WESTERN PACIFIC
REGIONAL BRANCH

Subsurface Process to Lower Well Targeting Risk, Some Lessons Learned

Ontowiryo A and Julfi Hadi, Supreme Energy
Ansul Bahar, Kelkar and Associate

Subsurface Process to Lower Well Targeting Risk, Some Lessons Learned

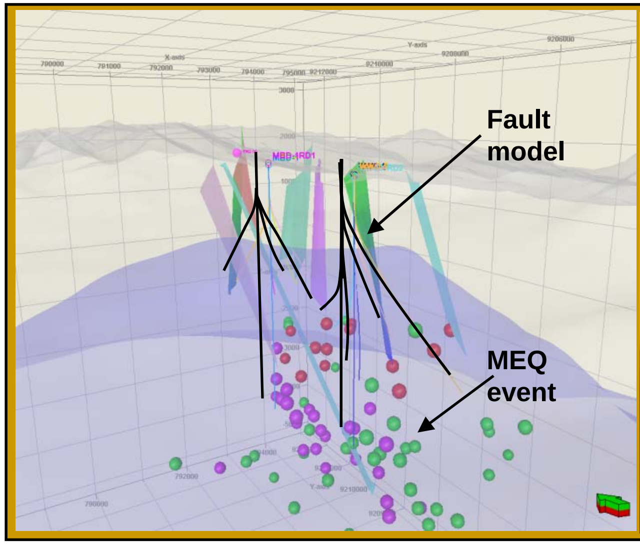
Ontowiryo A, Julfi Hadi[Supreme Energy]

Asnul Bahar[Kelkar & Associate]

Abstract

Present electric price formulation in Indonesia may force increasing MWe/well drilling average to reach economic of geothermal power project. Acquiring high certainty of well targeting becomes a critical process. Based on lessons learned from geothermal exploration and development, fault or fracture targeting is very effective permeable target to increase << 10 MWe well output to >> 10 MWe well output as fault/fracture highly control the behavior of geothermal fluid flow. First part of the process involve identifying key drivers or critical parameters to identify major fault or structure permeability to construct structural play of the area. Detail information of the fault such as rock type/facies type, fault angle and depth are critical part of the assessment. To lower uncertainty of the key drivers the parameters can be separated into surface, subsurface and development phase. During exploration phase, an effective surface program includes detail structure and alteration mapping which effectively distinguished major from minor fault or fracture. Later during initial development, open and closed fault can be distinguished by implementing FMS/FMI (fracture imaging) logging. Also implementation of subsurface program such as micro earthquake (MEQ) survey with moment tensor analysis adds significant value and might give a better fault system and orientation and distribution of stress. One of the problems in well targeting is fault modeling and fracture characterization. A big step forward of subsurface program including research for targeting the well is monitoring a passive seismic, enabling to observe a shear wave splitting to characterize the fault by drilling a shallow well (250 m). A different method for well targeting during development phase is by integrating geomechanical drivers such as proximity to fault, slopes and curvatures of the structure are discussed. This technique has been applied successfully in oil & gas industry to target the well. A subsurface process to target the well by reducing the associated risk has been implemented with the result shows a significant improvement in well output. In this case, the average of 9 MWe/well can be improved to 25 MWe/well based on our experience by applying those technologies.

Constructing an Effective MEQ Program from Reservoir Engineering Point of View, Lessons Learned



Ontowiryo A
Julfi Hadi
April 2008

Focus Items

- □ Drilling Challenge
- □ Targeting Permeability
- □ Case Study
- □ Improve MEQ Response
- □ Discussion

About Supreme Energy

supremeenergy

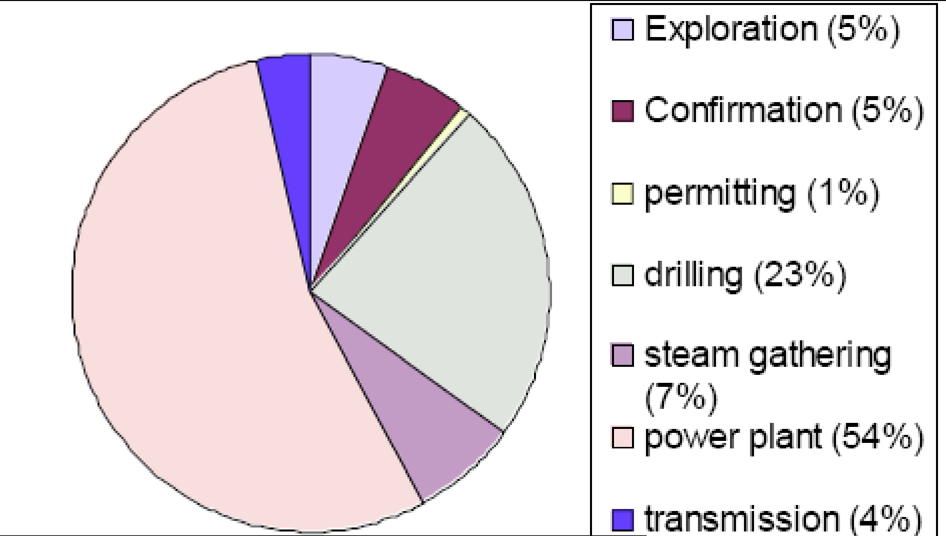
Our Vision is to be the biggest geothermal producer

√ Strong Exploration Team
√ Ex-Amoseas (Darajat) – 18 MW/well average - 40 MW well record
√ Ex-Star Energy (Wayang Windu) – 23 MW/well average - 41 MW well record
√ Pre-Feasibility Study in Sumatra

Focus Items

- □ **Drilling Challenge**
- □ Targeting Permeability
- □ Case Study
- □ Improve MEQ Response
- □ Discussion

