Thermal Effects on Rock Matrix and Fracture Properties

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Introduction

- Rock masses consist of matrix rock (mineral grains plus pores and microcracks) plus macrofractures
- Matrix effects of elevated temperatures (at constant mean stress): decreased modulus, decreased strength, increased permeability, increased thermal expansion
- Macrofractures: sensitive to thermally induced stresses

Introduction

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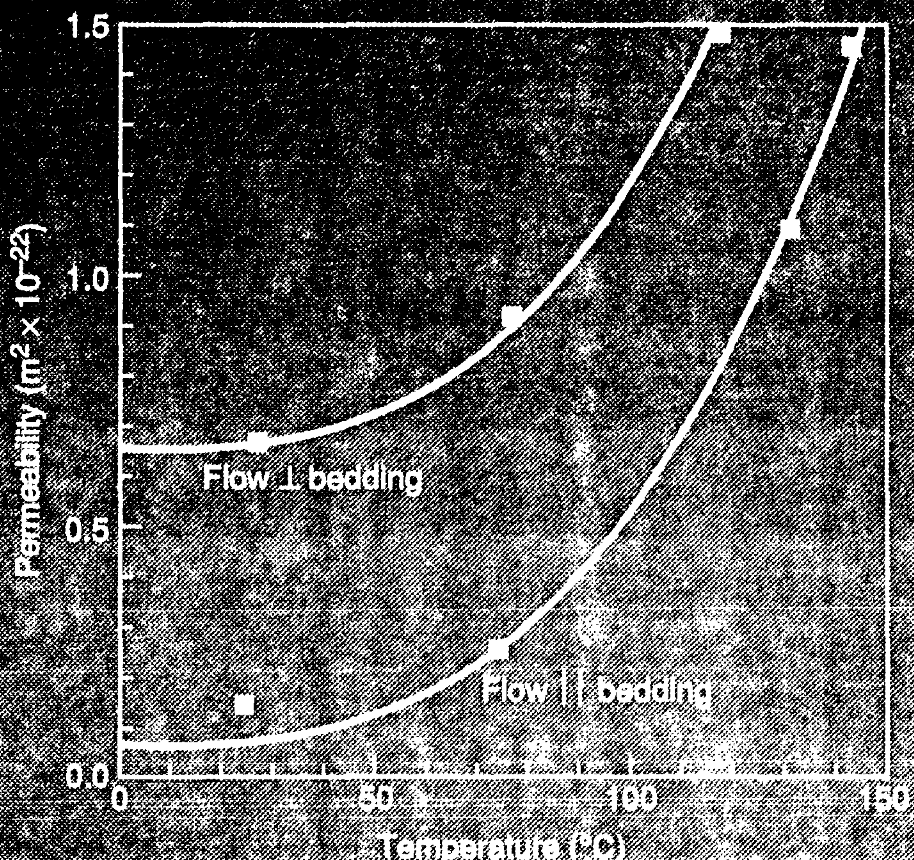
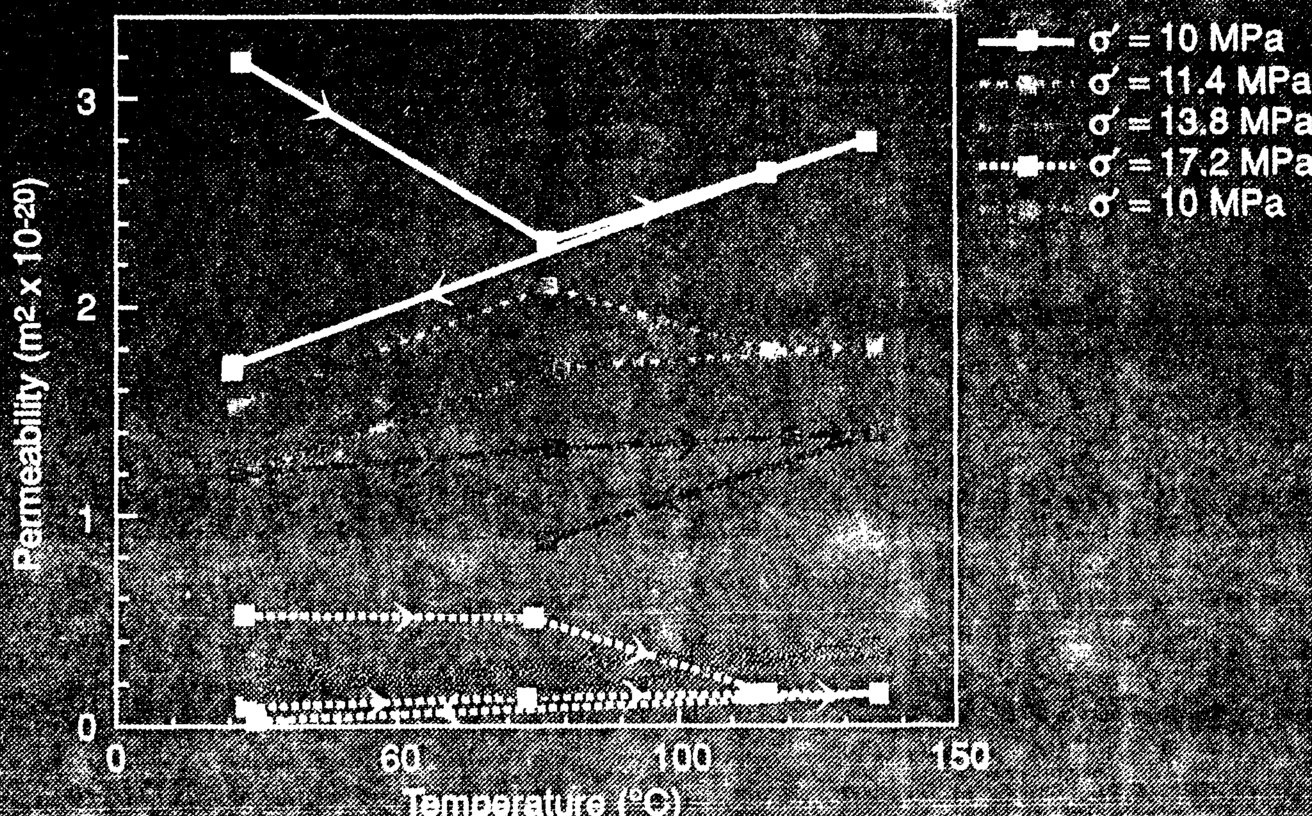
Thermal Effects on Rock Matrix

