Monitoring Stress and Elasticity in the Vicinity of a Deep Borehole Repository

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LANL

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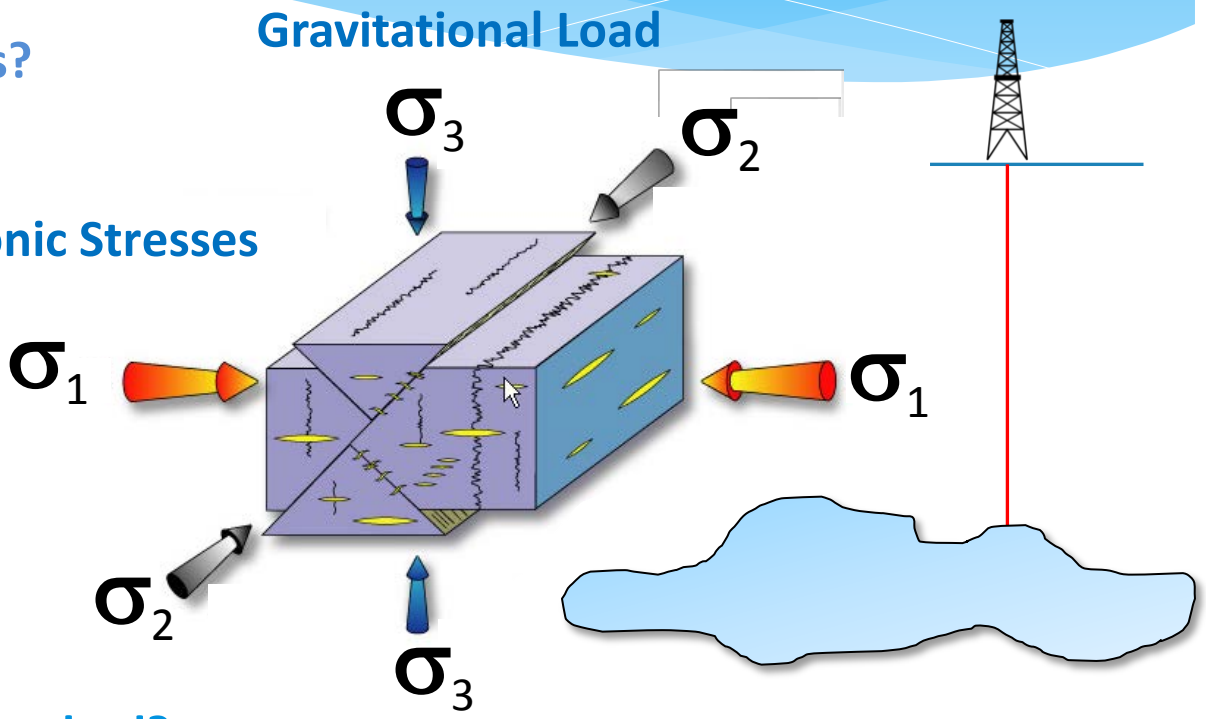
Motivation

Consider faults and fractures in a stress field ….

Need to know: 1) How stress and elasticity is evolving around the borehole that may lead to changes in containment and permeability.

1. What is the State of Stress?



2. How is the Stress Field Perturbed? (leading to changes in containment or permeability)

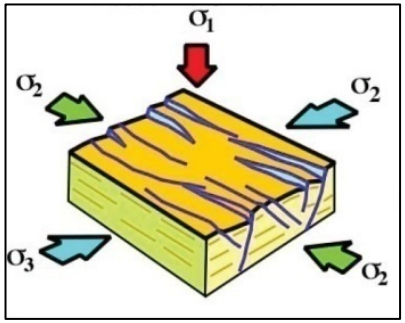
Natural Sources (Earth Tides, Seismic Waves, Pore Pressure)