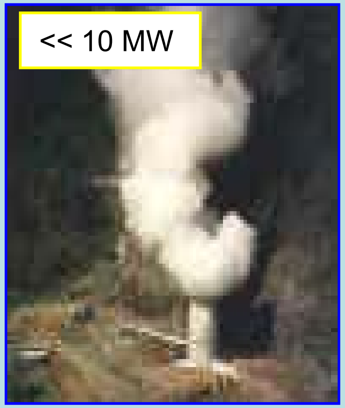
Present Drilling Challenge



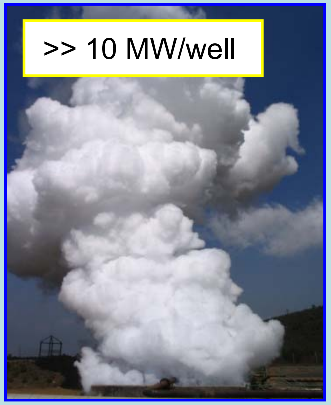
(Source : Geothermal Energy Association, 2005)

√ Drilling 23% project cost
√ Increasing drilling cost
√ Well output track record
√ Technology
√ MW/well

Drilling Risk



How do we get there



- Organization Capabilities
- Technology
- Subsurface Process

Focus Items

- □ Drilling Challenge
- □ **Targeting Permeability**
- □ Case Study
- □ Improve MEQ Response
- □ Discussion

Secondary Permeability as Well Target

Fault target key drivers:

√ Type of fault

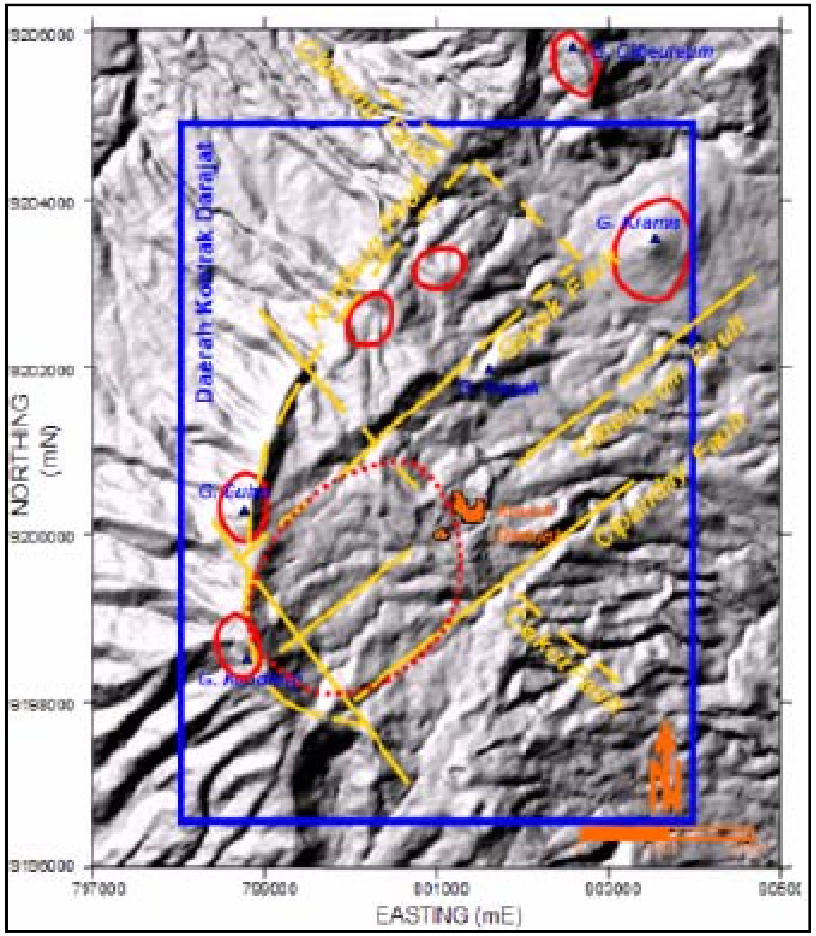
√ Rock Type

√ Depth

√ Dip angle

Secondary Permeability as Well Target

supremeenergy



After hadi et all, 2005

Fault target key drivers:

