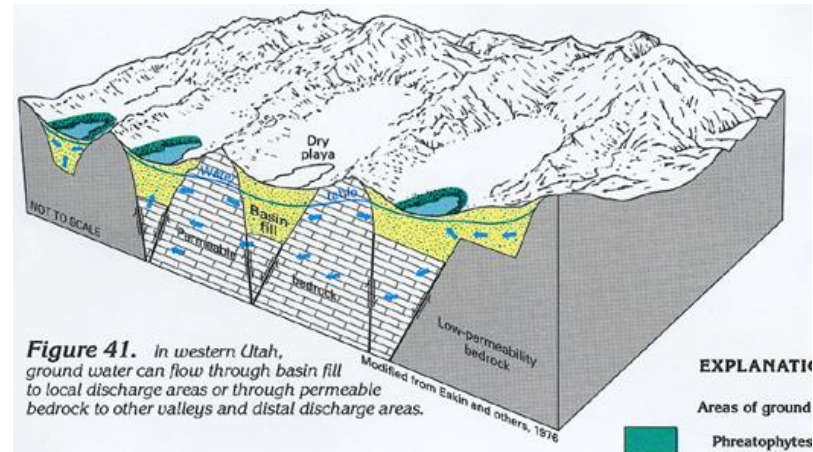
- Temperature can be “mapped” adequately with the limited surface and subsurface data that are typically available
- **Permeability has proved much more difficult to “map” and predict**
 - Useful new developments in logging & analysis techniques are likely to be aimed at understanding and mapping permeability (directly or indirectly)

Geothermal Environments

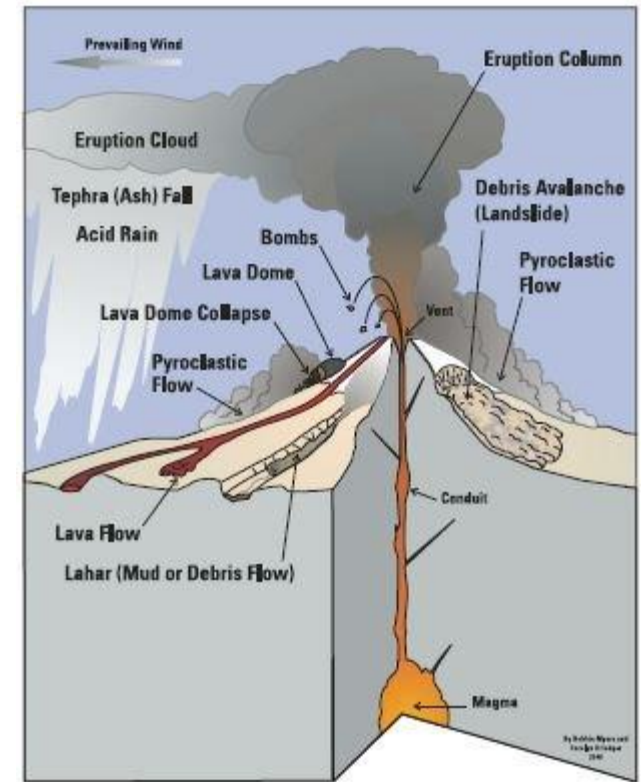
Sedimentary Basin



Extensional (Basin & Range)