- Effects related to crack generation
- Mechanisms
  - Thermal shock
  - Heterogeneity in grain properties
  - Subcritical crack growth
- Increase in σ_2 and σ_3 relative to σ_1 reduces crack growth

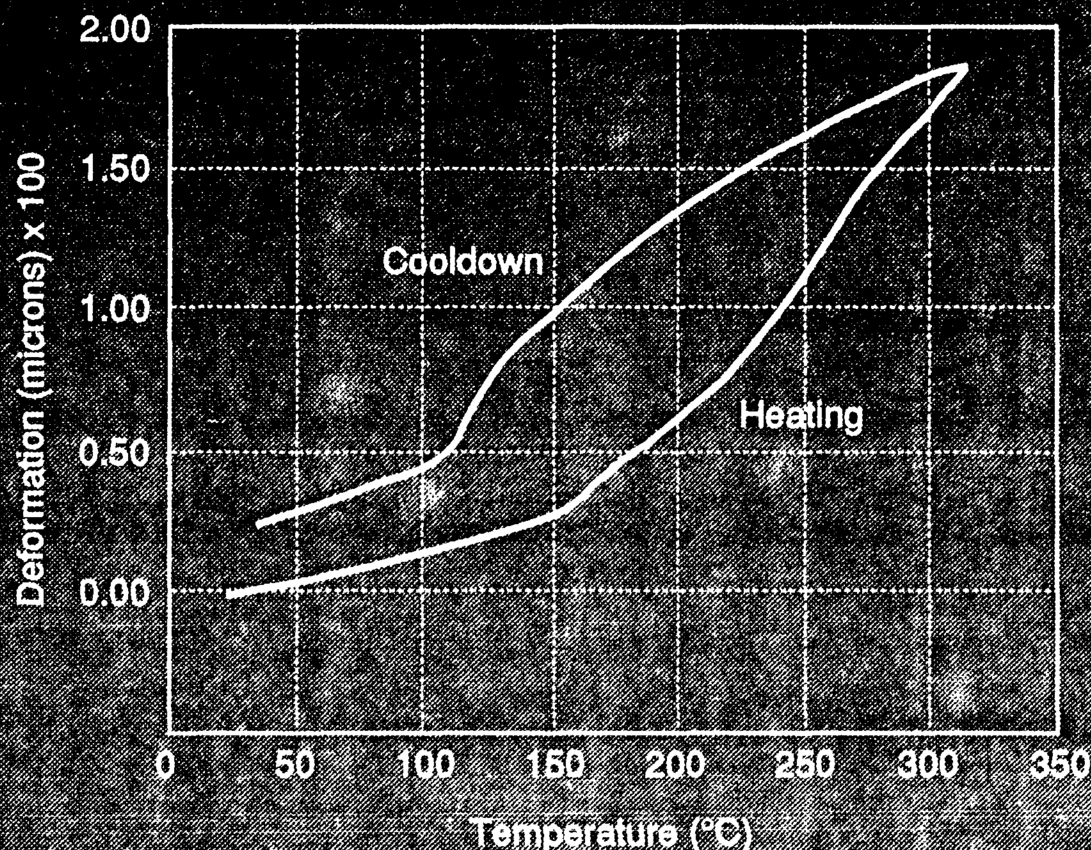
Permeability of a Marlstone



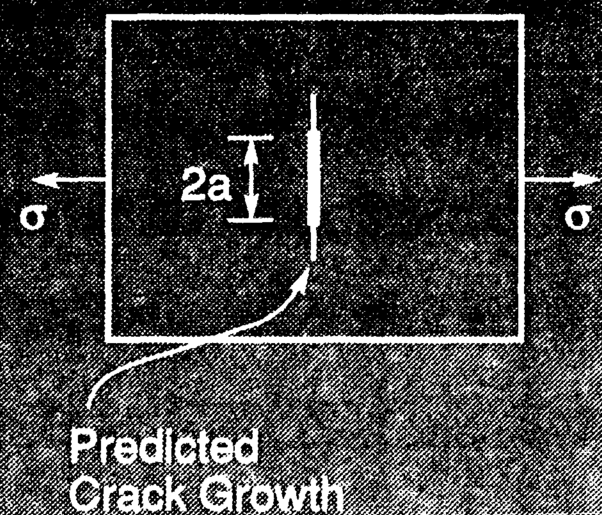
Permeability of Devonian Shale



Thermal Expansion of Tuff



Single Crack Under Uniaxial Tension (Mode I)

