Well and Seal Integrity

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Los Alamos, NM

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Session: Wellbore Integrity, Brighton 3 & 4

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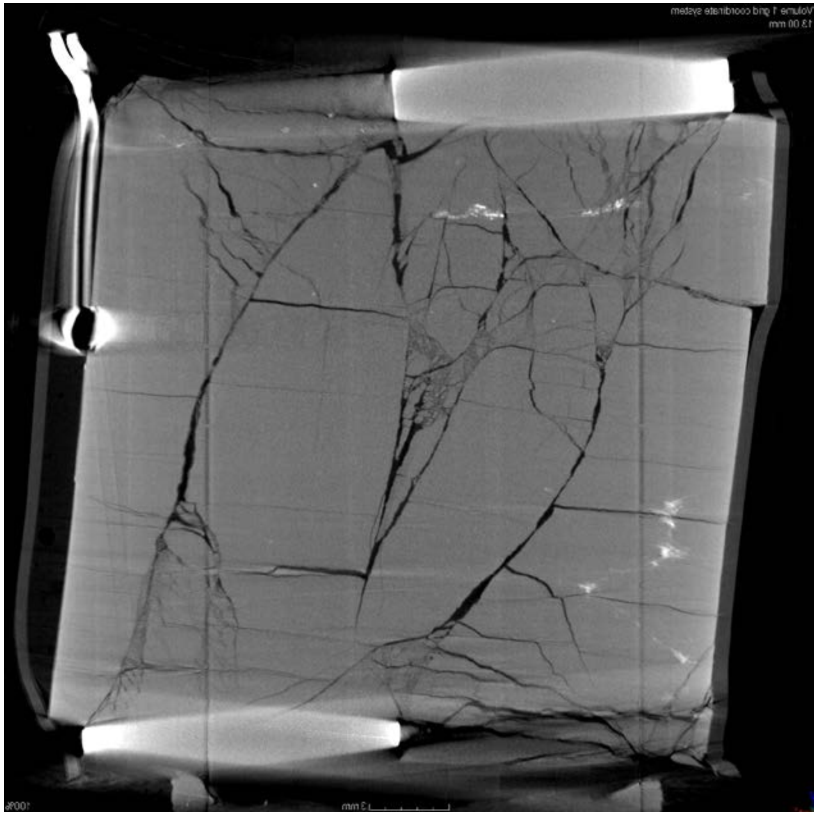
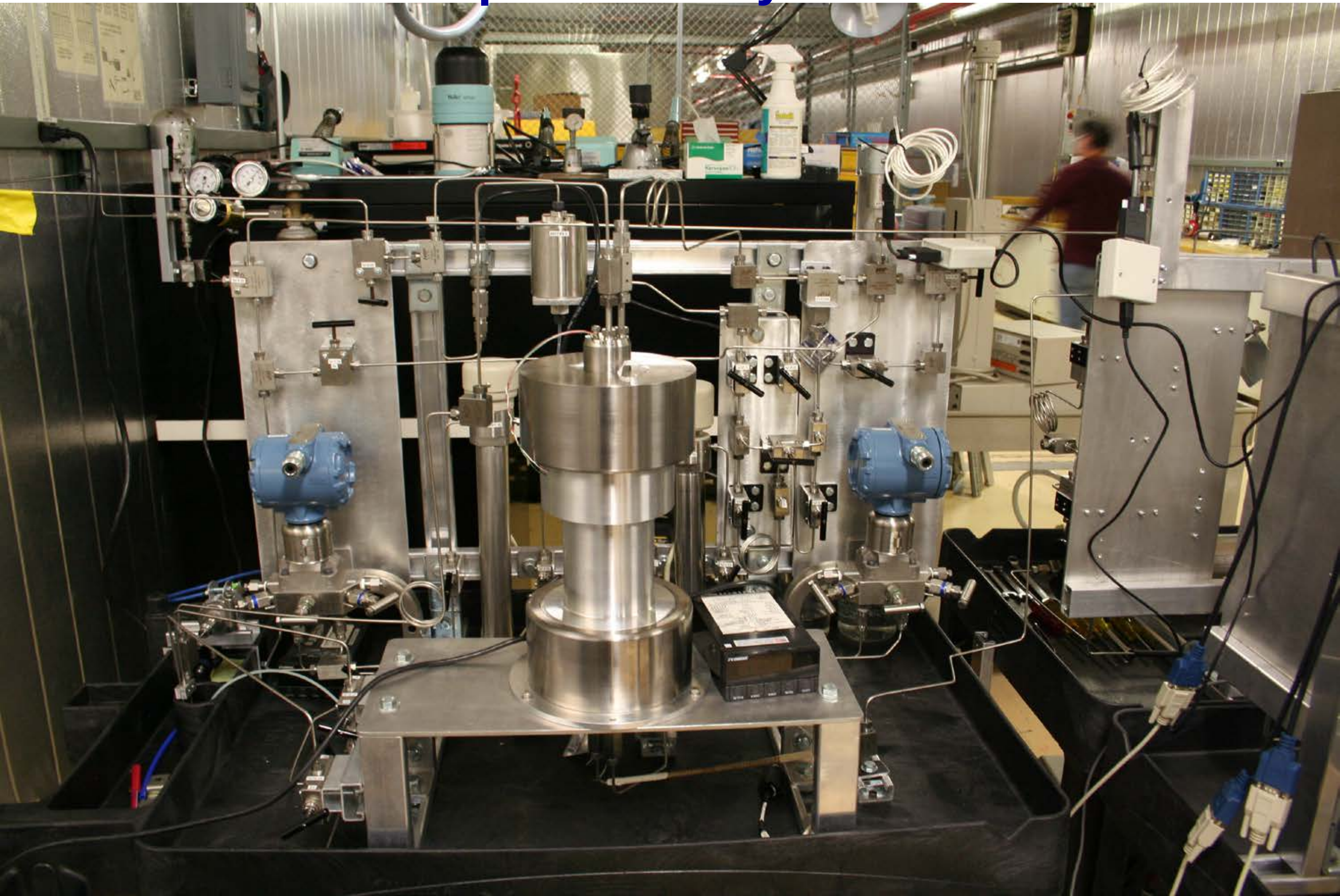
Experimental Studies

