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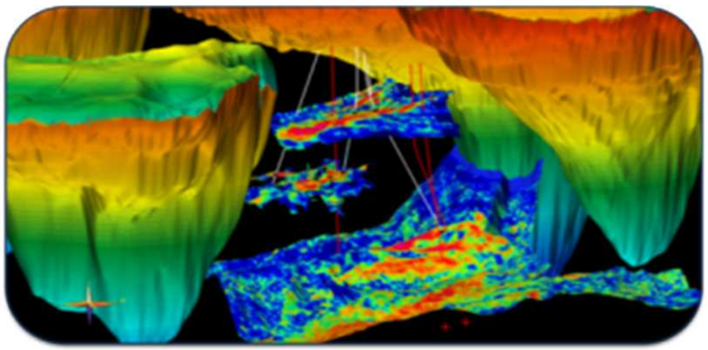

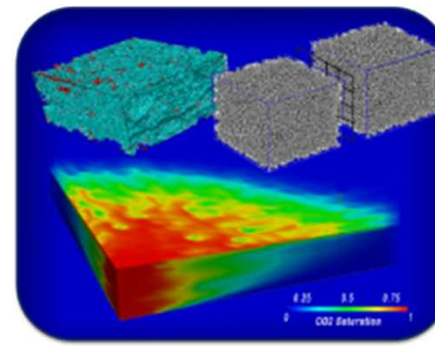

DOE Subsurface Technology and Engineering RD&D (SubTER) Overview

Marianne C. Walck, Ph.D.
Director, Geoscience, Climate and Consequence Effects Center

November 12, 2014

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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DOE has created a crosscutting Subsurface Tech Team

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SUBSURFACE TECH TEAM

Energy sources originating from beneath the Earth's surface satisfy over 80% of total U.S. energy needs. Finding and effectively exploiting these resources while mitigating impacts of their use constitute major technical and socio-political challenges and opportunities.

Next generation advances in subsurface technologies will enable increases in domestic natural gas supplies, as well as more than 100 gigawatts equivalent (GWe) of clean, renewable geothermal energy.

BENEFITS

The subsurface provides hundreds of years of safe storage capacity for carbon dioxide (CO2), and opportunities for environmentally responsible management and disposal of hazardous materials and other energy waste streams. The subsurface can also serve as a reservoir for energy storage for power produced from intermittent generation sources.

These opportunities have immediate connection to societal needs and administration priorities. Clean energy deployment and CO2 storage are critical components of the President's Climate Action Plan, necessary to meet the 2050 greenhouse gas (GHG) emissions reduction target. Increasing domestic energy supply from greater hydrocarbon resource recovery, in a sustainable and environmentally sound manner, are also Administration goals that enhance national security and fuel economic growth.

LEARN MORE

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CONTACT US

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Washington, DC 20585
Subsurface@hq.doe.gov

U.S. DEPARTMENT OF ENERGY

Careers & Internships | Contact Us

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Common Subsurface Energy Challenges

Sandia National Laboratories

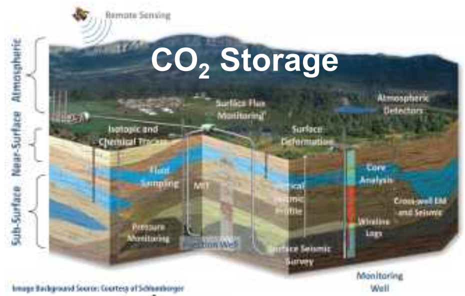
Discovering, Characterizing, and Predicting
Efficiently and accurately locate target geophysical and geochemical responses, finding more viable and low-risk resources, and quantitatively infer their evolution under future engineered conditions

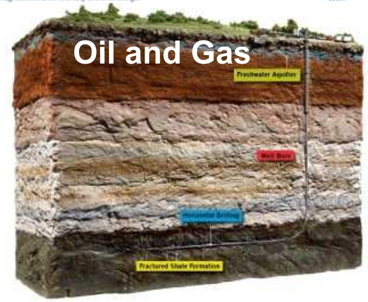
Accessing
Safe and cost-effective drilling, with reservoir integrity

