National Risk Assessment Partnership
Induced Seismicity Working Group

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U.S. Department of Energy
National Energy Technology Laboratory
Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
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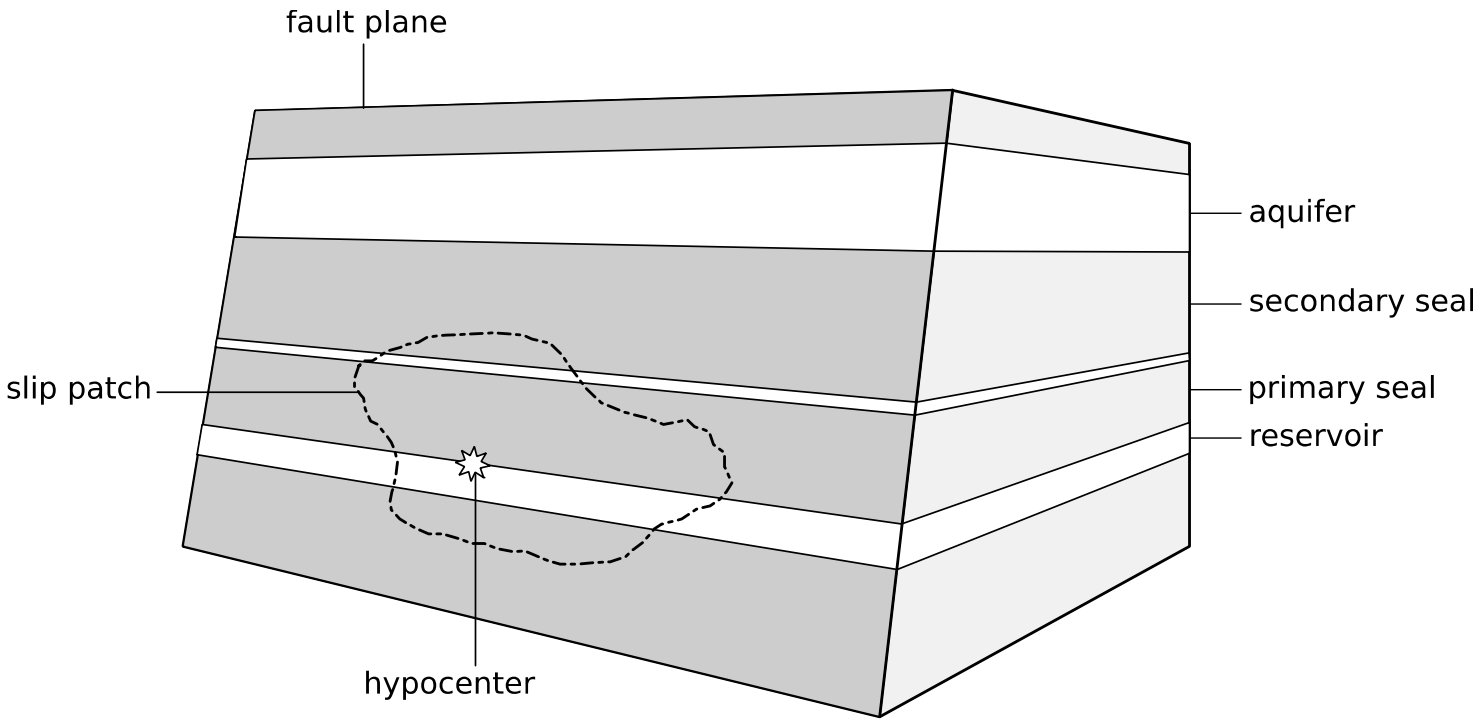
Working Group Goals

- Identify sites and operations that lead to low-risk—i.e. minimal hazard, minimal damage.

