2012 Rock Mechanics/Geomechanics Symposium

Welcome to Chicago!
Attendance

- About 600 Scientists and Engineers
  About 500 in San Francisco, 450 in Salt Lake City
- Attendees from 30-40 Countries
- 350 Papers Derived from 600 Abstracts
- 50% of Attendees from Outside the U.S.
- 30% Students

The ARMA annual symposium has become the go to meeting in rock mechanics and geomechanics for professionals and students from around the world-wide
• ARMA Exists to
  – Serve its members
  – Promote rock mechanics and geomechanics
  – Educate future professionals

• Through
  – Annual Symposia
  – Publication of Proceedings
    • OnePetro (> 3.5 million downloads in 2011)
  – Workshops and Short Courses
Rock Mechanics, Geomechanics and The Energy/Environment Nexus
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but first......A few thanks
Rock Mechanics, Geomechanics and The Energy/Environment Nexus

A few new developments
Corporate Membership in ARMA

Membership
Corporate Membership in the American Rock Mechanics Association (ARMA) is open to any company, firm, non-profit organization, university, government laboratory or agency with an interest in rock mechanics and geomechanics.

What are the benefits of Joining ARMA as a Corporate Member?
Becoming a Corporate Member will:

- Connect you to the broader rock mechanics and geomechanics community, including industry, academia, and government.
- Demonstrate your support for professional practice in rock mechanics and geomechanics.
- Augment ARMA’s promotion of rock mechanics and geomechanics as a discipline, especially with students.
- Present communication opportunities with ARMA and associated societies.
- Recognize your support of and participation in the activities and discussions of ARMA and rock mechanics/geomechanics.

What Is ARMA?
ARMA serves as an advocate for firms and individuals for all aspects of rock mechanics, rock engineering, and geomechanics. ARMA provides a communications link, a forum, and an information resource for members, related organizations, and the public.

ARMA’s goal is to disseminate information through meetings, publications, and the Internet. ARMA publishes ARMA e-Newsletter, a quarterly electronic newsletter; conducts educational workshops and short courses; organizes topical symposia; and sponsors the annual U.S. Rock Mechanics/Geomechanics Symposium.

ARMA serves as an information repository on the development of rock mechanics, rock engineering, and geomechanics, and promotes the development of knowledge within the field. ARMA maintains U.S. membership in the International Society for Rock Mechanics.

What Is the Fee?
The annual fee for Corporate Members is $2,500 USD.
ARMA
More Than the Annual Symposium

- Topically Focused ARMA Forums
  - John McClennan
- International Meetings
  - Abu Dhabi – January 2014?
- Co-Sponsoring International Meetings
International Conference for Effective and Sustainable Hydraulic Fracturing

May 20-22, 2013 Brisbane, Australia

http://hfconference2013.hydrofrac.wikispaces.net
The 6th International Symposium on In-situ Rock Stress

Rock Stress: Its Role and Measurement for Earth Science and Engineering

Organized by JCRM, Sponsored by ISRM, Co-sponsored by ARMA

Aug. 20-22, 2013
Sendai, Japan
(Abstract due Nov. 30, 2012)

Inviting topics related to rock stress at a wide variety of depths ranging from tens meters to tens kilometers!!

- Frontiers of in-situ stress measurements
- Integration of stress data and methods
- Practical approaches to in-situ stress measurements
- Deep mining
- Storage of carbon dioxide and radioactive waste in rock stress field
- Oil, natural gas and geothermal resource developments and rock stress
- Induced seismicity
- Rock mass deformation and fluid migration
- Earthquakes and stress in the earth's crust
Rock Mechanics, Geomechanics and The Energy/Environment Nexus

– Shale Gas Development and Environmental Protection
– Induced and Triggered Seismicity
– CO$_2$ Sequestration
Global Energy and Environment Challenge

How Do We Provide Accessible, Affordable, and Secure Energy While Protecting the Planet (2x by 2050, 3-4x by 2100)?