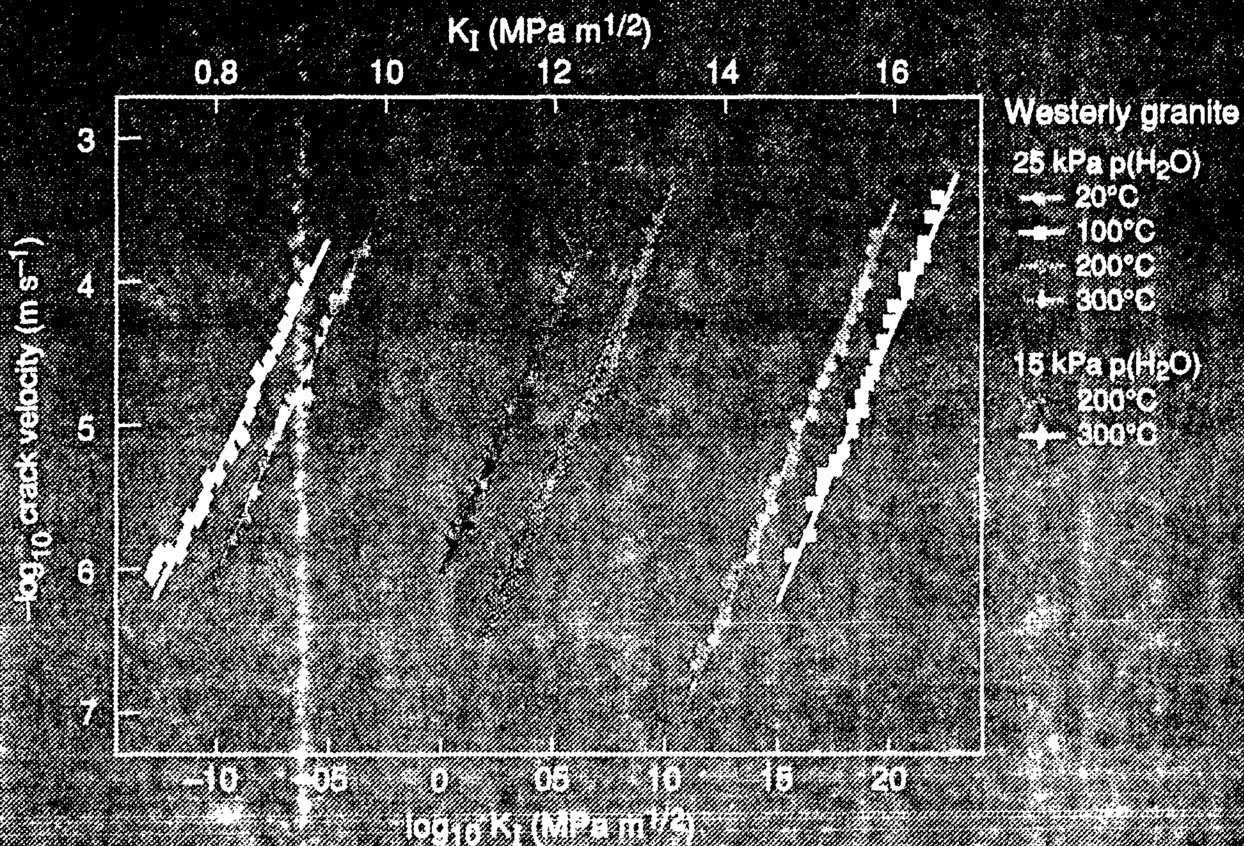


$K_I = \sigma\sqrt{\pi a}$

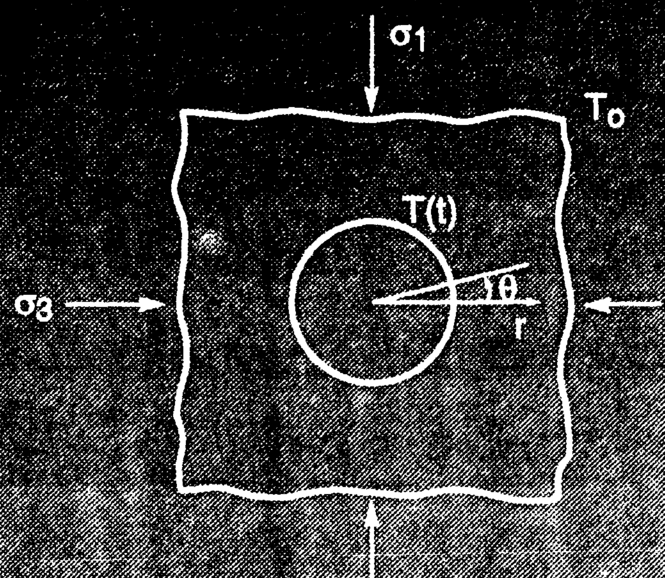
Crack Propagation for:
$K_I = K_{IC}$

Subcritical Crack Growth for:
$K_I < K_{IC}$

Subcritical Crack Growth in Granite



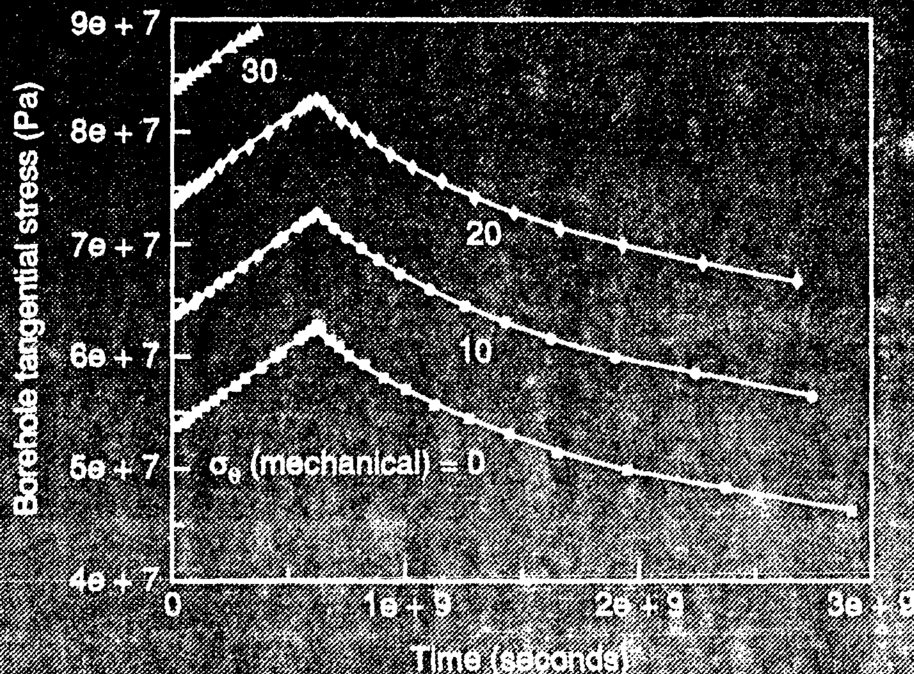
Geometry for Analysis of Subcritical Crack Growth