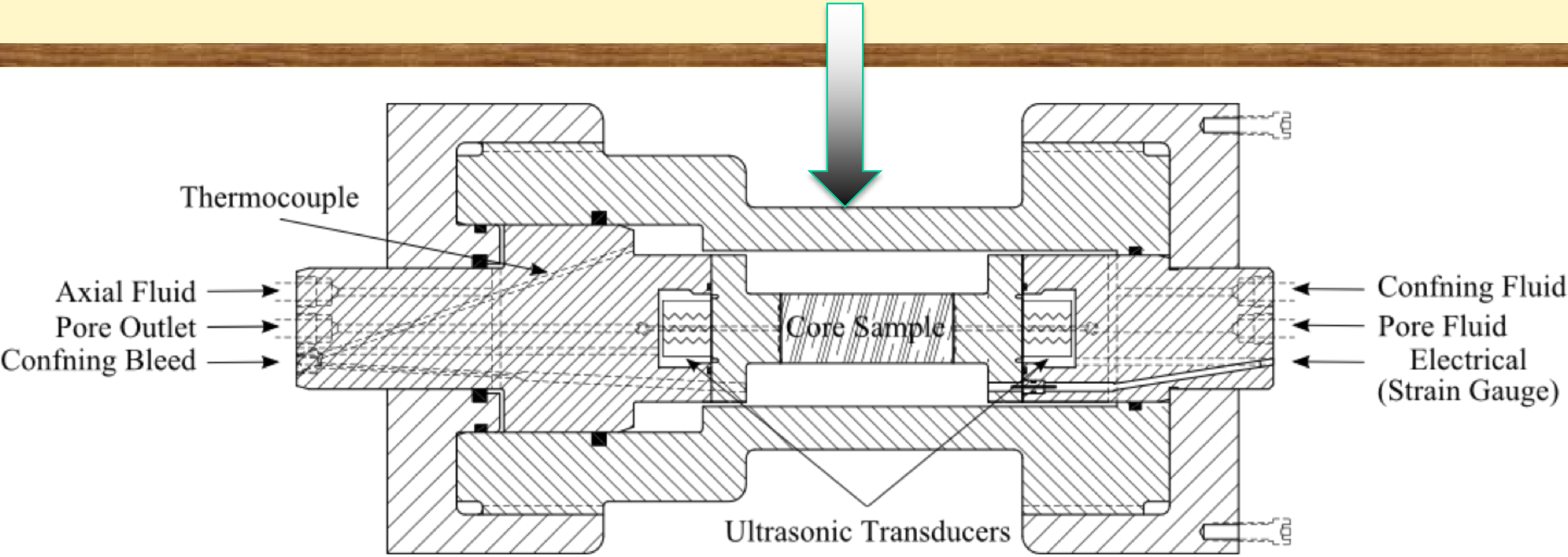
- Materials
  - Caprock:
    - Shale and anhydrite caprock
  - Wells
    - Type G oilwell cement and wellbore composites (Shale-Cement-Steel)
- Permeability of damaged materials
- Plastic behavior of shale, cement and anhydrite
- Pure shear configuration



Triaxial Coreholder: Self-supported triaxial stress with permeability measurement



In Situ X-ray or Neutron Tomography with triaxial coreflood



Triaxial Coreflood:
Confining pressure
Axial load
Multiphase fluid injection

Portable for use in different facilities
Max operating conditions: 100 ^oC, 350 bar confining/pore, 4,800 bar axial load
Samples: 1x3"

Strain measurement
Piston displacement
Acoustic velocity
Fluid pressure
Temperature
Fluid samples