Waste Emplacement and Thermal Effects

The Need: A Way to Quantify the State of Stress

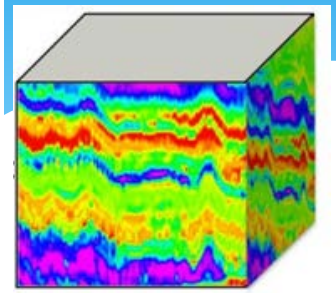
Overview

* We will use seismic and gravity data to monitor changes in stress and elasticity in a volume surrounding the deep borehole repository.
  * Gravity data can be obtained by satellite or local campaigns.
  * Seismic data must be obtained by local deployment, but may be augmented by nearby permanent stations.
* We will use the rate and pattern of seismicity to detect critical state behavior in the reservoir



Proposed Workflow

Volumetric Elastic Modulus (K)



Joint Inversion

Advance Multi-Physics Tomography (AMT)

Background Tectonic Stresses

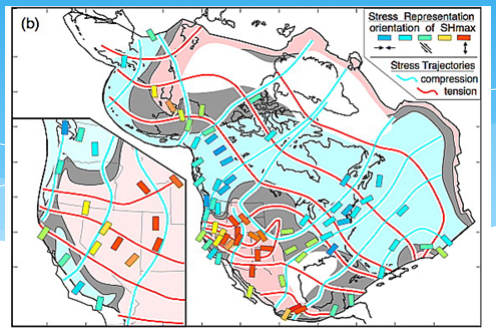
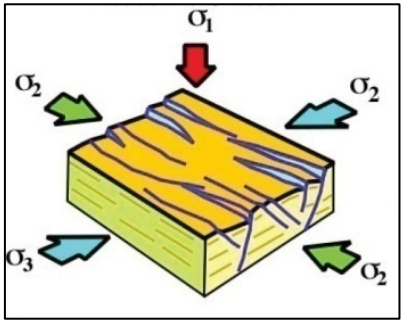
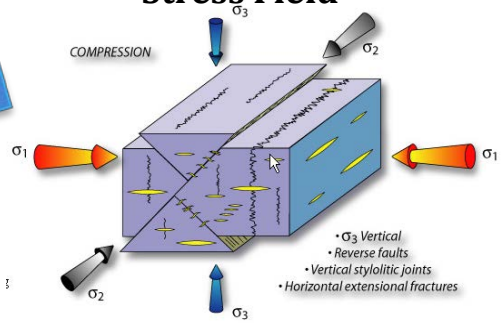


Plate-Scale Finite-Element Modeling

1. Full Stress Tensor (State of Stress)

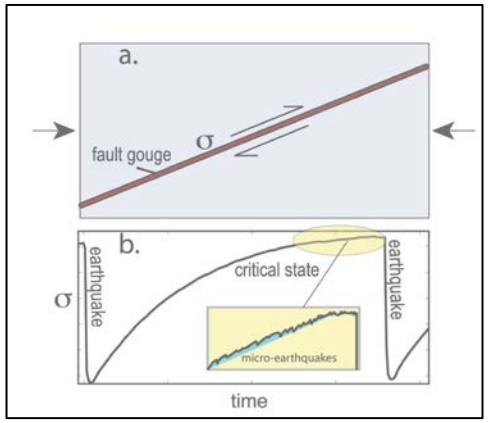


2. Perturbations of the Stress Field



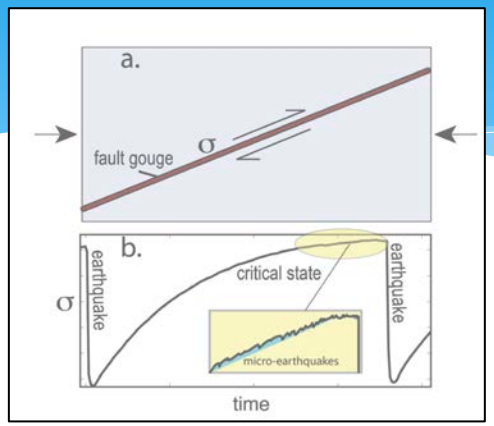
Faults slipping, fractures opening ....