- Develop techniques to quickly identify and manage seismicity problems if they should appear



NRAP Phase I -- Tools and Products

Tools	**Short-term seismic forecasting tool**	V1.0 Available
	Ground motion prediction tool	V1.0 Available
	Probabilistic seismic risk assessment tool	Mature
	Seismic simulation capabilities	Mature
Reports	**Seismic risk assessment and mitigation strategies**	Available

Also, numerous journal papers describing the science basis are available.

NRAP Phase II -- Induced Seismicity Activities

Task	Description
3.1	Real-time hazard forecasting
3.2	Active seismicity management
3.3	Probabilistic seismic risk assessment
3.4	Fault leakage
3.5	Seismicity management protocols
5 + 6	Overlap activities: field demonstration and key questions

Significant Accomplishments in FY17

1	New field demonstration partnerships
2	New probabilistic state-of-stress assessment workflow
3	Application of seismic simulation capabilities to site characterization and management questions
4	Four journal publications

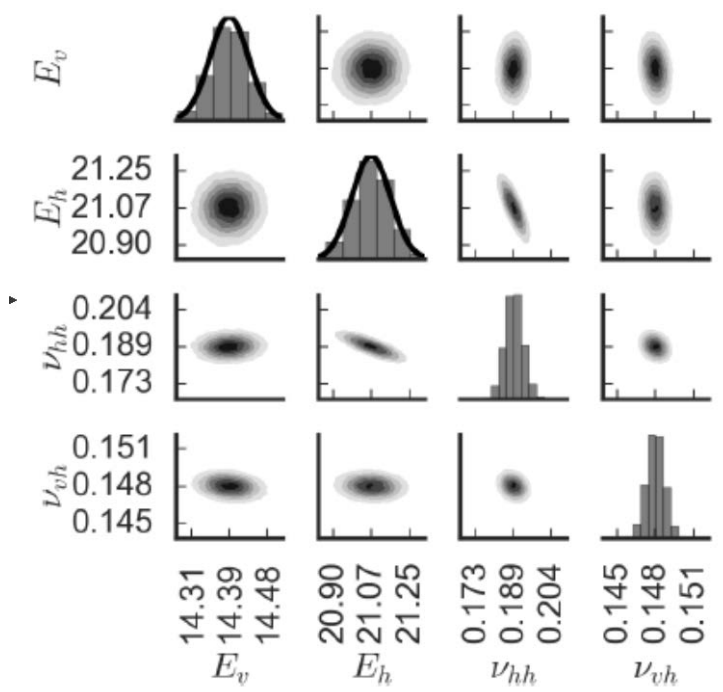
Field Demonstration Activities

- Current
  - **Farnsworth**
    - Local and regional stress data used to perform a probabilistic state-of-stress assessment.
  - **Oklahoma**
    - Waste-water disposal as analog for large-scale CO_2 storage
    - Collaborative with OGS and USGS
    - Using well pressure and microseismic data
- Planned
  - **Other Regional Partnership Collaborations**
    - Will use microseismic data to test seismic forecasting approach

Probabilistic State-of-Stress Assessment Workflow

- **Objective:** Incorporate stress and mechanical observations into a fully probabilistic assessment of fault reactivation potential.