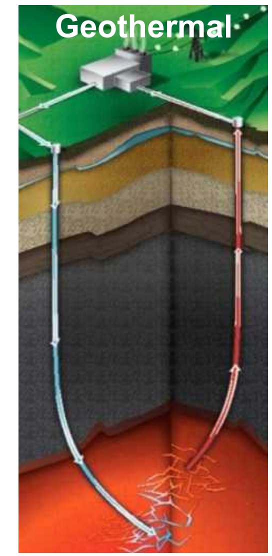
Engineering
Create/construct desired subsurface conditions in challenging high-pressure/high-temperature environments

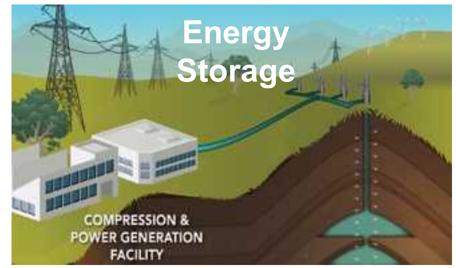
Sustaining
Maintain optimal subsurface conditions over multi-decadal or longer time frames through complex system evolution

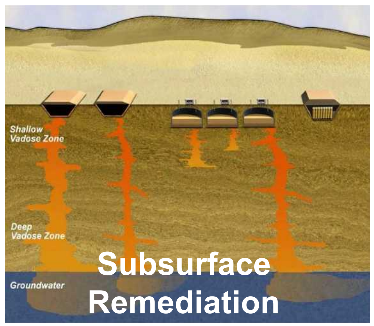
Monitoring
Improve observational methods and advance understanding of multi-scale complexities through system lifetimes

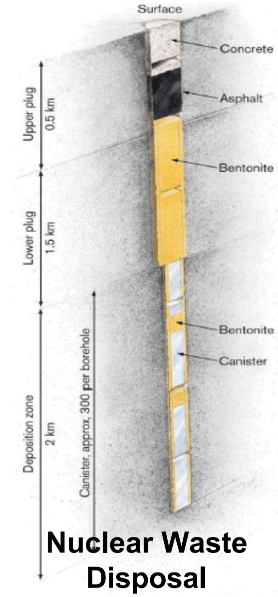












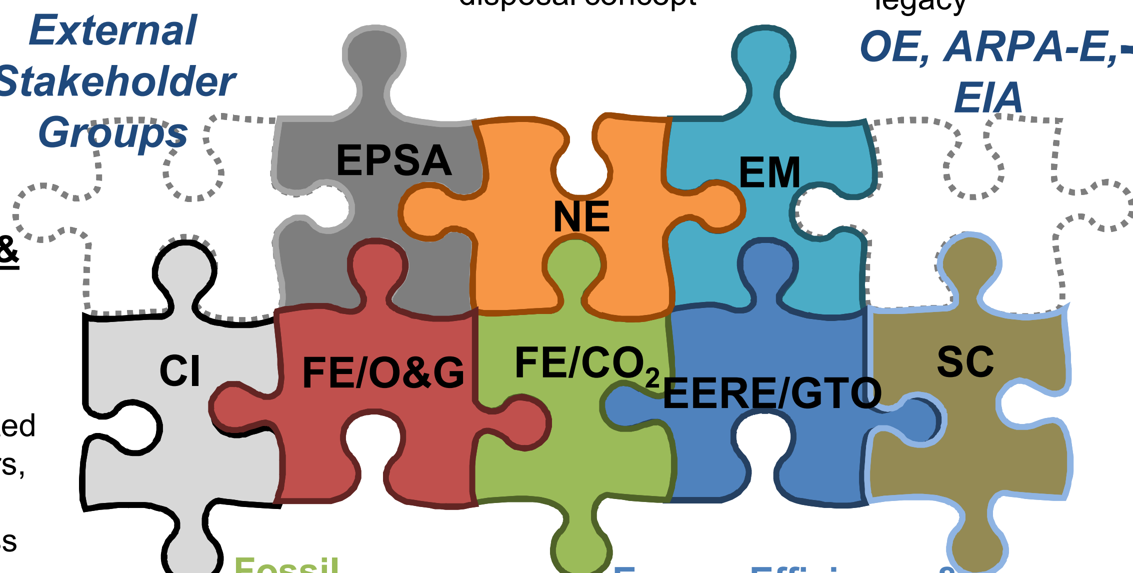
Overview of Program Roles

Sandia National Laboratories

Energy Policy & Systems Analysis
- Advisement: Secretary of Energy
- Policy: low-carbon and secure energy economy
- Technical assistance: States and local entities