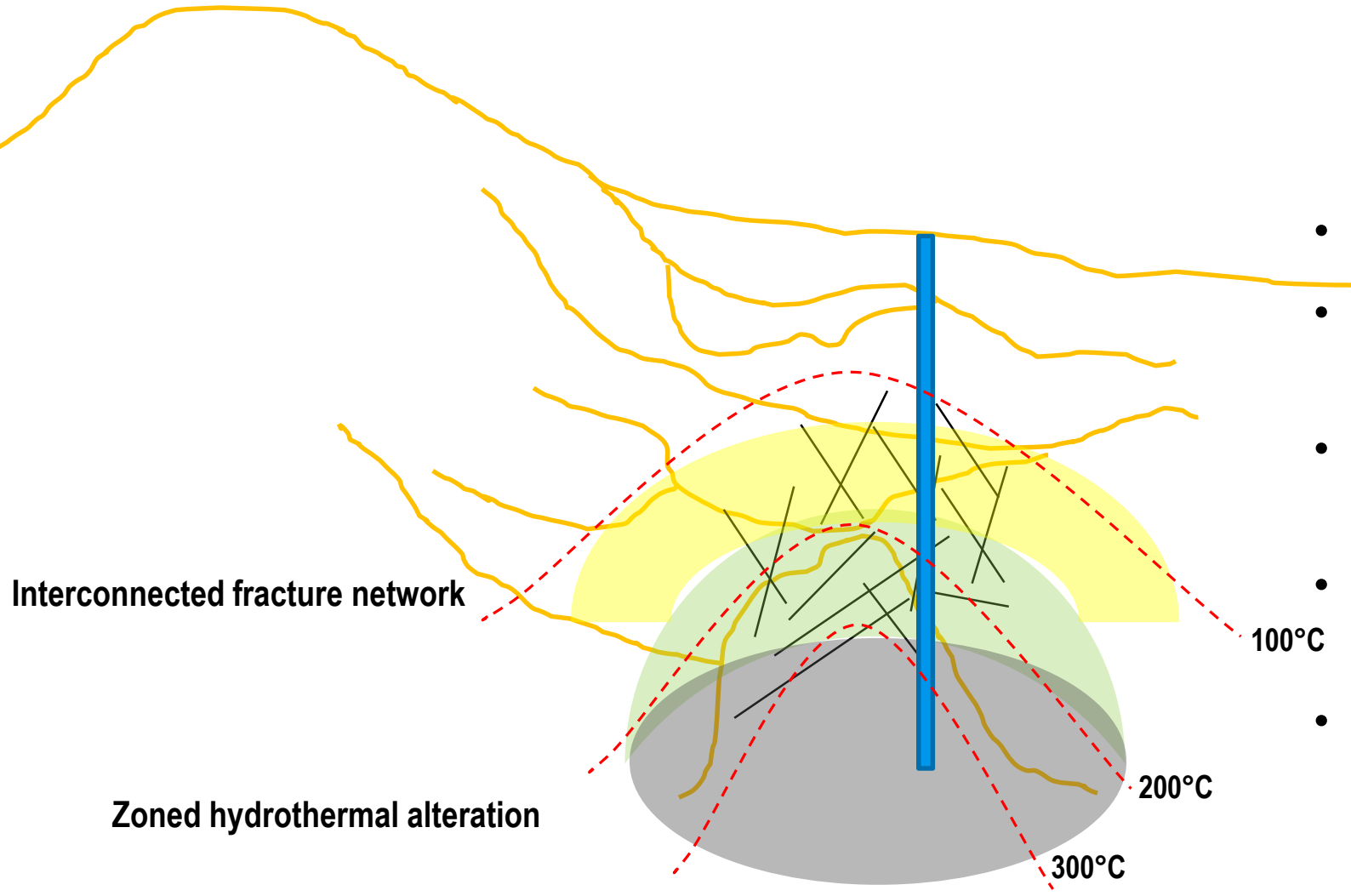
Volcanic



Geothermal Environments

- Higher-temperature geothermal systems are likely to be in environments that are more:
 - Structurally and lithologically complex
 - Dominated by fracture permeability
 - Changed by hydrothermal activity

Volcanic Environments



- Young, dynamic environment
- Discontinuous and irregular rock units (lavas, pyroclastics, debris flows)
- Complex (tectonic + volcanic) stresses & structures
- Few or no reliable indicators of structural deformation
- Hydrothermal alteration changing original rock properties

Volcanic Environments



Opportunities

- Logging to better characterize lithologies and fracture conditions
- Objective characterization of stratigraphy for correlation
- Better integration of downhole data with surface data (electromagnetic, passive seismic; active seismic in sedimentary environments)
- Assessment and prediction of fracture permeability at reservoir scale (improved well placement strategy)
- Reservoir “mapping” by means other than delineation drilling

Limitations & Challenges

- High temperatures (often $>250^{\circ}\text{C}$) in zones of greatest interest
 - *Logging-while-drilling tools might be effective in avoiding high-temperature problems*
- Unstable wellbore conditions in reservoir zone
- Data sets are small (often just a few wells)
- Lack of detailed “map” of rock properties
 - *Conventional geomechanical analysis is difficult, if possible at all*
- Uncertainty in projecting conditions away from wellbore
 - *Can more sophisticated logging data be used to characterize and predict permeability over greater volumes, away from the wellbore?*

Challenges

- Developing case histories with demonstrably better commercial results than would have been achieved if the technique had not been applied