√ Type of fault

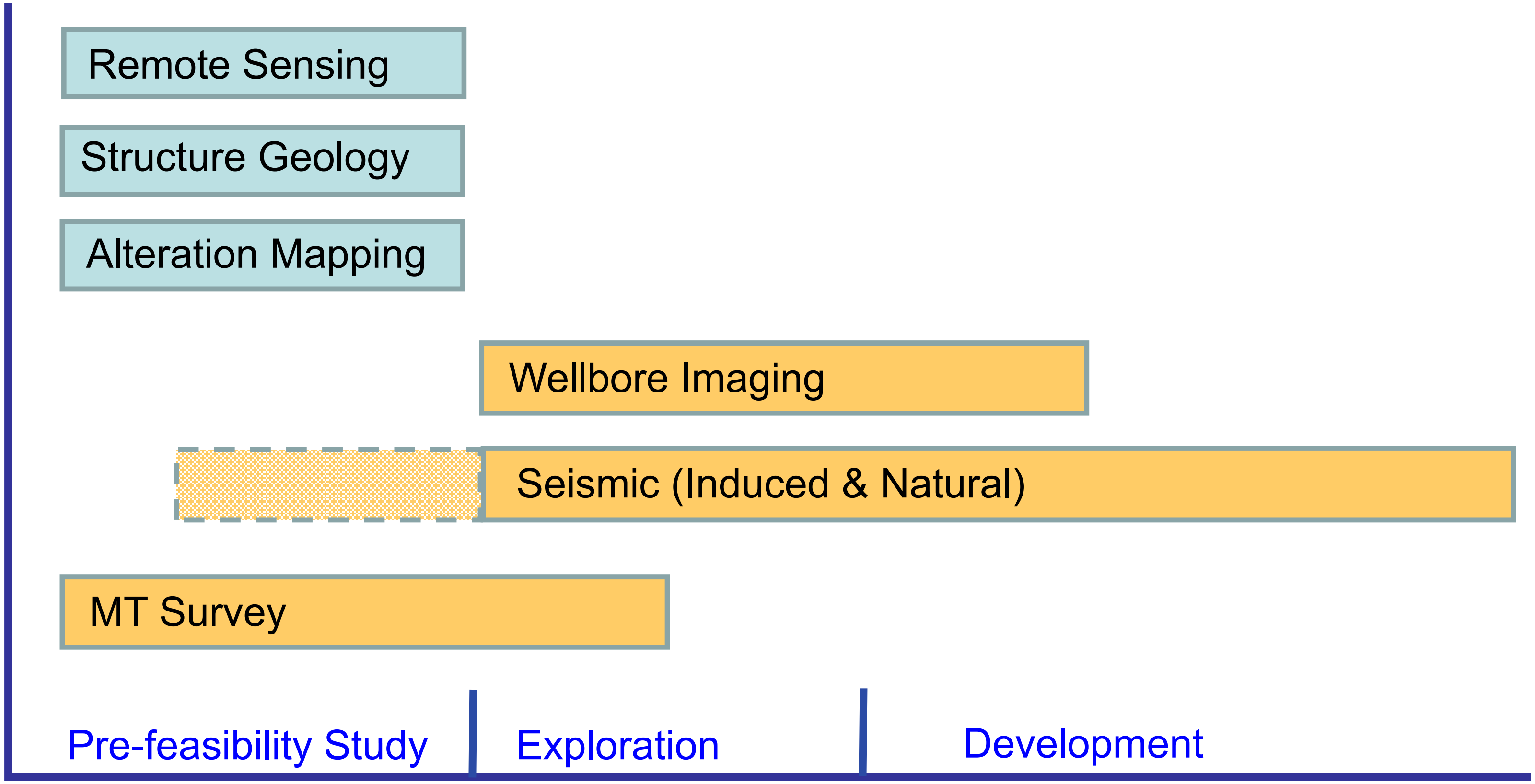
√ Rock Type

√ Depth

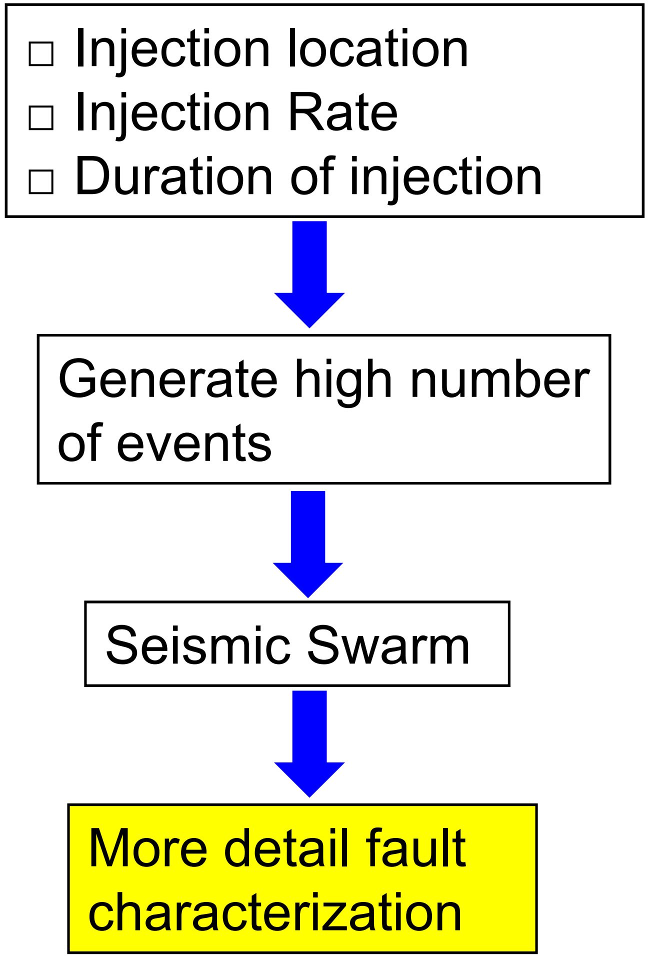
√ Dip angle

Tools to Lower Uncertainty

supremeenergy



Rational Thinking



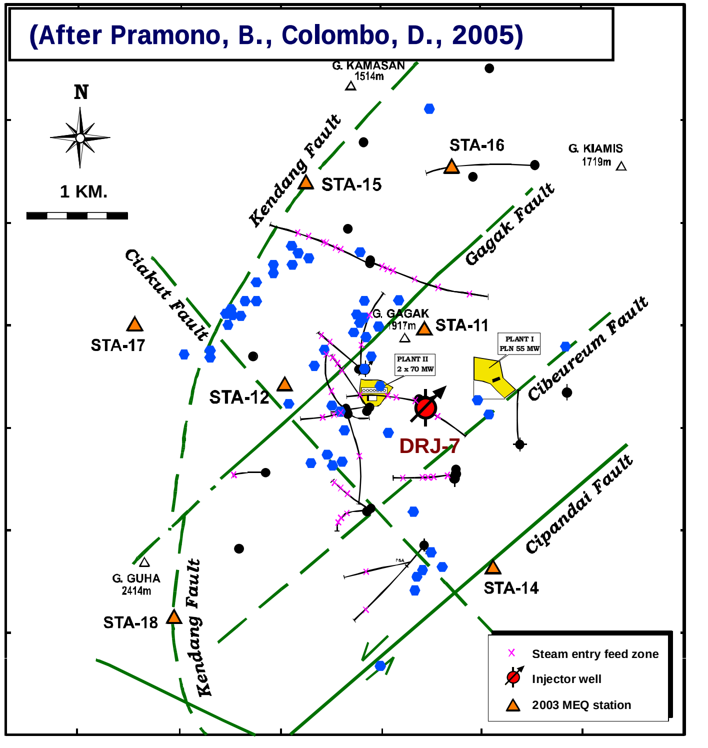
Focus Items

supremeenergy

- ☐ Drilling Challenge
- ☐ Targeting Permeability
- ☐ **Case Study**
- ☐ Improve MEQ Response
- ☐ Discussion