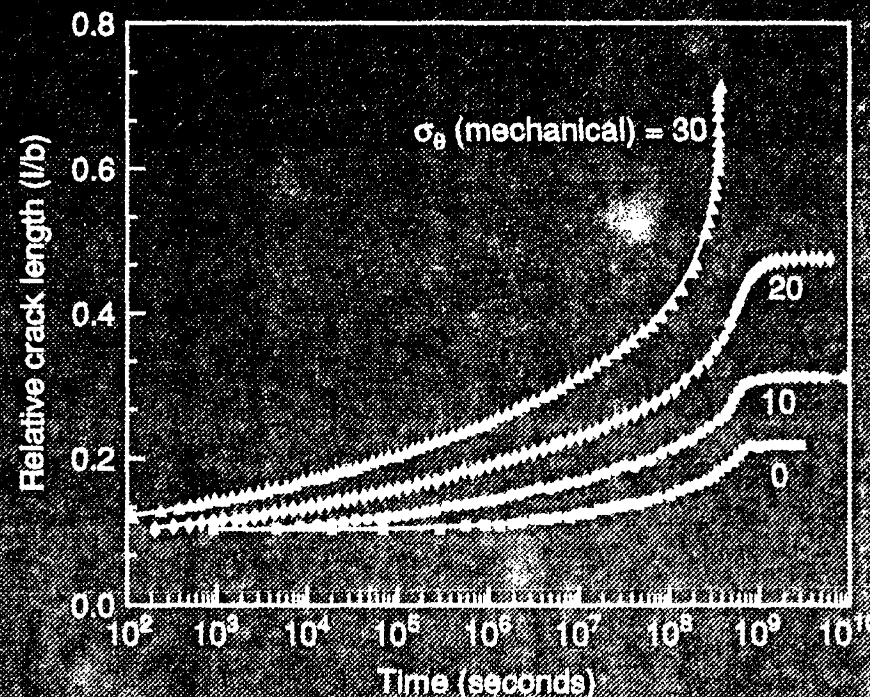
$$\sigma_\theta(\text{thermal}) = \frac{\alpha E(T(t) - T_0)}{2(1-\nu)}\left(1 + \frac{a^2}{r^2}\right)$$

$$\text{crack velocity} = A \exp(-H/RT)K_I^n$$

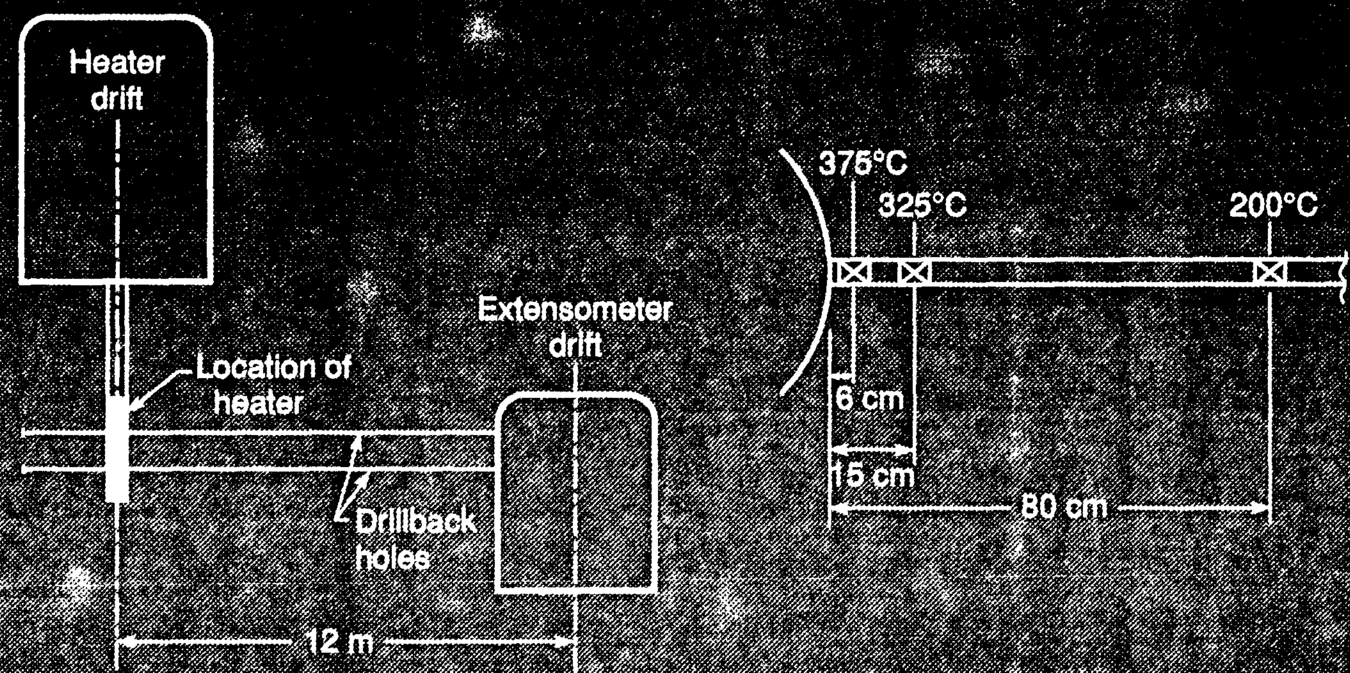
Change in Stress with Time Near Borehole Boundary