Source: U.S. Census Bureau, International Data Base, December 2008 Update.
North American Shale Plays

- Palo Duro
- Woodford
- Avalon
- Barnett
- Haynesville (Shreveport/Louisiana)
- Fayetteville
- Michigan Basin
- Antrim
- Niobrara/Mowry
- Cane Creek
- Monterey
- New Albany
- Green River
- Lewis/Mancos
- Bakken
- Montney Deep Basin
- Colorado Group
- Horn River Basin/Cordova Embayment
- Green River
- Marcellus
- Montney Deep Basin
- Marcellus
- Antrim
- Utica Shale
- Horton Bluff Formation
- Michigan Basin

~2300 TCF (85% Shale Gas)

“100 years of Natural Gas” U.S. Consumption 23 TCF/y
~22,600 TCF of Recoverable Reserves
6600 TCF from Shale (40%)
Current use ~160 TCF/year (140 years)
Rock Mechanics and Geomechanics Are Keys To Exploitation of Shale Gas

Horizontal Drilling and Multi-Stage Slick-Water Hydraulic Fracturing Induces Microearthquakes (M~ -1 to M~ -3) To Create a Permeable Fracture Network


Source: Texas Railroad Commission
• Hydraulic Fracturing
• Microseismic Monitoring
• Stimulating Fractured Reservoirs
• Modeling Stimulated Reservoirs

• Importance of Formation Properties, Pre-existing Fractures and Faults, State of Stress, etc.
- Rock Strength
- Rheological Properties
- Transport Properties
- Petrophysics for Calibrating Geophysical

- Importance of Composition (Clay and Kerogen Content), Maturation, Diagenesis, etc.
• Importance of Composition on Rock and Transport Properties
• Role of Adsorption and Diffusion on Ultimate Recovery
Environmental Issues

- Surface Contamination
- Gas Leakage From Wells
- Disposal of Flow-back Waters
- Hydraulic Fracturing Affecting Well Water
- Earthquake Triggering Associated with Injection of Flow-back Water
- Impacts on Residents and Land Use
Environmental Issues

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SEAB - Summary

- Shale gas is extremely important to the energy security of the United States
- Shale gas currently accounts for 30% of the total US natural gas production
- Shale gas development has a large positive economic impact on local communities and states
- Shale gas development creates jobs
- Shale gas can be developed in an environmentally responsible manner.
Casing and Cementing

Aquifers
Coal Seam
Saline Aquifer
Minor Gas Producing Shales
Top of Cement
Secondary Casing
Production Casing

Surface Casing at 500 ft.

Additional Casing at 2000 ft. provides secondary barrier to leakage.

API Recommended Practice
Best Practice

Courtesy George King, Apache Corp.
Range Resources
Washington County, Pennsylvania
Injection Triggered Seismicity
Liquid carbon dioxide has been injected into the Sleipner gas- and oilfield in the North Sea for 15 years without triggering any seismicity. It serves as a good example of how fluid injection can be done safely.

Managing the Seismic Risk Posed by Wastewater Disposal

Mark D. Zoback

From an earthquake perspective, 2011 was a remarkable year. While the devastation accompanying the magnitude-9.0 Tohoku earthquake that occurred off the coast of Japan on March 11 still captures attention worldwide, the relatively stable interior of the U.S. was struck by a somewhat surprising number of small-to-moderate earthquakes that were widely felt. Most of these were natural events, the types of earthquakes that occur from time to time in all intraplate regions. For example, the magnitude 5.8 that occurred in central Virginia on Aug. 23 was felt throughout the northeast, damaged the Washington Monument, and caused the temporary shutdown of a nuclear power plant. This earthquake occurred in the Central Virginia Seismic Zone, an area known to produce relatively frequent small earthquakes.