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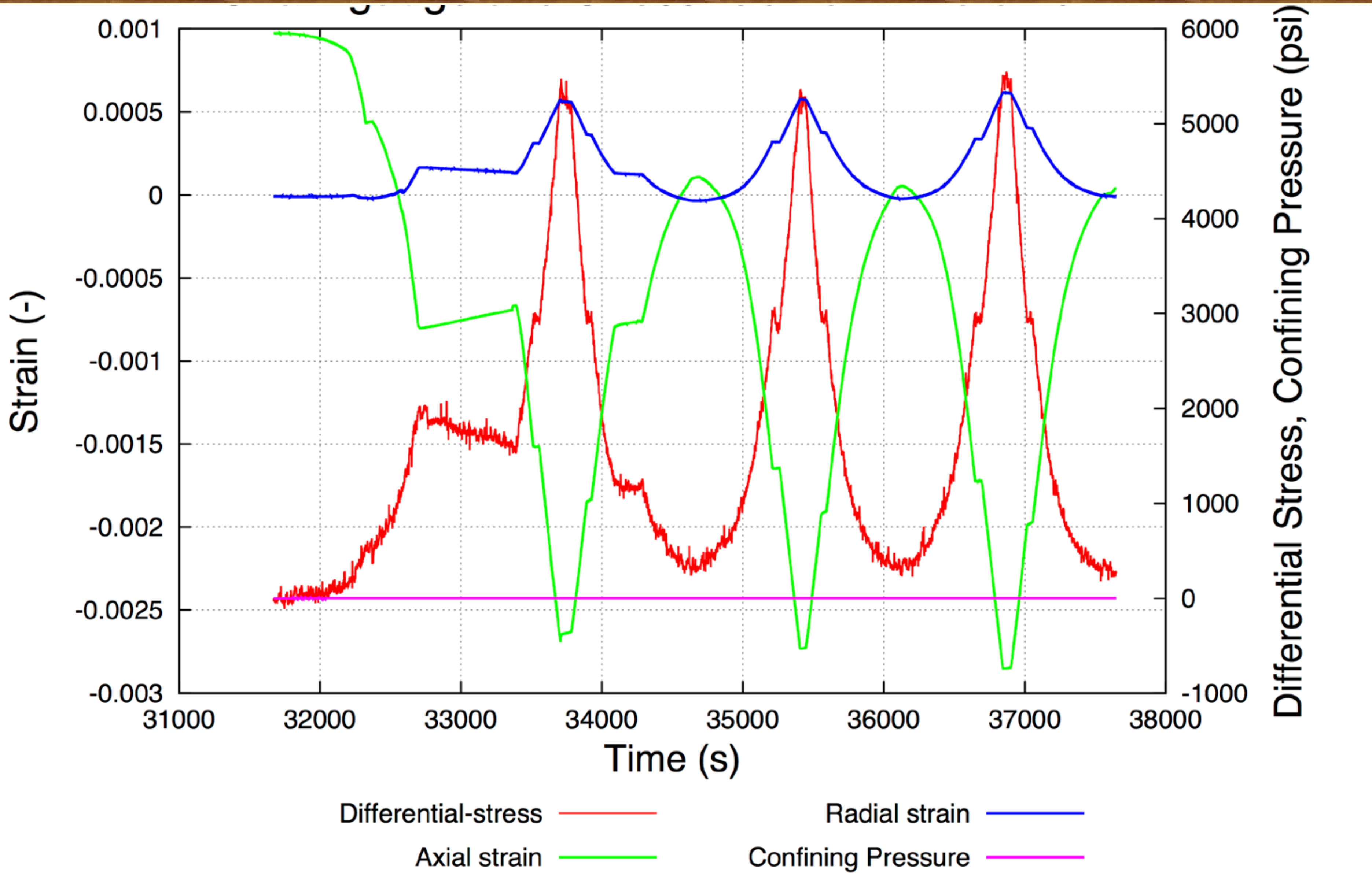
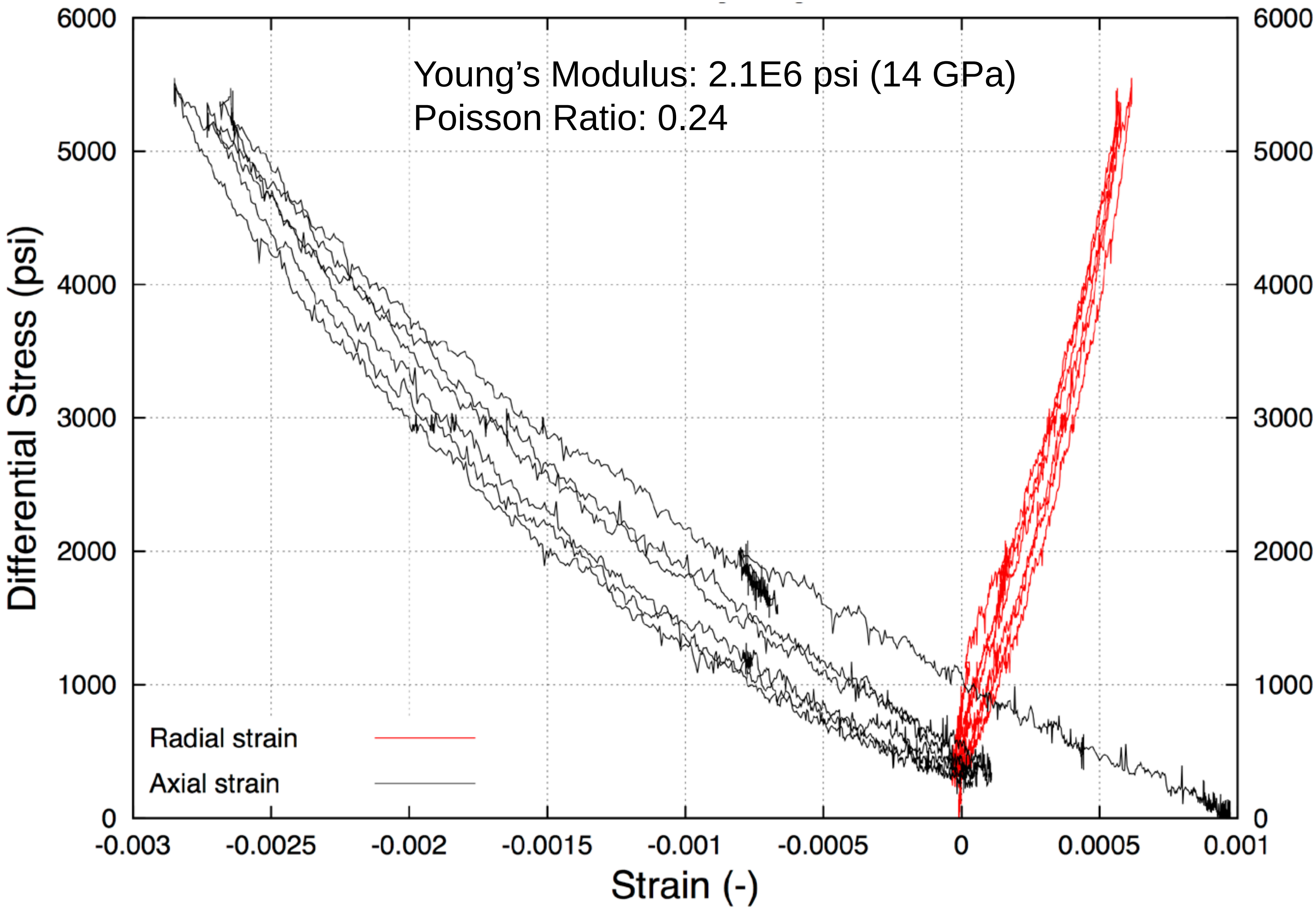
Fractured Cement with Supercritical CO_2

- Type G oilwell cement with cement/water ratio of 0.4
- Experiment at 45 ^{o}C and 1700 psi (117 bars)
- Multi-stage
  - Elastic measurements of intact cement (room temperature without confining pressure)
  - Fracture cement in pure shear
  - Measure permeability to water
  - Measure relative permeability of mixed water-supercritical CO_2 flow
  - Measure permeability to water
  - Repeat over the course of 7 days
    - Sample “rests” at ambient condition overnight
- X-ray tomography