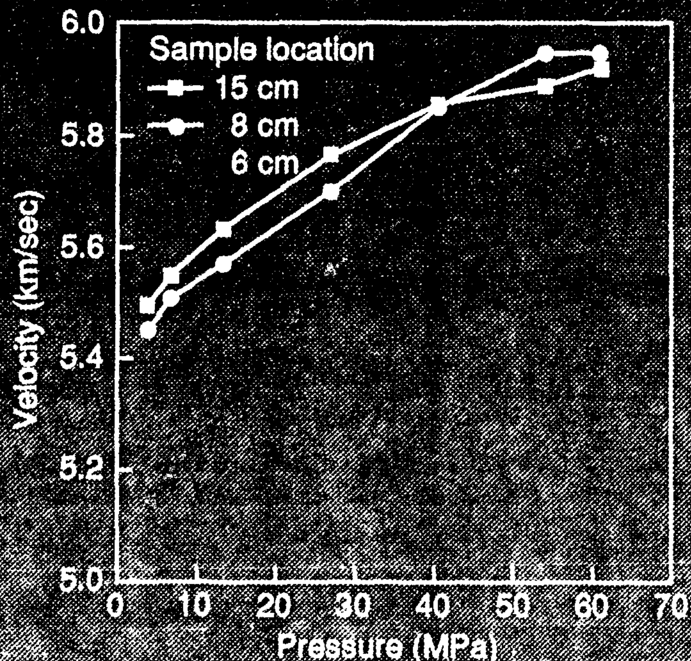
Subcritical Crack Growth Near Borehole Boundary