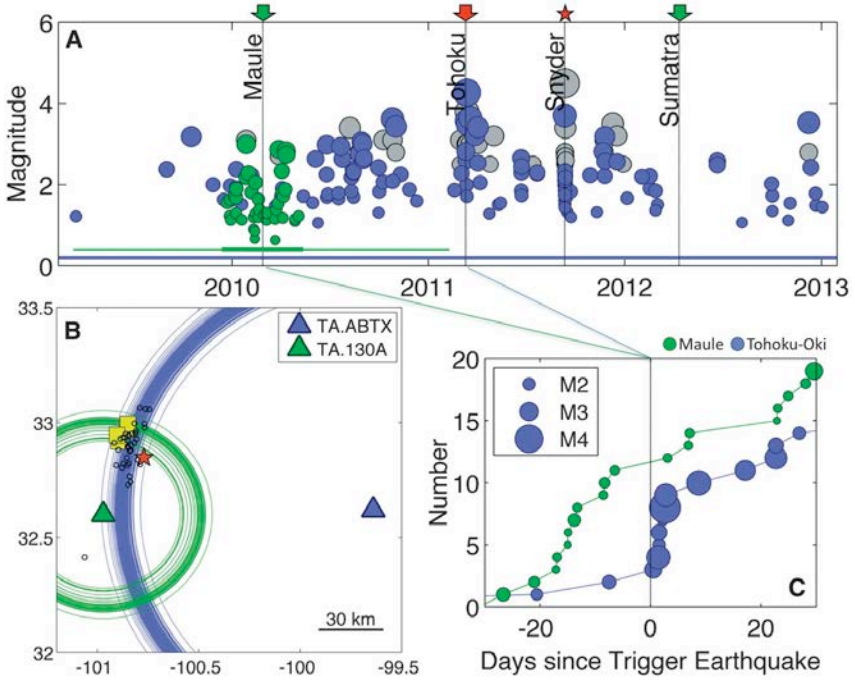
Critical Stress State



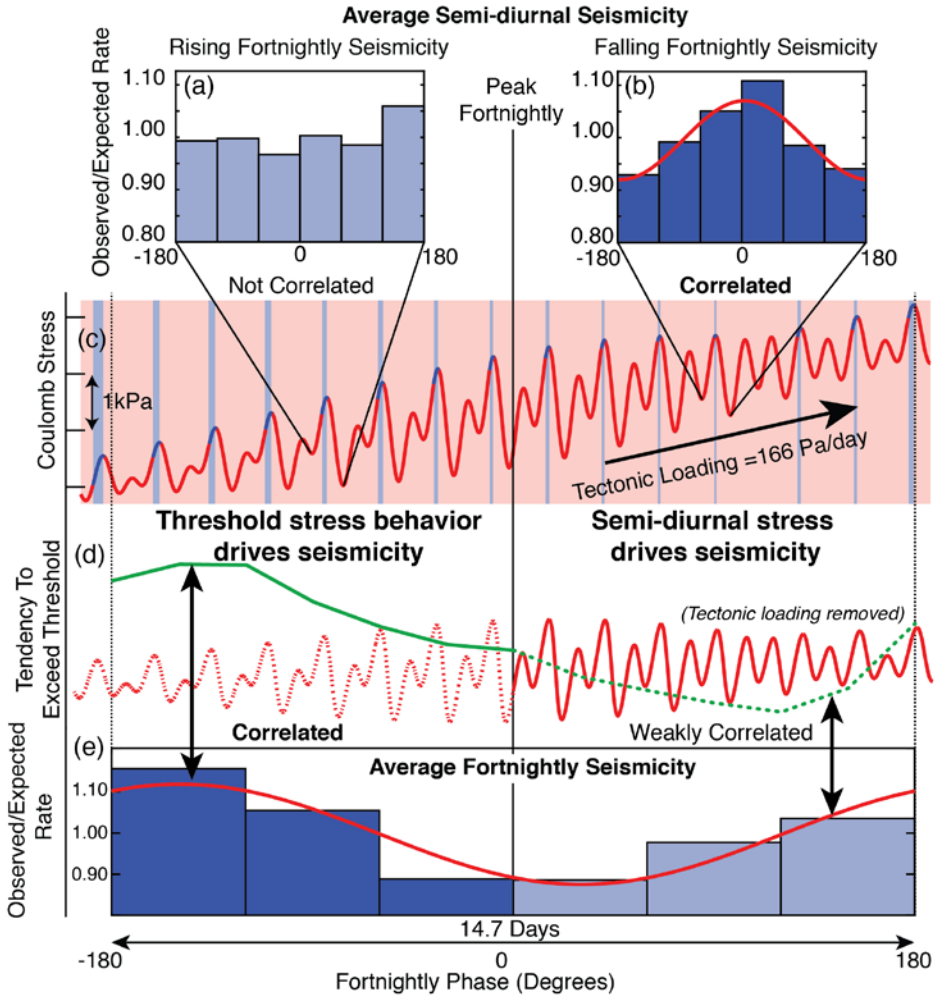
Micro-Seismicity due to Natural Transient Stresses