Probabilistic Stress Polygon



Probabilistic Transversely Isotropic Elasticity Model

Probabilistic State-of-Stress Assessment Workflow

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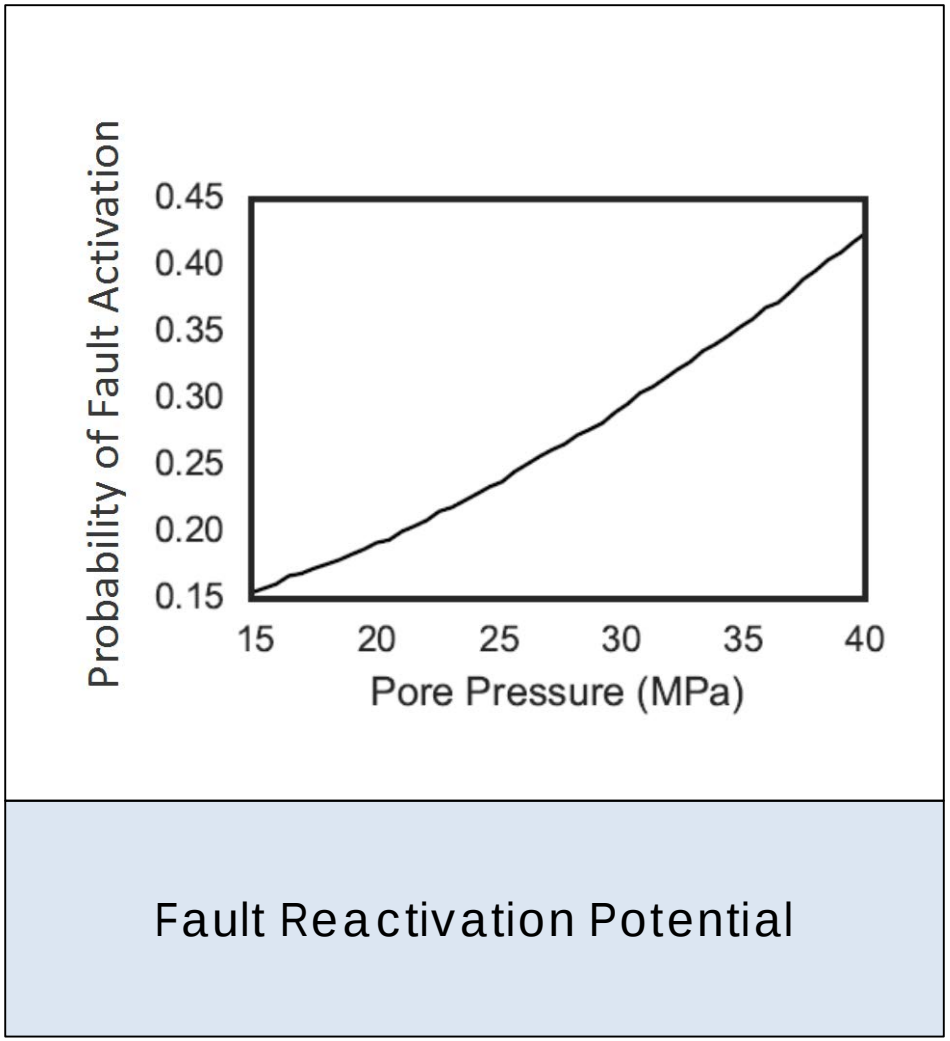
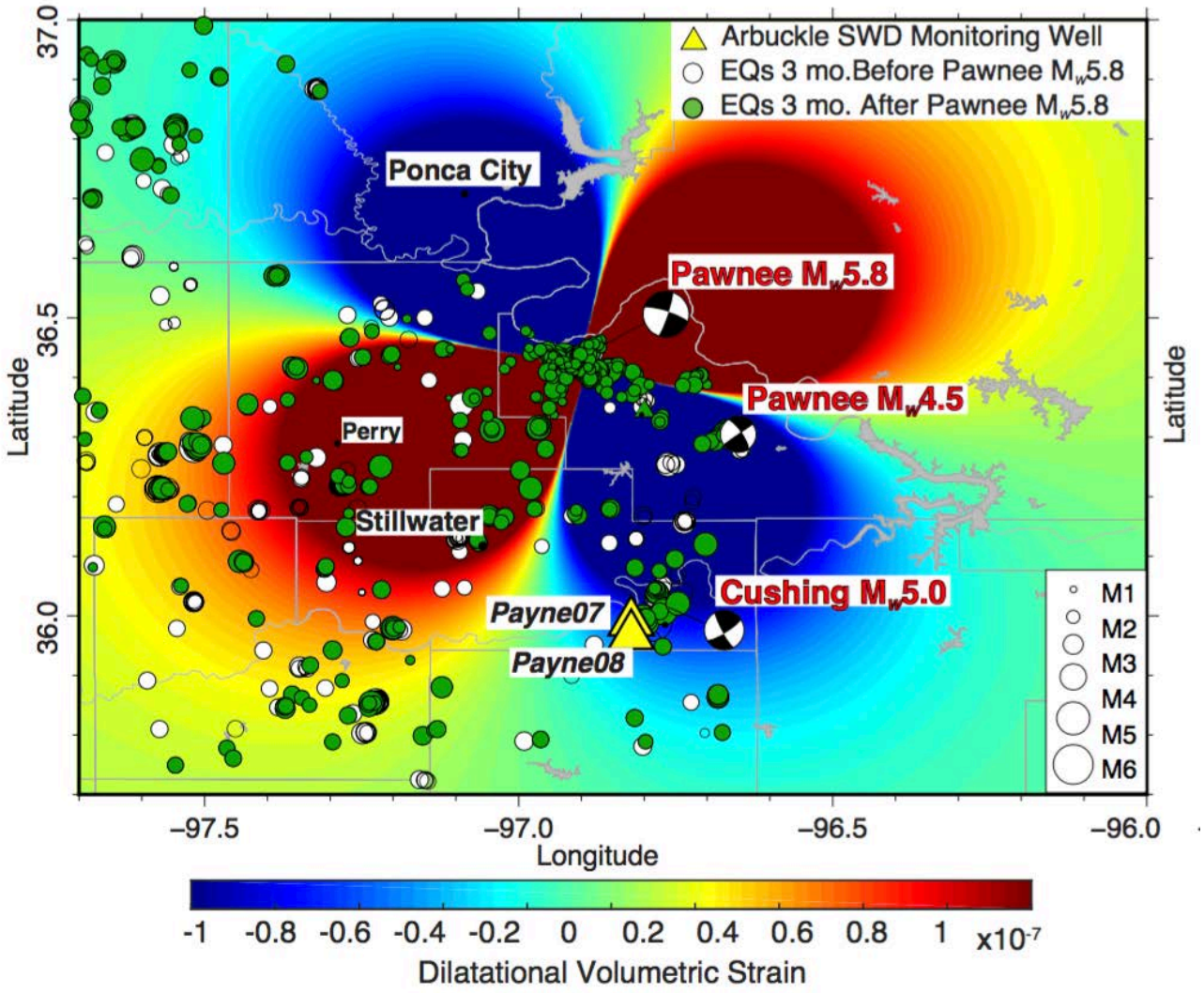
Stress Data