Case-1, Increase Injection Rate (After Pramono and Colombo, 2005)

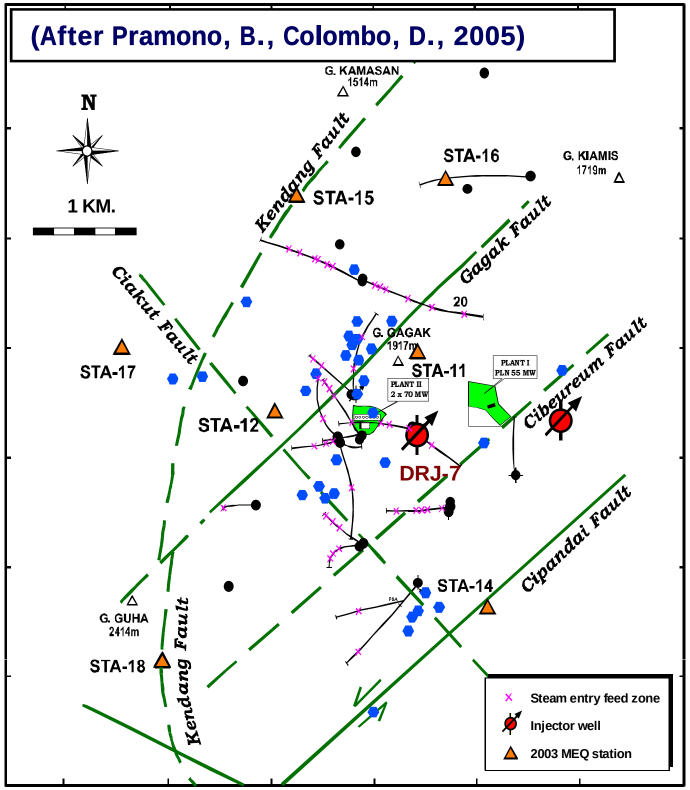
- MEQ data from 3 surveys show different seismic characteristic
- First survey (1997), induced by additional fluid injection, showed good result
  - Good correlation between events and injector location
  - Formed organized swarms
  - High number of events per day
  - Event distribution consistent with known structural trends



Case-2, No Additional Injection (After Pramono and Colombo, 2005)

supremeenergy

- MEQ data from 3 surveys show different seismic characteristic
- Second survey (1997), no additional injection program, showed unclear result
  - Low number of event per day
  - No clear swarms pattern
  - Scattered event distribution

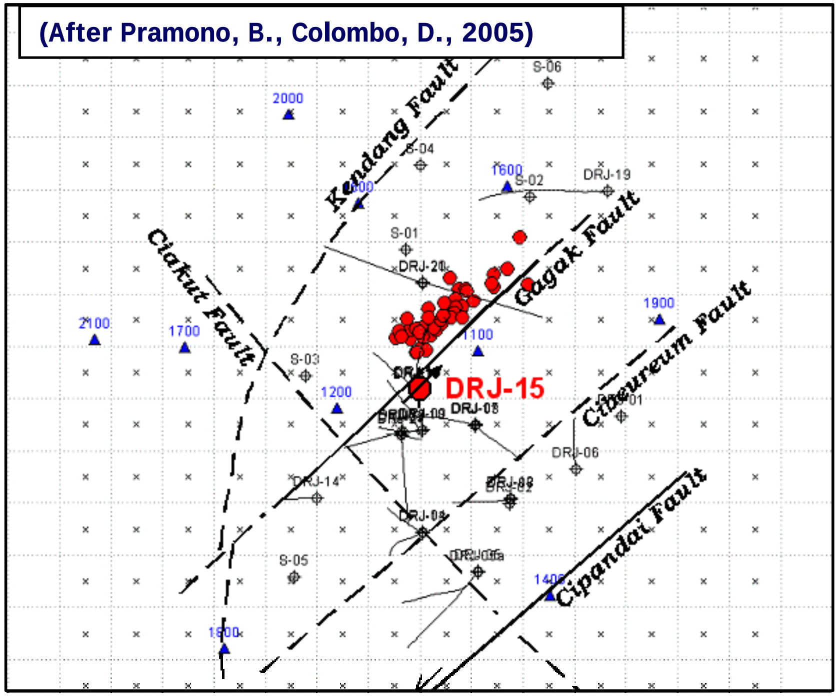


(After Pramono, B., Colombo, D., 2005)

Case-3, Additional Injector (After Pramono and Colombo, 2005)

supremeenergy

- MEQ data from 3 surveys show different seismic characteristic
- Third survey (2003),), induced by additional fluid injection, showed good result
  - High number of event per day
  - New seismic swarms
  - Event distribution consistent with known structural trends



(After Pramono, B., Colombo, D., 2005)

Focus Items

supremeenergy

- □ Drilling Challenge
- □ Targeting Permeability
- □ Case Study
- □ **Improve MEQ Response**
- □ Discussion