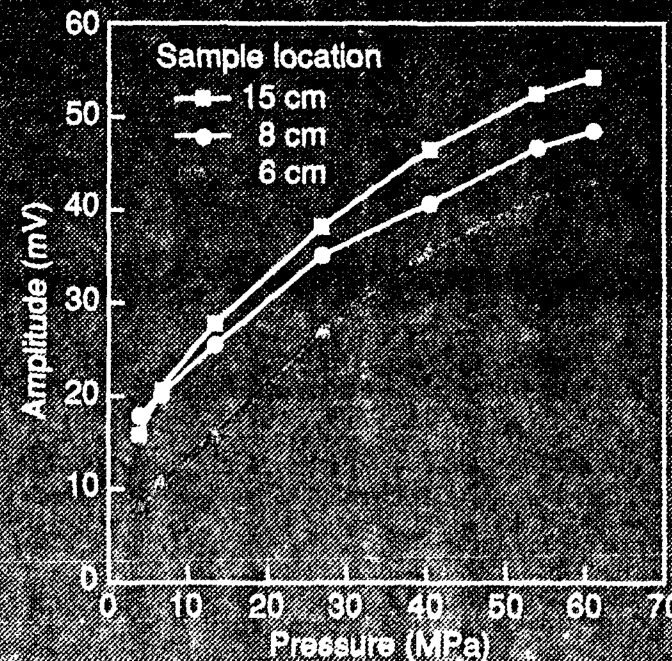


Stripa Drillback Experiment



Seismic Measurements on Stripa Drillback Cores

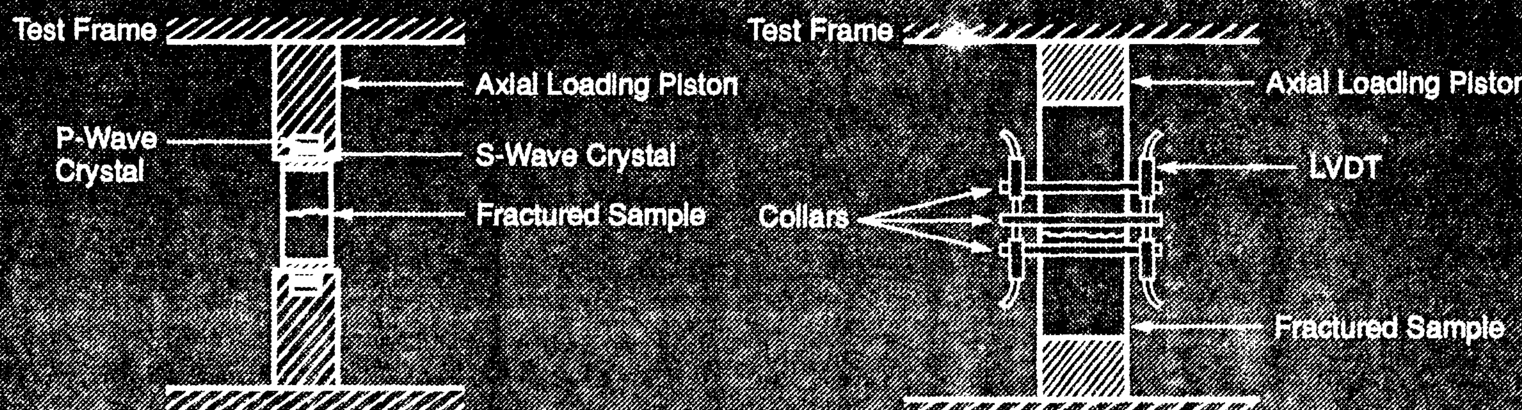




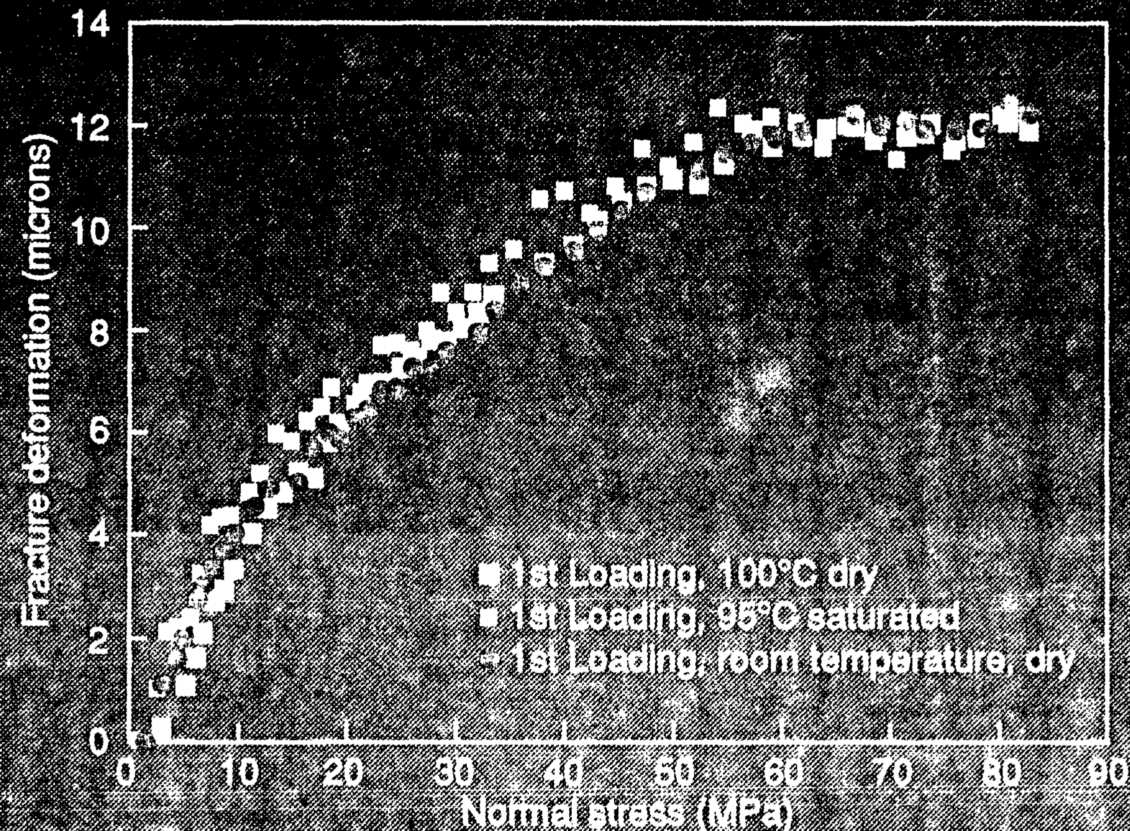
Macrofractures

- Little effect of temperature under constant stress conditions
- Very sensitive to thermally induced stress changes