Elastic Properties of Cement



Stress-Strain Curves



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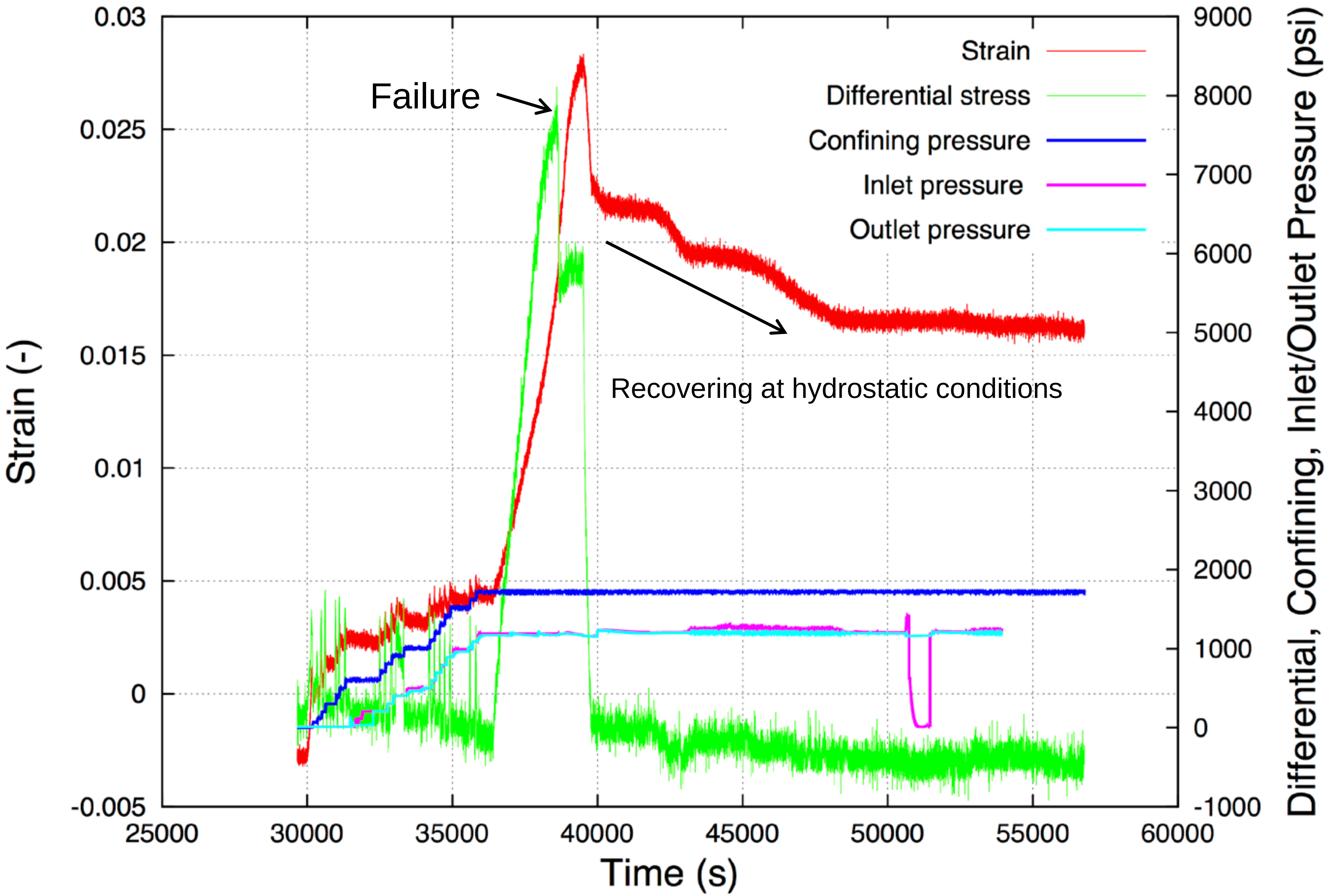
Fracturing Cement in Pure Shear