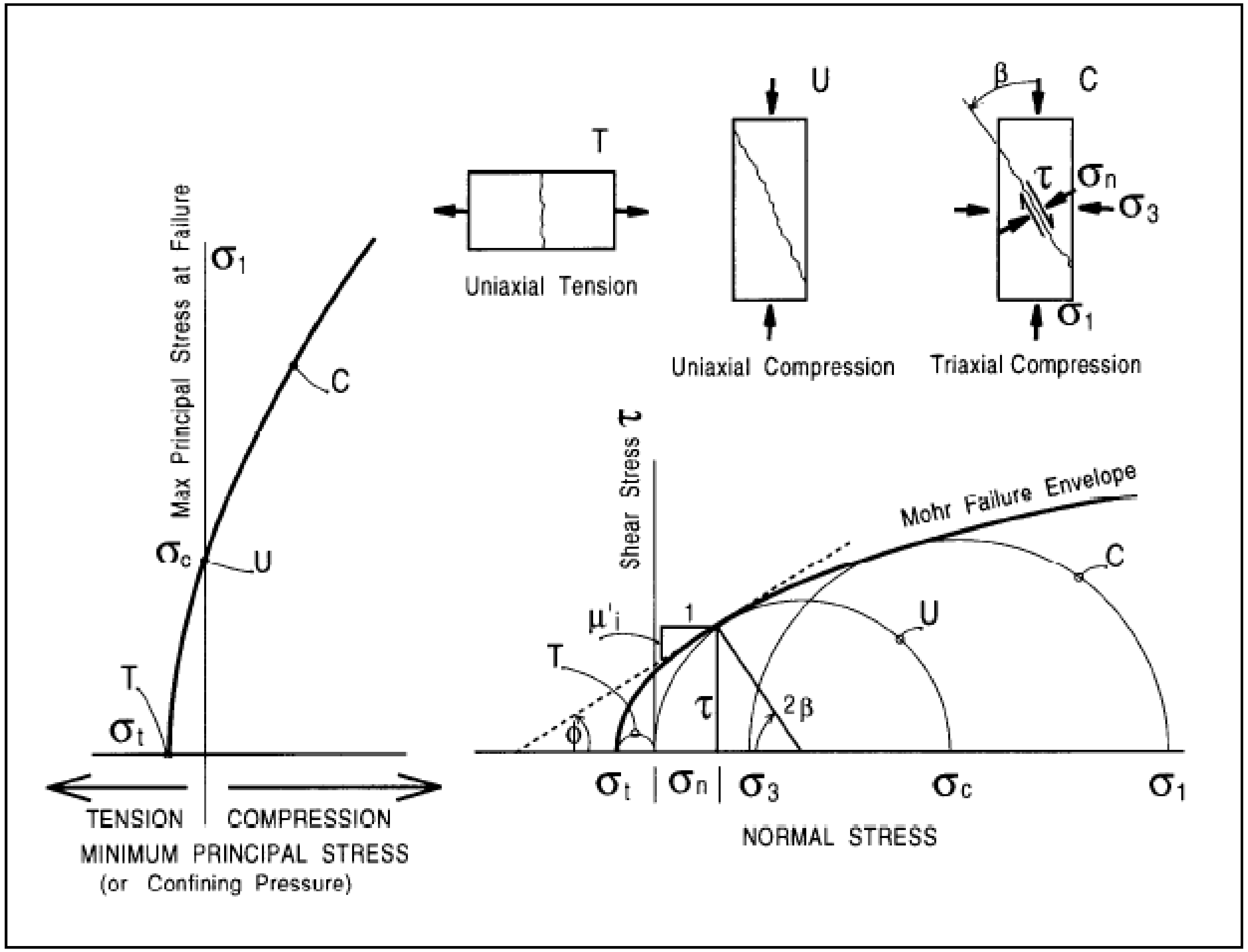
Mechanism of Induced Seismicity

supremeenergy

Several Different Mechanism

- □ Pore Pressure
- □ Temperature
- □ Volume Change
- □ Chemical Alteration

Failure Criterion

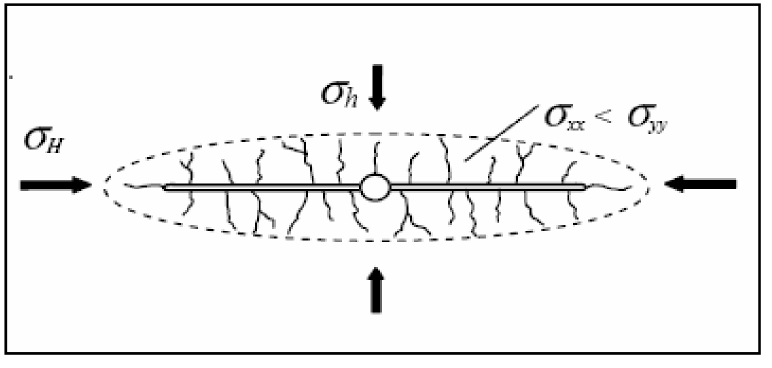


Temperature

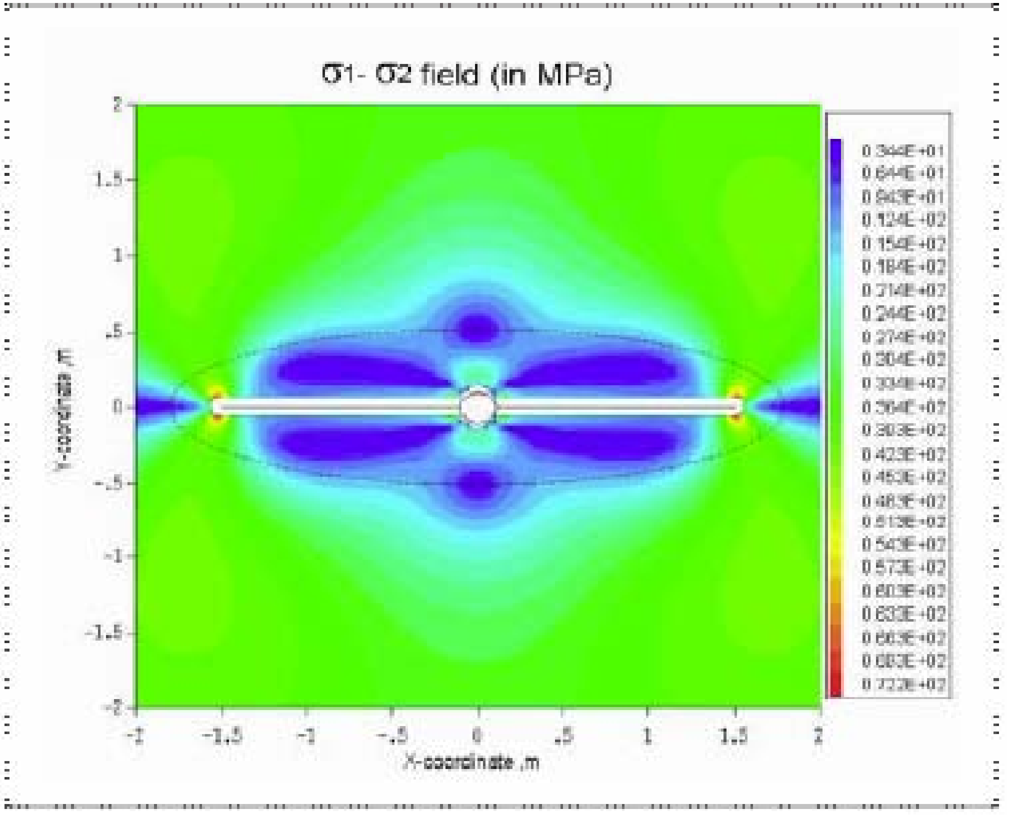
supremeenergy

Cooled Crack, (After A. Ghassemi, 2007)

√ Impact of a cooled fracture on stress and pore pressure
√ Cooling introduces a transient reduction in pore pressure