Nuclear Energy
- Policy and technology: disposition of used nuclear fuel and waste
- R&D: deep borehole disposal concept

Environmental Management
- Modeling and tools: subsurface evaluation and characterization
- Cleanup: nuclear weapons legacy



SubTER Tech Team
- Encompasses relevant offices
- Reports to Under Secretary for Energy and Science
- Identifies and facilitates crosscutting subsurface R&D and policy priorities for DOE
- Develops collaborative spend plan and funding scenarios

Congressional & Inter-governmental Affairs
- Interactions: elected officials, regulators, and stakeholders
- Information access for change agents

Fossil Energy/Oil & Gas
- R&D and access: clean, affordable traditional fuel sources
- R&D: drilling, well construction and integrity, and hydraulic fracturing technologies

Fossil Energy/Carbon Storage
- Policy and technology: challenges of CO_2 storage to inform regulators, industry, and the public
- R&D: CO_2 offshore and onshore storage

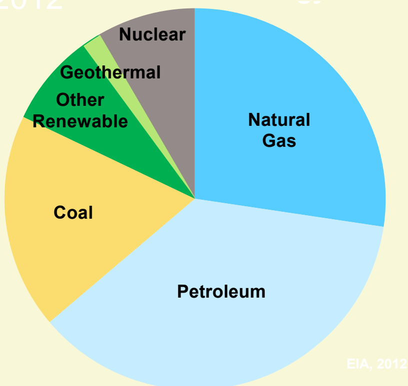
Energy Efficiency & Renewable Energy/ Geothermal Technologies Office
- R&D: locate, access, and develop geothermal resources
- R&D: access, create, and sustain enhanced geothermal systems (EGS)

Science
- Basic research: geology, geophysics, and biogeochemistry
- Expertise: subsurface chemistry, complex fluid flow

The National Labs Subsurface Big Idea – March, 2014: Adaptive Control of Subsurface Fractures and Flow

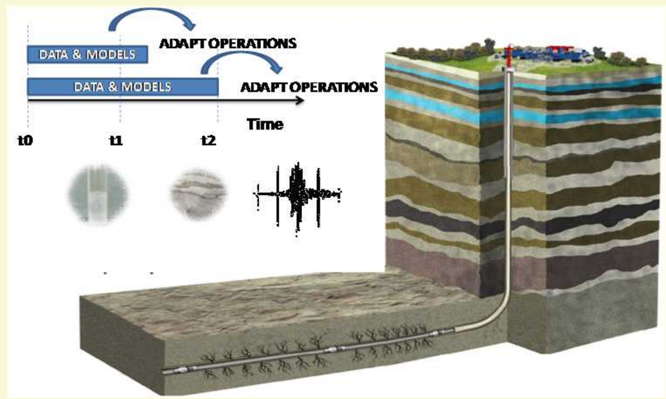
Sandia National Laboratories

FRACTURE CONTROL IS CRITICAL FOR MANY SUBSURFACE ENERGY STRATEGIES
shale hydrocarbon, geologic carbon sequestration, enhanced geothermal energy, nuclear waste disposal, compressed air energy storage



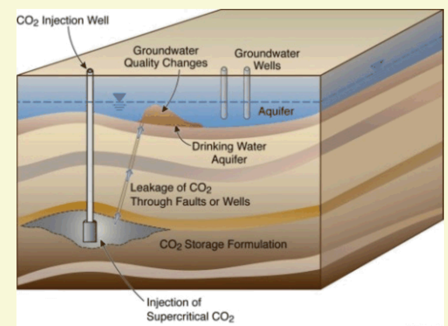
The subsurface supplies >80% of US Energy