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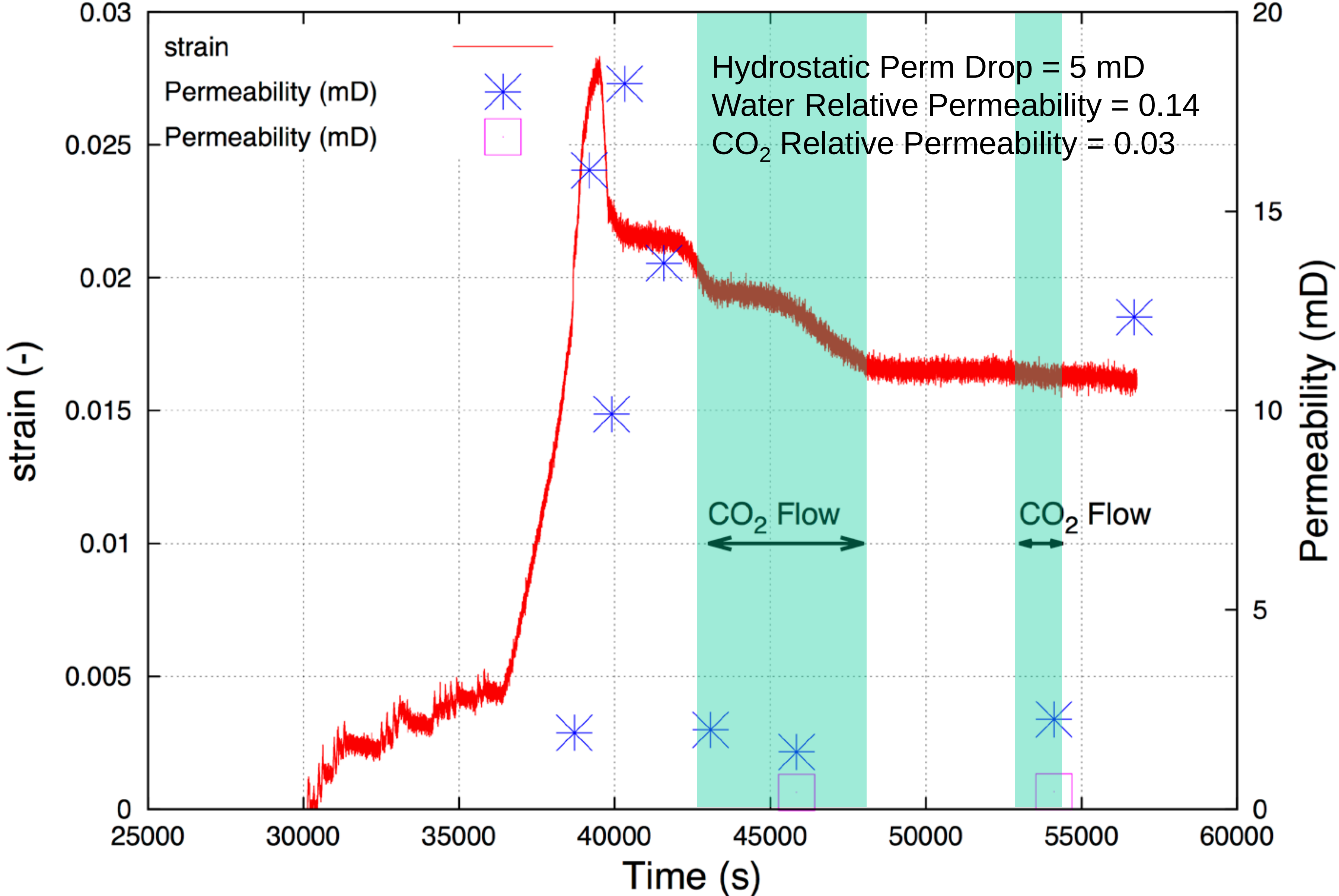