√ Effect shear failure of intact rock and slip on pre-existing cracks
√ Create a new secondary cracks



Formation of secondary fracture within cooled region



Different between principal stresses around an injection well an a longer fracture

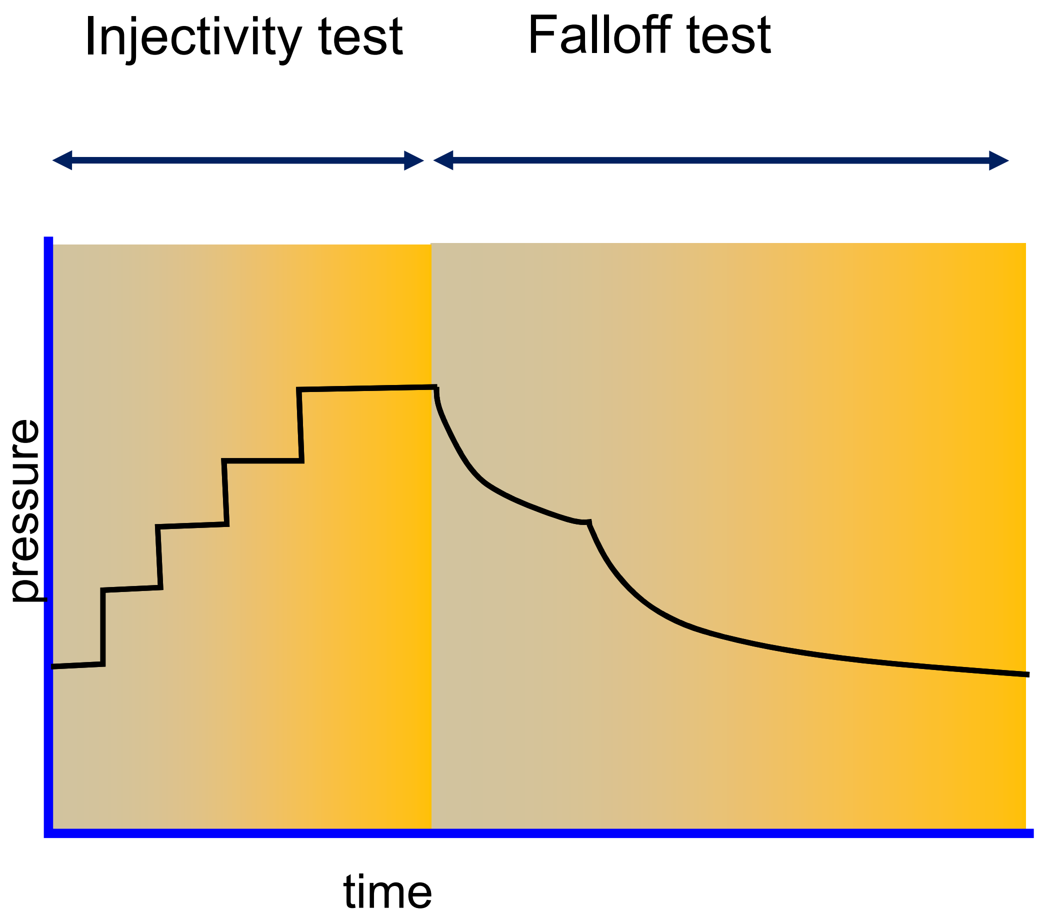
Factor Affecting the Mechanism

- Orientation and magnitute of the deviatoric stress
- Extent of faults and fracture
- Rock mechanical properties
- Hydrologic factor
- Historical natural seismicity

How likely can the “microseismic mechanism” occur ?