Critical State Behavior





Snyder, TX [van der Elst 2013]



Using the Differential Stress Field

Data

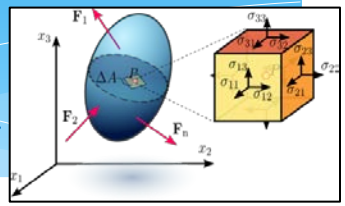
Gravity, Seismics

Joint Inversion

Body Force Component

Obtain: Density [ρ], Vp, Vs;
Compute Elastic Moduli (e.g., K);
Calculate $\sigma = K\,\varepsilon$

Full Stress Tensor

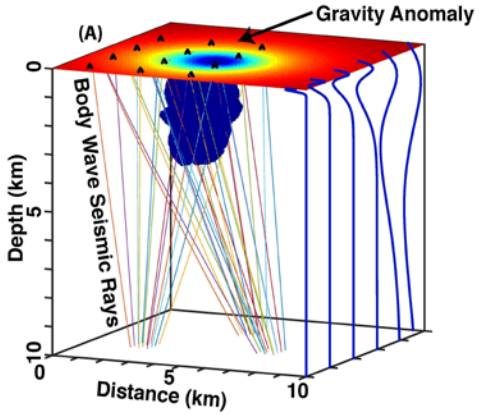


Tectonic Component

Finite-Element Modeling

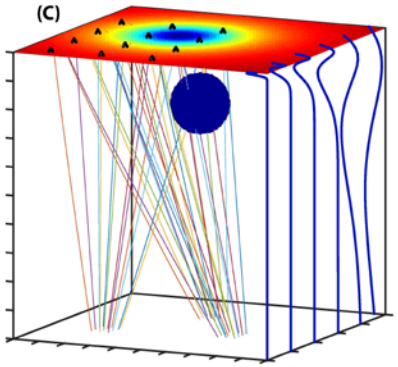
Empirical Green's Functions

Surface Wave Seismic Data



Time 1

Pore Pressure Change?



Time 2

Body Wave Seismic Data

Key Innovations

Key Innovations:

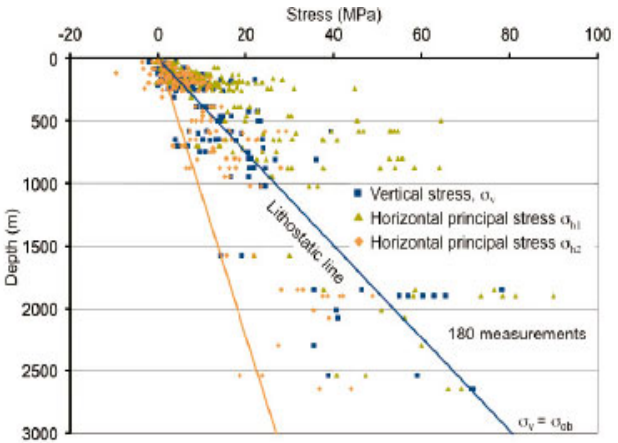
1. **New method for mapping elastic modulus and density (based the joint inversion of multiple data sets such as gravity and seismic data).**