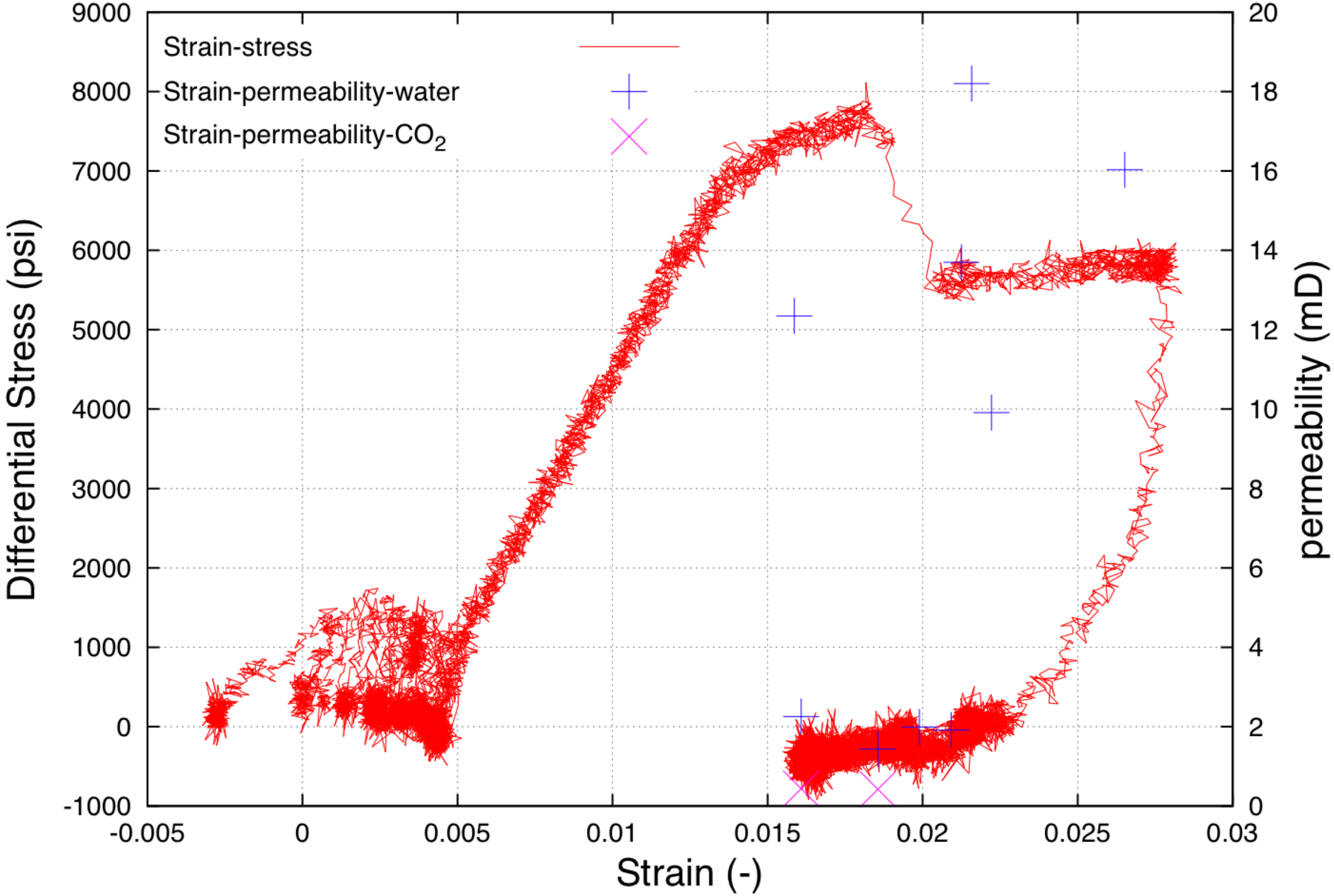
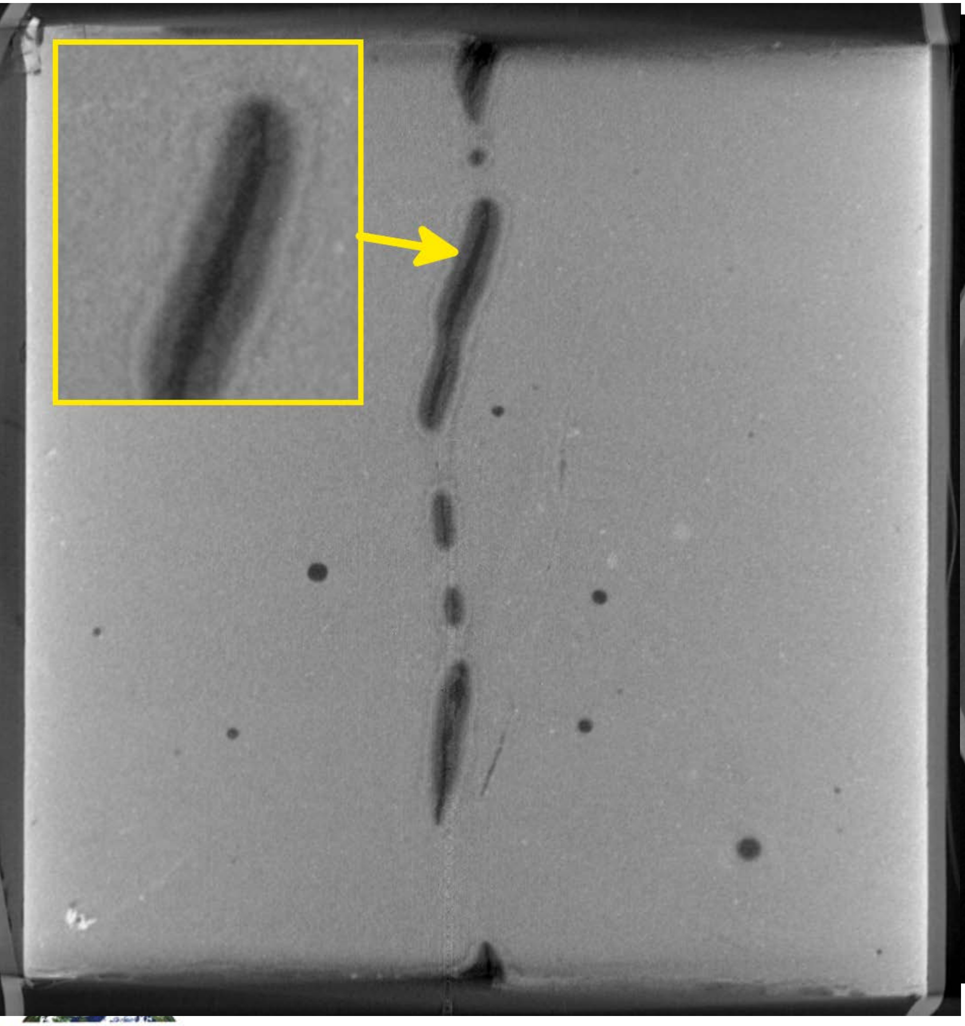
Fracture-Permeability in Cement