Mechanical Data



Oklahoma Field Application

- **Objective:** Use observation data and seismic simulations to characterize poroelastic parameters of the Arbuckle group.



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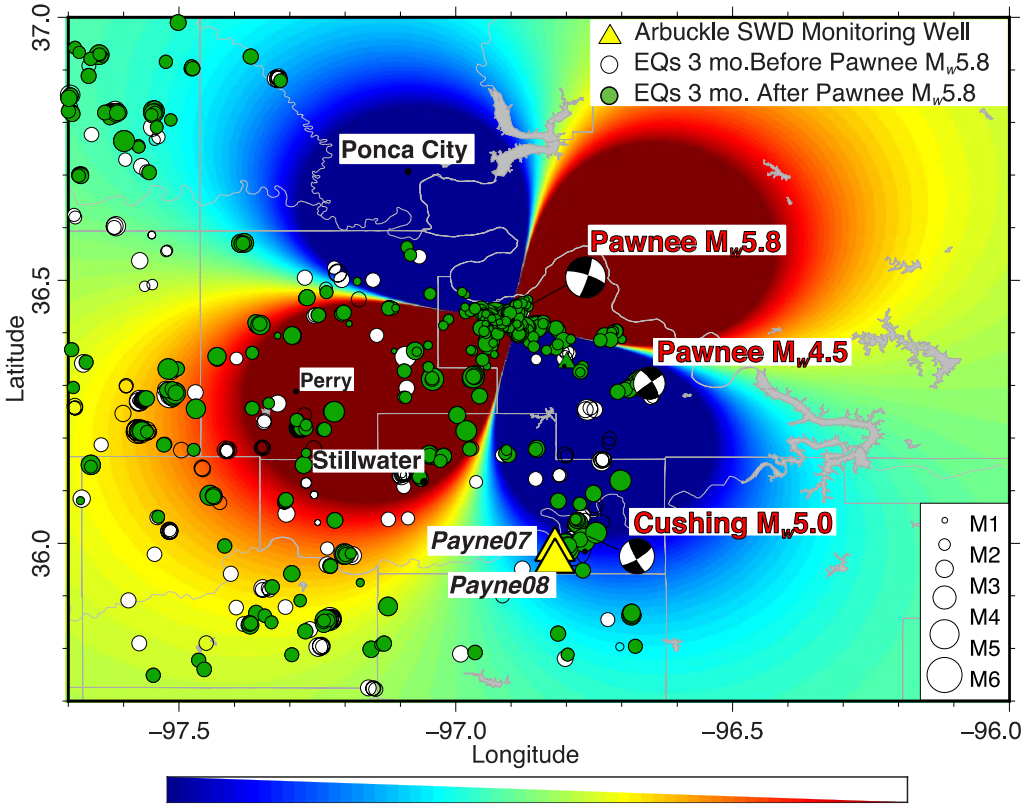

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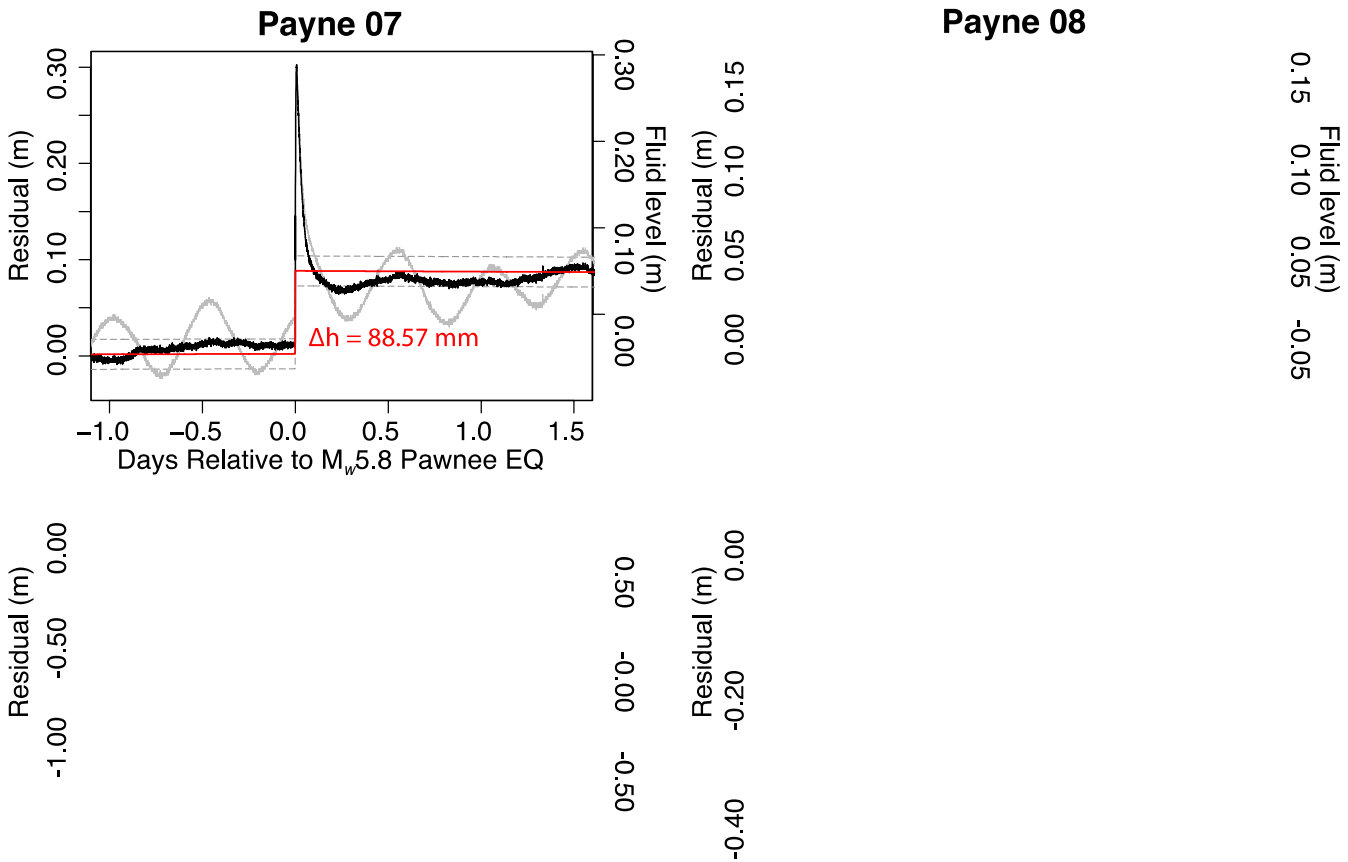