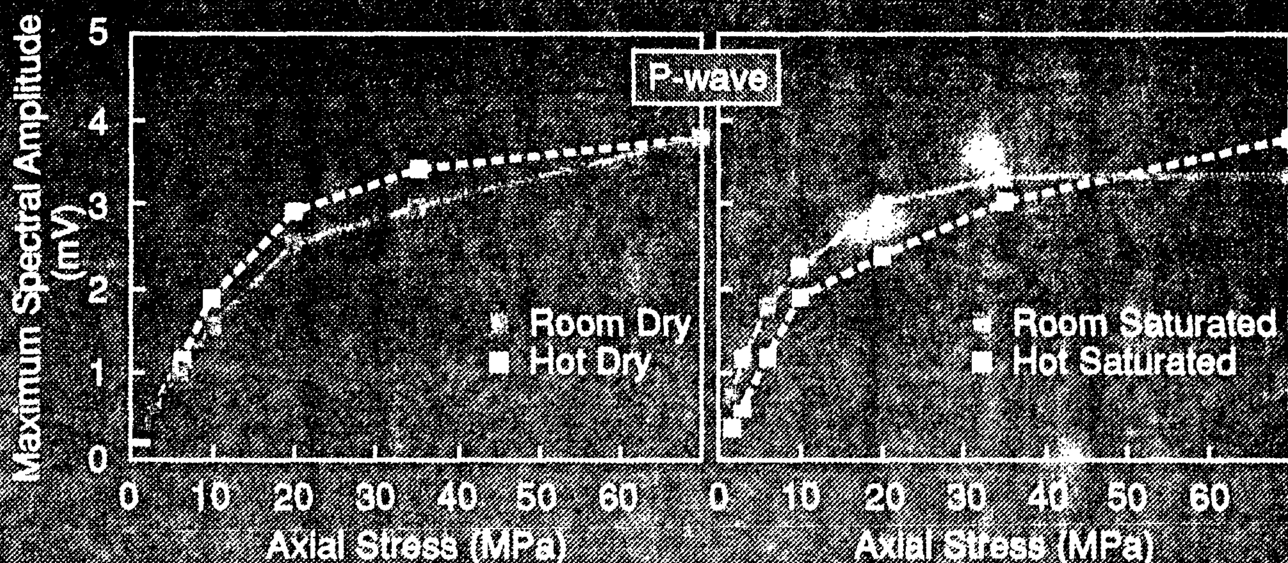
Mechanical and Seismic Measurements on Single Fractures



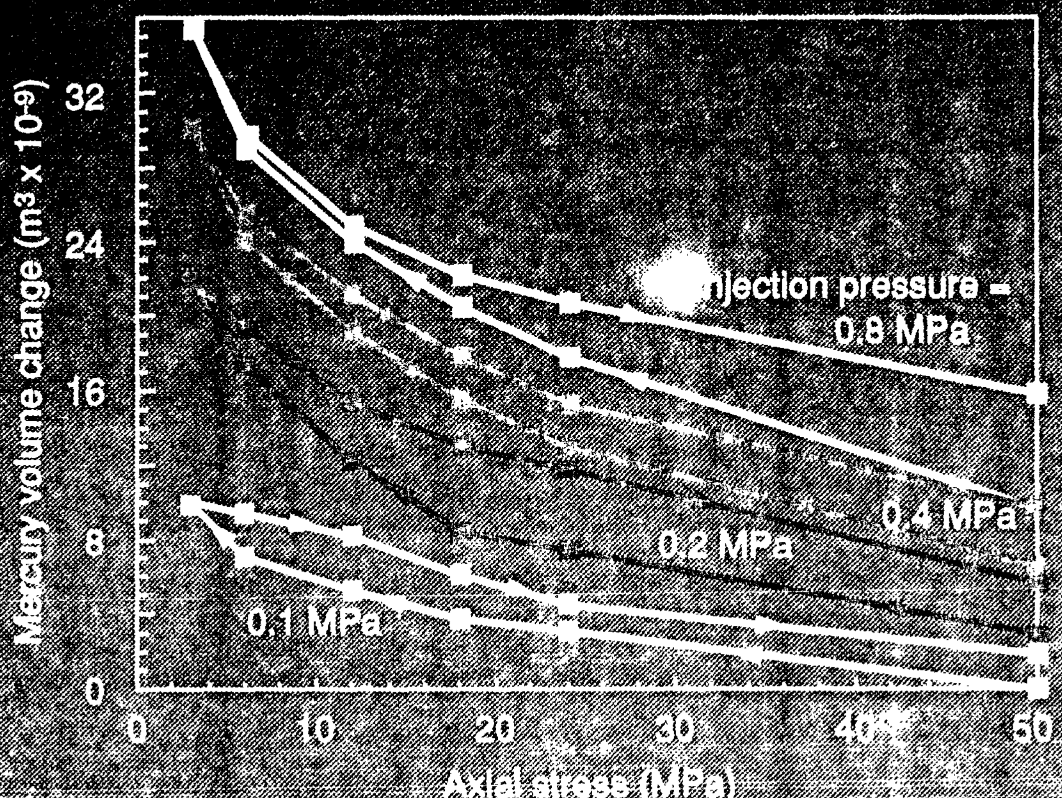
Deformation of a Single Granite Fracture