1. **Use of micro-seismic triggering of critically stressed faults by earth tides or other transient stresses as a probe for the critical stress state.**

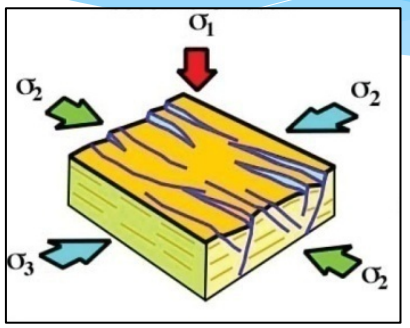
These are both short-term and long-term monitoring techniques to quantify the stability of a deep borehole repository

Stress Beyond the Borehole

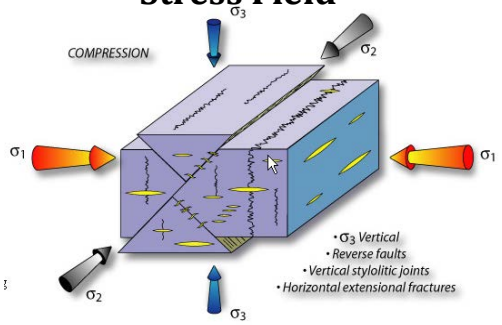
Point measurement at the borehole



Volumetric measurement



Perturbations of the Stress Field



Faults slipping, fractures opening ….

Perturbation of the Stress Field

Key Goals:

Fault Slip on Critically Stressed Faults: New technique for recording and evaluating very small events generated by Earth tides. A method for identification, probing, and monitoring of critical faults.

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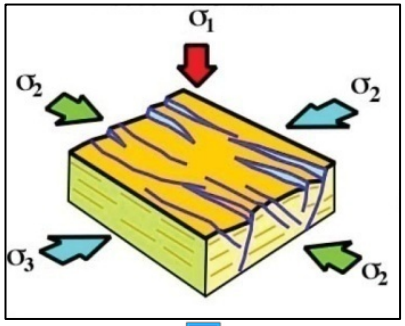
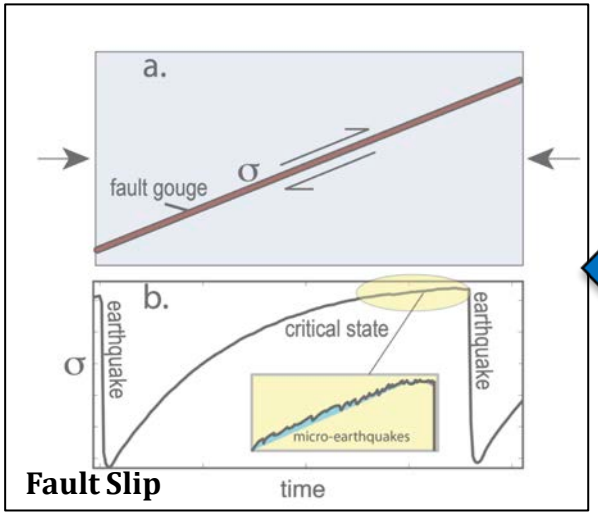
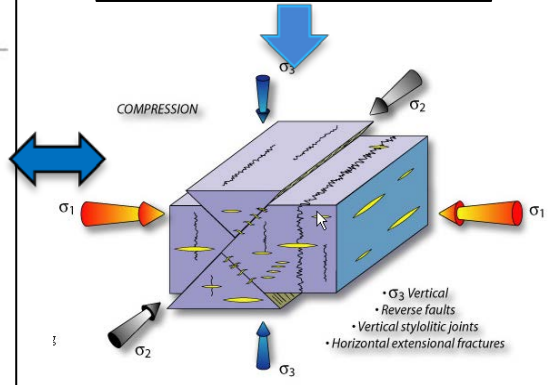


Critical Stress State



Fault Slip



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