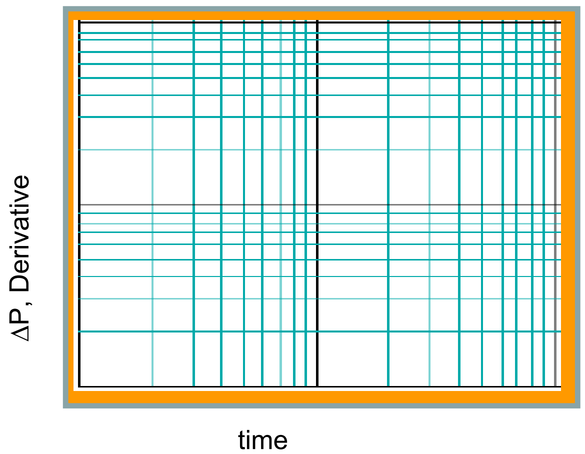
EGS & Hydrofracturing

Preliminary survey

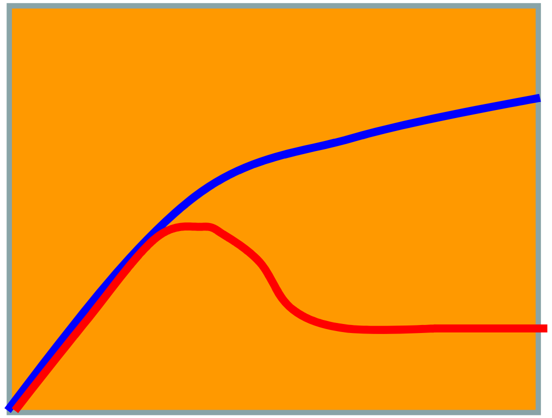


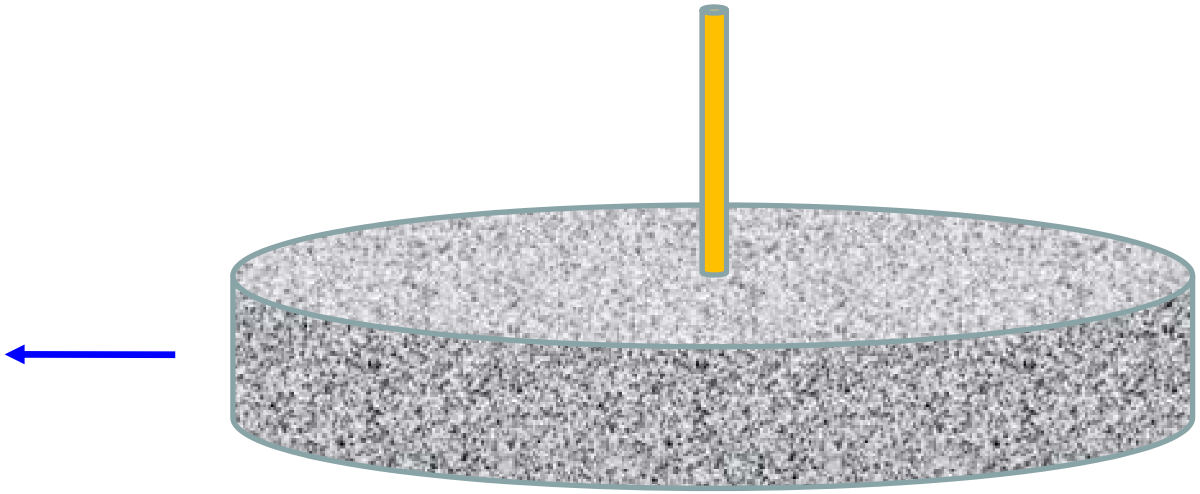
- Injectivity Index
- Closure Pressure
- Flow geometry
- Boundary

Transient Analysis (Derivative Diagnostic Plot)