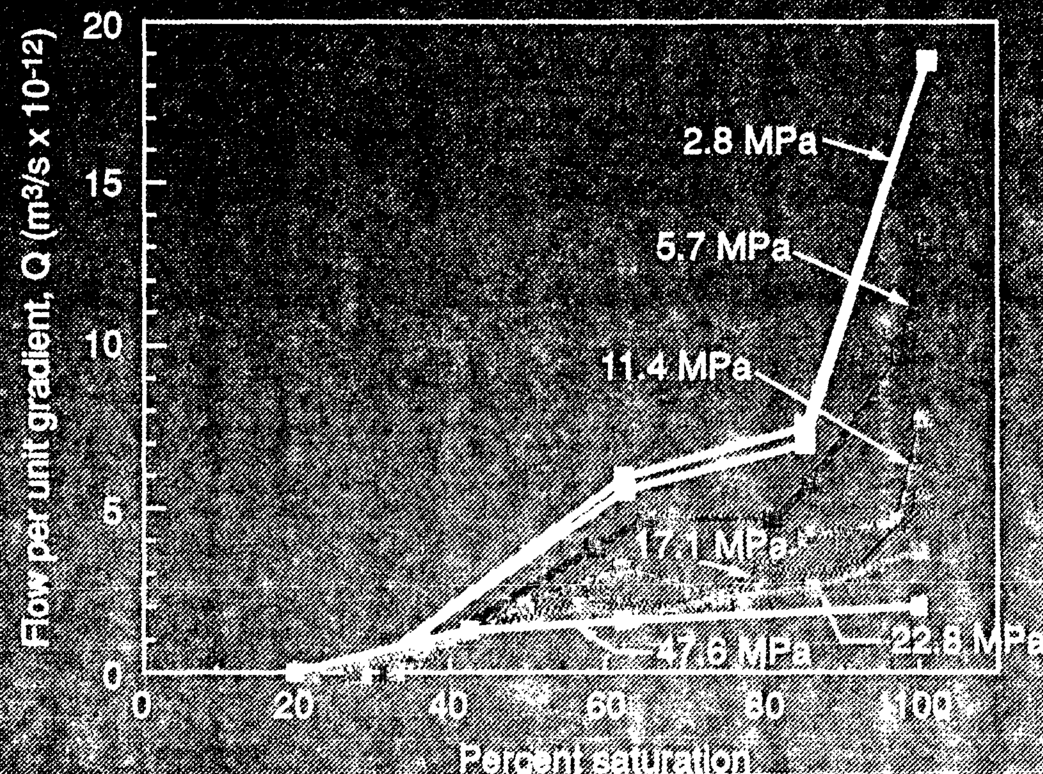
Seismic Measurements on Single Granite Fractures



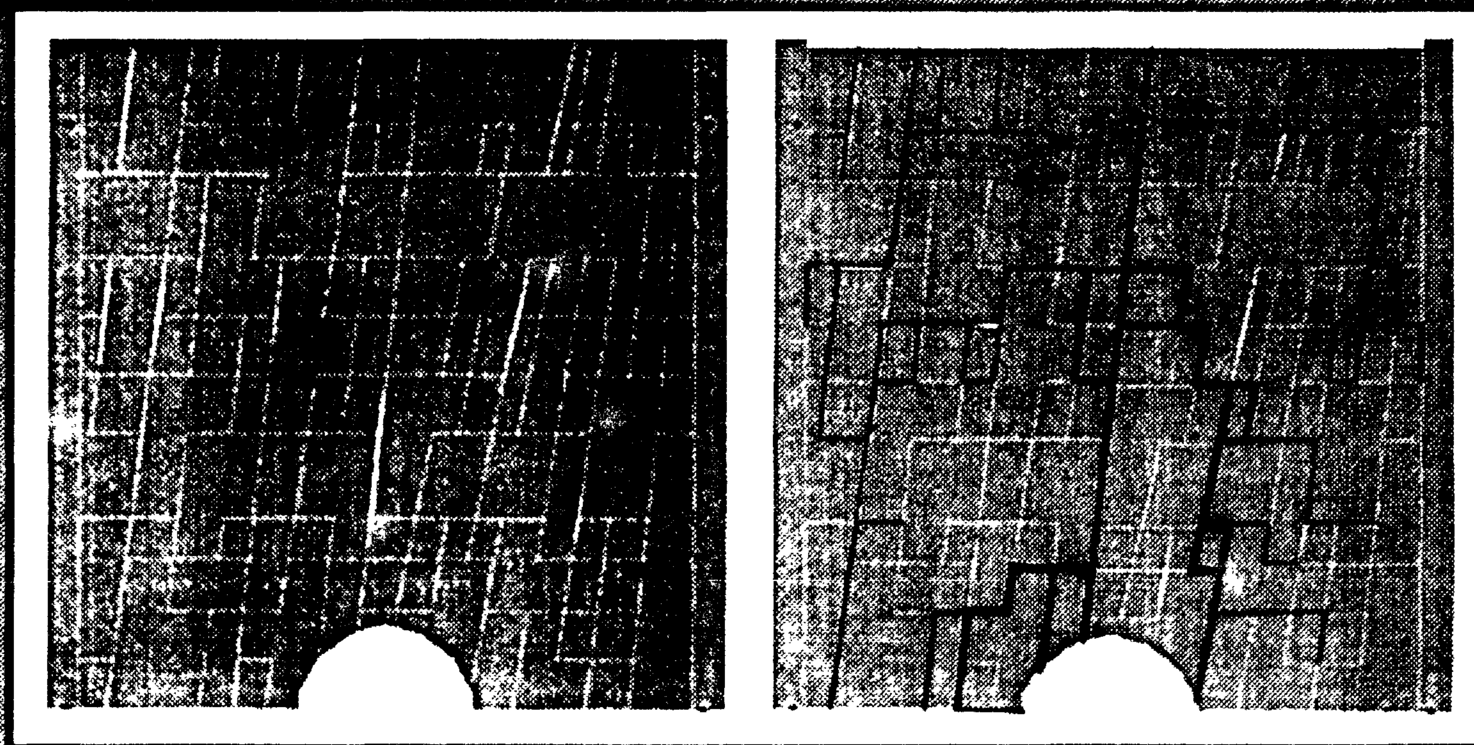
Mercury Porosimetry Measurements on a Single Granite Fracture



Flow of Non-wetting Phase (Mercury) in a Single Granite Fracture



Discrete Element (DDA) Analysis with Identification of Critical Paths



Conclusions

- Many effects understood in principle
- Little site-specific data
- Required Areas of Study
  - Thermomechanical and hydromechanical measurements under in-situ conditions (chemistry important)
  - Thermohydromechanical modeling explicitly incorporating fractures