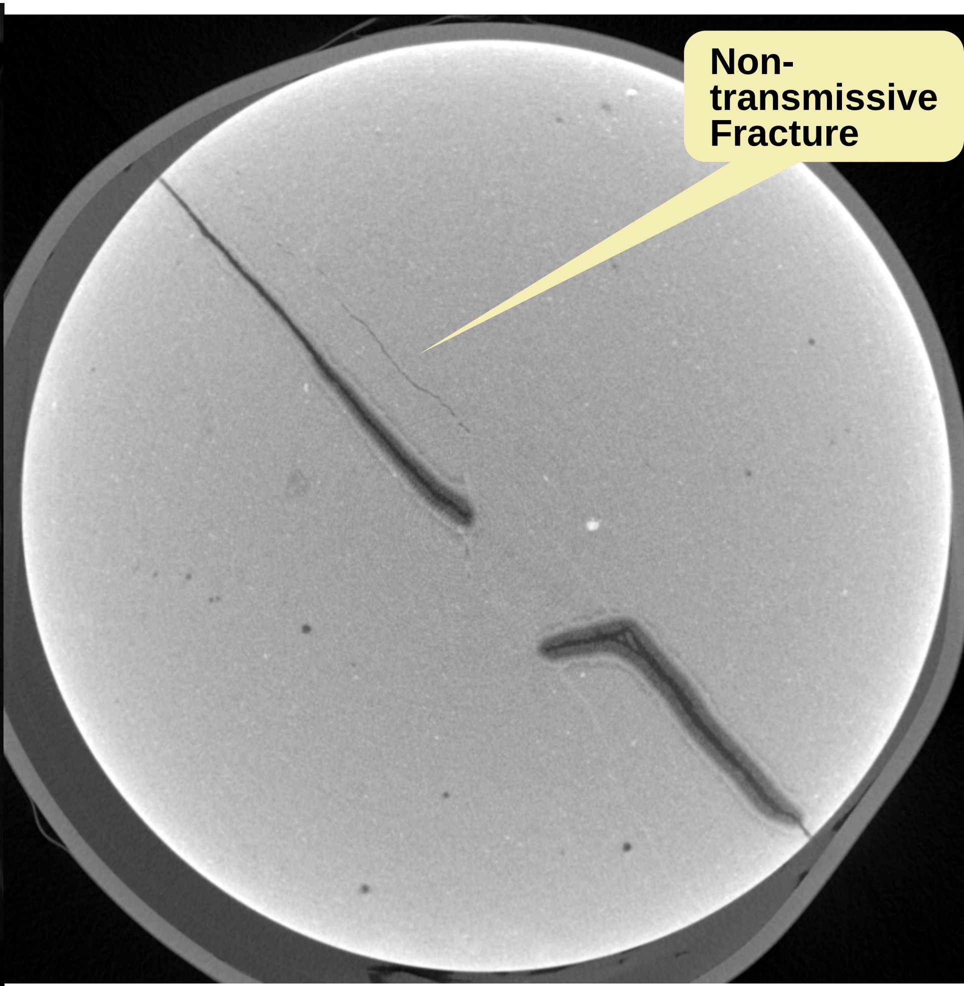


Strain-Stress-Permeability in Cement

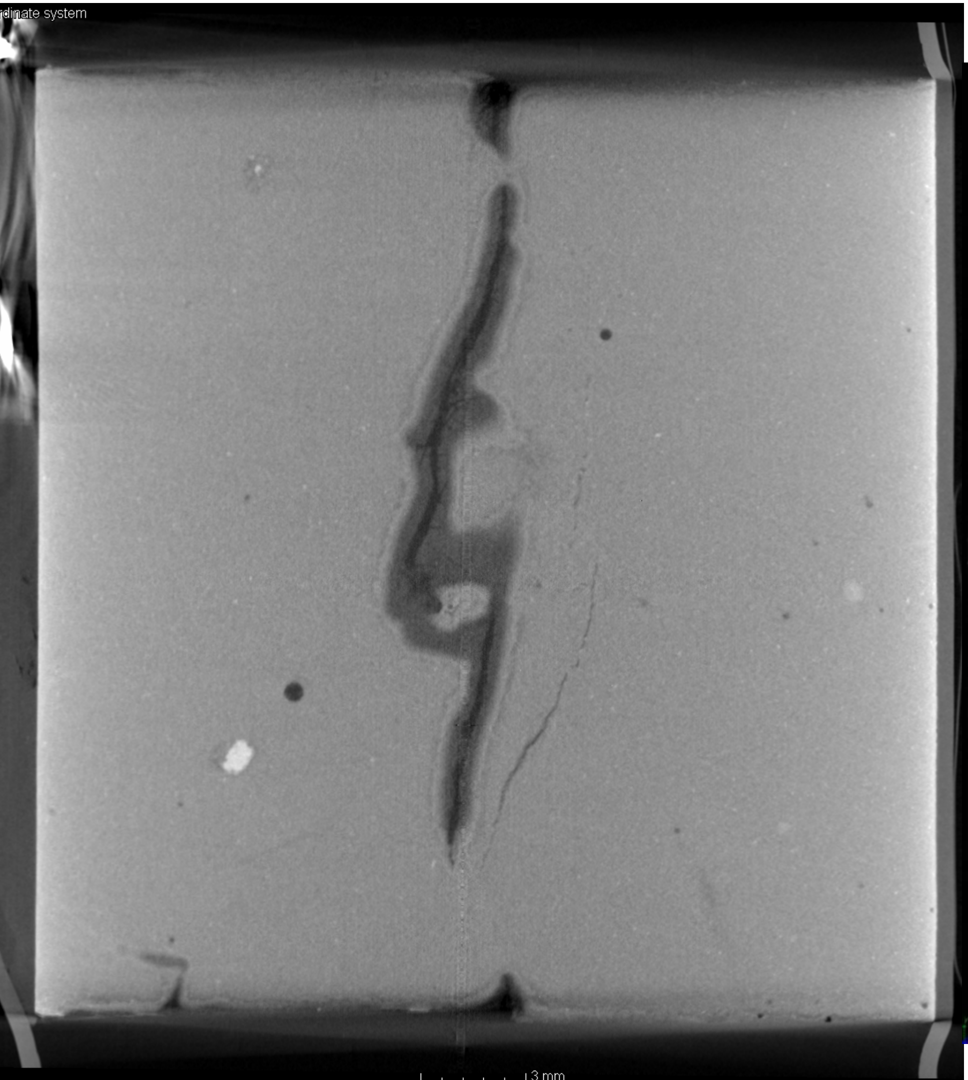


X-ray Tomography

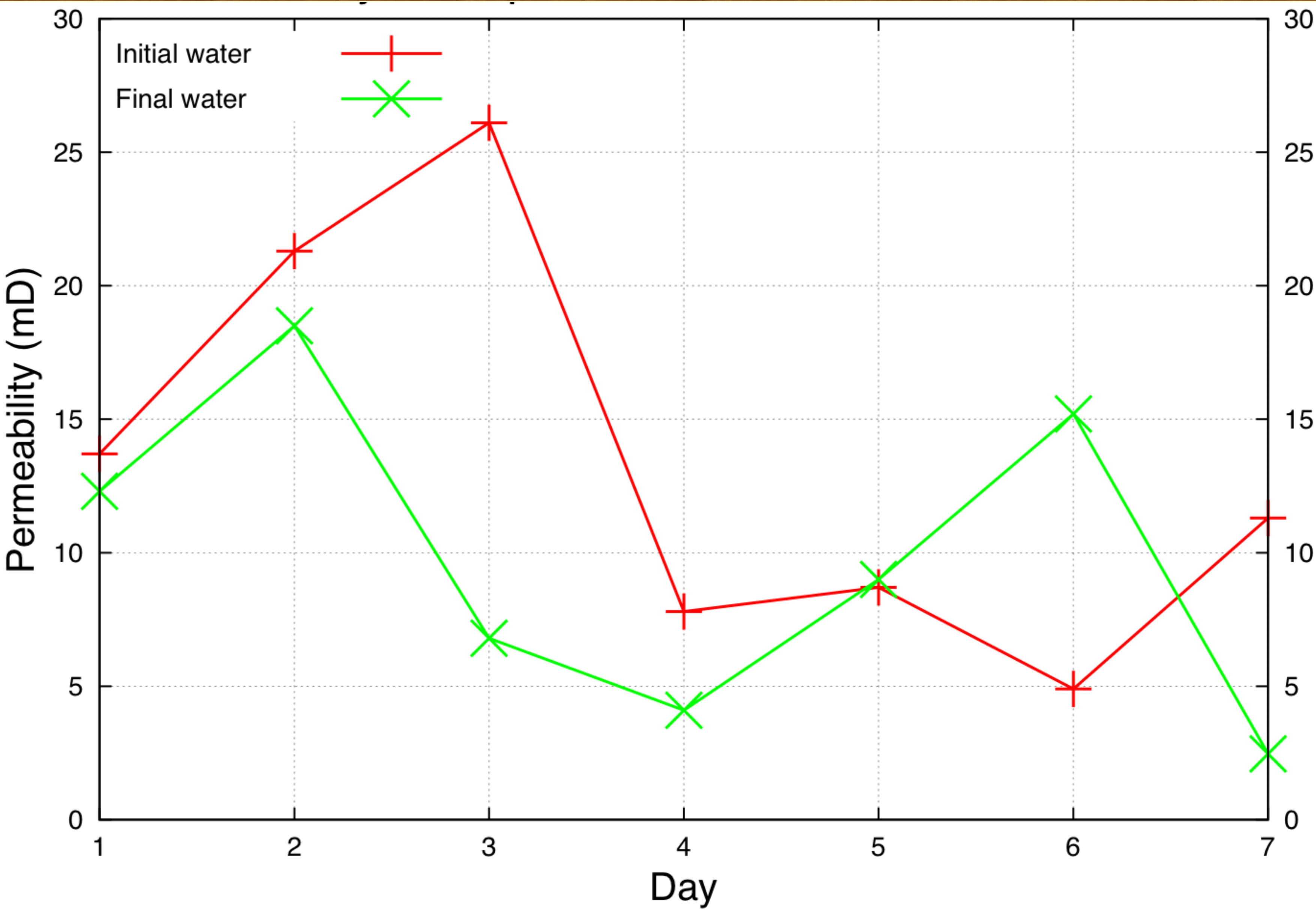




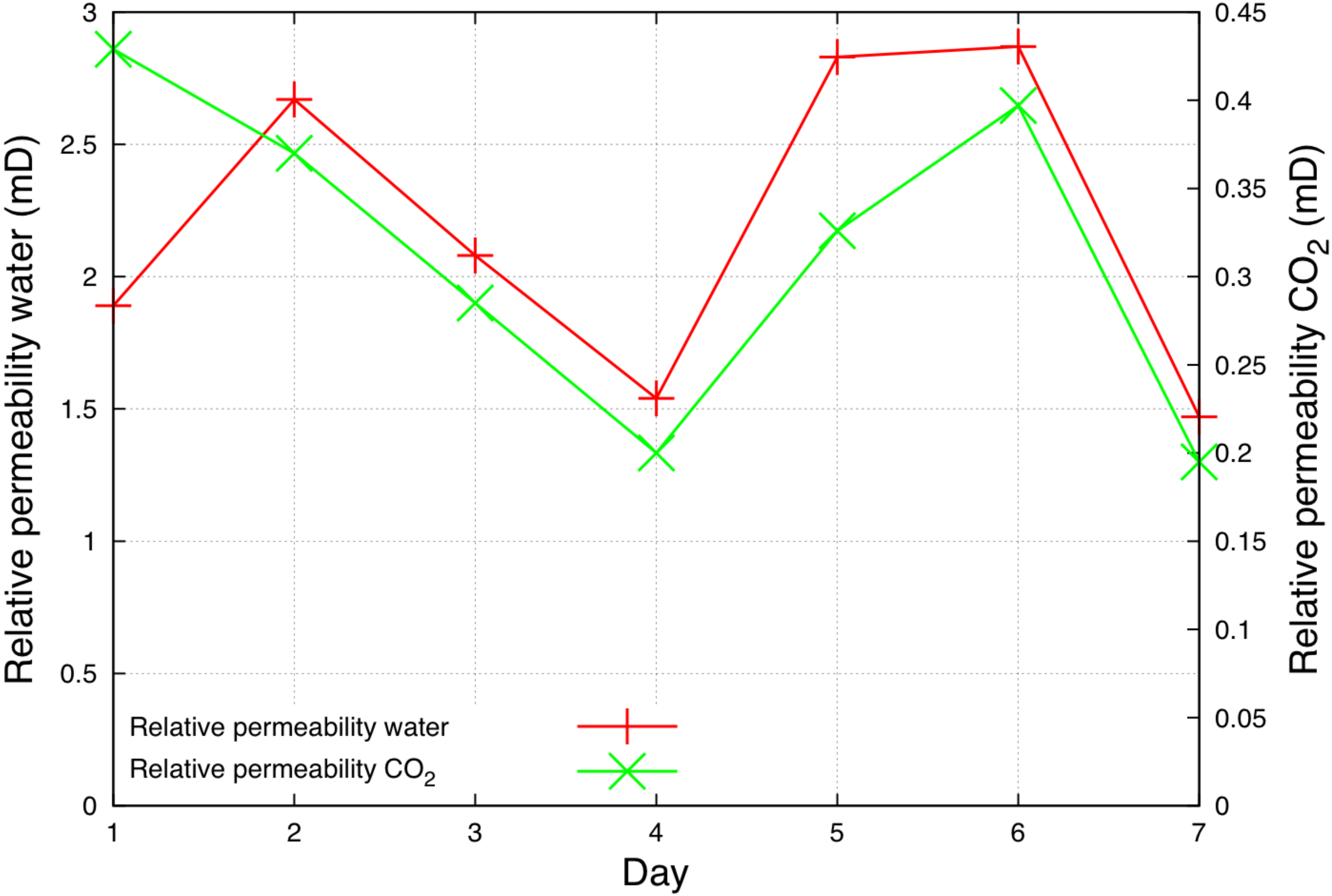
X-ray tomography



Water permeability as function of time



Relative permeability as a function of time



Pure Shear Results

- Cement fractures in shear at 8000 psi (550 bars)
- Fracture occurs at 1% shortening
- Supercritical CO_2 dissolves cement and creates clear reaction patterns in x-ray CT
- Permeability initially 15 mD decreases to 7 mD over 7 days (17 hours CO_2 exposure)
- Relative permeability of water = 0.31
- Relative permeability of CO_2 = 0.04

Conclusions

- **Extensive strain required to generate connected fractures**
  - **May limit consequences in actual field conditions**
- **Flow through damaged cement equivalent to 7 mD but relative permeability creates further limits to flow**
- **Supercritical CO_2 does not increase permeability of damaged cement (also see Carey et al. 2010; Walsh et al. 2013; Carey and Newell 2013; Huerta et al. 2013)**
- **Future work will measure fracture apertures and connectivity under in situ conditions**

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