Oklahoma Field Application

- **Implications:**
  - Approach provides an additional scheme to constrain poroelastic properties
  - Pressure monitoring could provide evidence of hydrologic changes after an earthquake .
  - Clearly demonstrates importance of accounting for poroelastic effects in interpreting monitoring data (e.g. in an above-zone monitoring well).

Recent Publications: Burghardt 2017 (submitted)

Rock Mechanics and Rock Engineering

Geomechanical Risk Assessment For Subsurface Fluid Disposal

J. Burghardt
Pacific Northwest National Laboratory

Recent Publications: Kroll et al. 2017

Seismological Research Letters

Poroelastic properties of the Arbuckle Group in Oklahoma derived from well fluid level response to the 3 September 2016 M_w5.8 Pawnee and 7 November 2016 M_w5.0 Cushing Earthquakes

Kayla A. Kroll[1], Elizabeth S. Cochran[2], and Kyle E. Murray[3]

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[3]Oklahoma Geological Survey, University of Oklahoma, Norman, Oklahoma, USA.

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Recent Publications: Nguyen et al. 2017

Original Research Article

Recent Publications: Nguyen et al. 2017

Journal of Rock Mechanics and Geotechnical Engineering 8 (2016) 828e845

Contents lists available at ScienceDirect

Journal of Rock Mechanics and Geotechnical Engineering

journal homepage: www.rockgeotech.org

Full Length Article

Three-dimensional analysis of a faulted CO_2 reservoir using an Eshelby-Mori-Tanaka approach to rock elastic properties and fault permeability

Ba Nghiep Nguyen*, Zhangshuan Hou, George V. Last, Diana H. Bacon

Pacific Northwest National Laboratory, Richland, WA, USA

Lessons Learned

- Data access remains a challenge.
  - Modeling tools getting ahead of field data to constrain them.
- We could do a better job integrating new assessment methods into **existing** industry practices.
  - Important for improving industry engagement
  - For example, how can NRAP tools best be used within a bow-tie (or similar) framework.
  - Should focus on generating recommended practice documentation.

Synergy Opportunities

- Always looking for partners with microseismic data.
  - CO_2 injection is most relevant, but other injection types can be reasonable analogs.

Program Goal No. 4

- Develop Best Practice Manuals for monitoring, verification, accounting, and assessment; site screening, selection and initial characterization; public outreach; well management activities; and risk analysis and simulation.

Benefit Statement

- An understanding of induced seismicity is essential for effective risk management of storage sites.
- This project seeks to develop:
  - An open toolkit to support seismic characterization and management.
  - Support best-practices to minimize risk while supporting the growth of the CO_2 storage industry