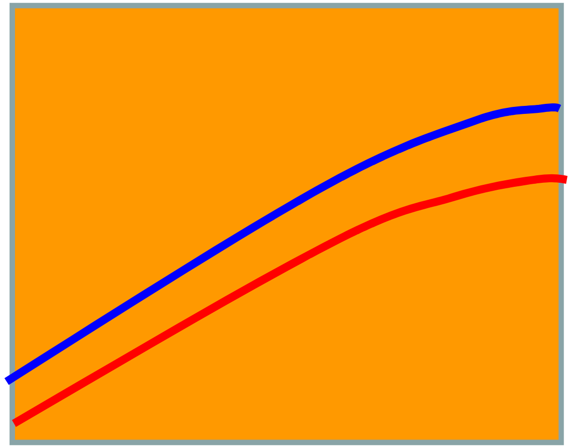


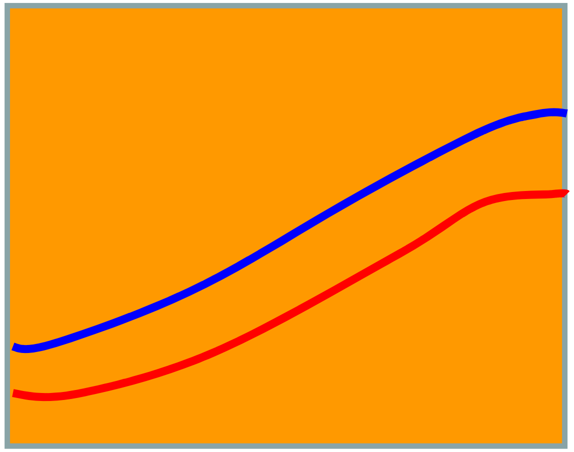
Well penetrating homogeneous reservoir



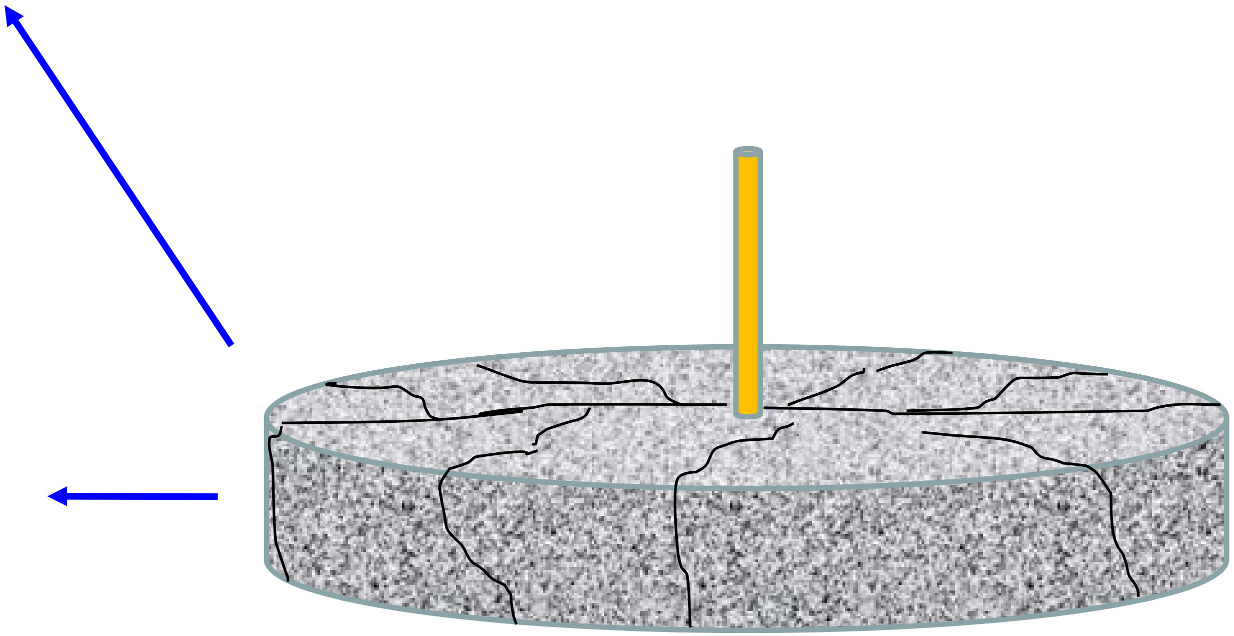


Transient Analysis (Derivative Diagnostic Plot)

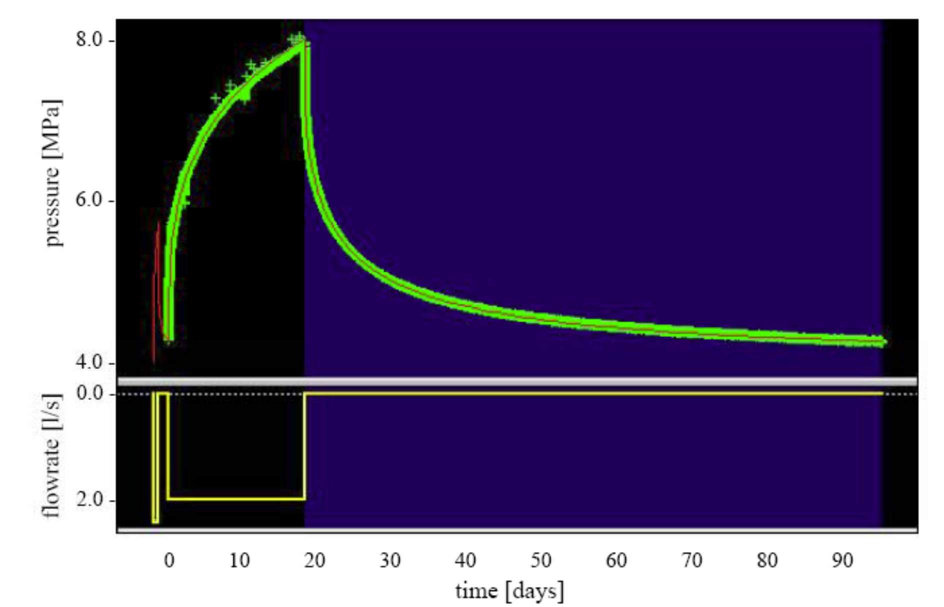


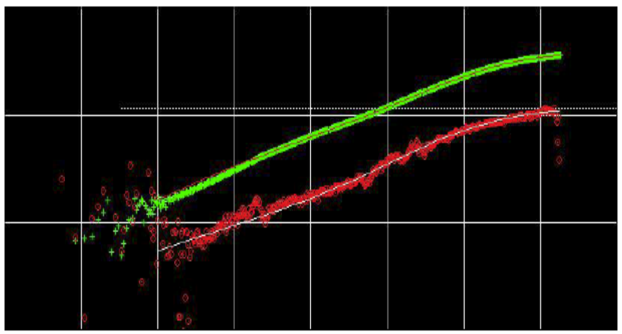


Well penetrating fracture reservoir



Case-1(Günter Zimmerman, 2006)





Log-Log plot: dp and dp' [Pa] vs dt [hr]

- Good data quality
- Fracture dominated flow during the test
- New cracks or opening pre-existing fracture

Focus Items

- □ Drilling Challenge
- □ Targeting Permeability
- □ Case Study
- □ Improve MEQ Response
- □ **Discussion**

Disccusion

- □ Injector location
- □ Rock permeability
- □ Rock connectivity
- □ Injectivity & Falloff test
- □ New cracks or opening pre-existing fracture