However, a number of the small-to-moderate earthquakes that occurred in the U.S. interior in 2011 appear to be associated with the disposal of wastewater, at least in part related to natural gas production. Several small earthquakes were apparently caused by injection of wastewater associated with shale gas production near Guy, Ark.; the largest earthquake was a magnitude-4.7 event on Feb. 27. In the Trinidad/Raton area near the border of Colorado and New Mexico, injection of wastewater associated with coalbed methane production seems to be associated with a magnitude-5.3 event that occurred on Aug. 22, and small earthquakes that appear to have been triggered by
Induced Seismicity Potential in Energy Technologies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu
Risk Associated with Injection and Triggered Seismicity

Microseismic Events Associated with Hydraulic Fracturing
• Very Low Risk to Public
  • Limited rock volume, limited pumping volume/time
  • Very few events > M 2 in 100,000’s of frac stages

Seismic Events Associated with Wastewater Injection
• Low Risk to Public
  • Much Larger Pumping Volumes
  • Can be Effectively Managed by Effective Site Characterization, Monitoring and Proactive Planning
  • Minimize Injection by Water Recycling

Potential of Triggered Seismicity with Large Scale CCS
• Injection of extremely large volumes pose considerable risk
Earthquake triggering and large-scale geologic storage of carbon dioxide

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Despite its enormous cost, large-scale carbon capture and storage (CCS) is considered a viable strategy for significantly reducing CO₂ emissions associated with coal-based electrical power generation and other industrial sources of CO₂ [Intergovernmental Panel on Climate Change (2005) IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change, eds Metz B, et al. (Cambridge Univ Press, Cambridge, UK); Szulczewski ML, et al. (2012) Proc Natl Acad Sci USA 109:5185-5189]. We argue here that there is a high probability that earthquakes will be triggered by injection of large volumes of CO₂ into the brittle rocks commonly found in continental interiors. Because even small- to moderate-sized earthquakes threaten the seal integrity of CO₂ repositories, in this context, large-scale CCS is a risky, and likely unsuccessful, strategy for significantly reducing greenhouse gas emissions.

carbon sequestration | climate change | triggered earthquakes

The combustion of coal for electrical power generation in the United States generates approximately 2.1 billion metric tons of CO₂ per year, ~36% of all US emissions. In 2011, China generated more than three times that of CO₂, being noted for recorded intraplate earthquakes in south and east Asia (4). The seismicity catalogs are complete to magnitude (M) 3. The occurrence of these earthquakes means that nearly everywhere in continental interiors a subset of the preexisting faults in the crust is potentially critically stressed. In March, where the largest earthquake was M 4.7. In the Trinidad/Raton area near the border of Colorado and New Mexico, injection of produced water associated with coalbed methane production seems to have triggered a number of earthquakes, including M 5.1.
The Critically-Stressed Crust
Sleipner Field

- 1996 to present
- 1 Mt CO₂ injection/yr
- Seismic monitoring

27 Billion Barrels/Year

1 GT C/y wedges

Pacala and Socolow (2004)
Earthquake triggering and large-scale geologic storage of carbon dioxide

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1. Multiple lines of evidence indicate that preexisting faults found in brittle rocks almost everywhere in the earth’s crust are subject to failure, often in response to very small increases in pore pressure.

2. In light of the risk posed by even small- to moderate-sized earthquakes, potential reservoirs must be carefully chosen.

3. In addition to being well sealed by impermeable overlaying strata, they should also be weakly cemented (so as not to fail through brittle faulting) and porous, permeable, and laterally extensive to accommodate large volumes of CO\textsubscript{2} with minimal pressure increases.

4. The issue is not whether CO\textsubscript{2} can be safely stored at a given site; the issue is whether the capacity exists for sufficient volumes of CO\textsubscript{2} to be stored geologically for it to have the desired beneficial effect on climate change.

5. In this context, it must be recognized that large-scale CCS will be an extremely expensive and risky strategy for achieving significant reductions in greenhouse gas emissions.
Public Enemy Number 1
Thank You!

46th U.S. Rock Mechanics Geomechanics Symposium
Chicago    24-27 June 2012
ARMA Awards

Steve Brandon, Chair Awards Committee
VP, Lachel & Associates