Shale Hydrocarbon Production



Control fracture length & branching patterns, and flow

Safe Subsurface Storage of CO_2



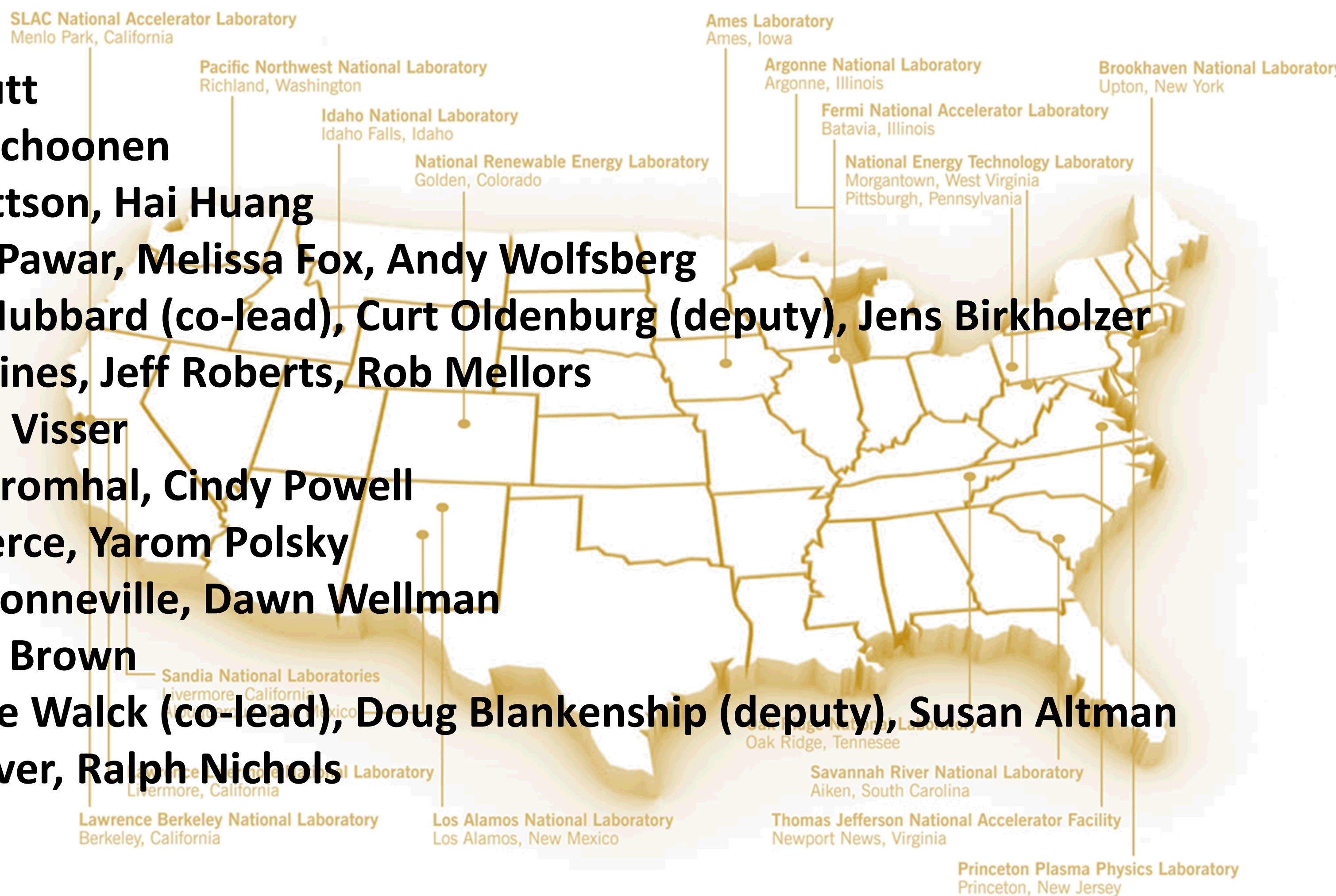
Enhance injectivity, optimize storage, plug leakage pathways

Anticipated Outcomes:

- Doubling of recovery efficiency from tight hydrocarbon reservoirs
- Order-of-magnitude increase in geothermal production
- Technical basis for safe and secure carbon sequestration and geologic nuclear waste disposal
- Increased public confidence
- Sustained U.S. leadership in subsurface technologies

Subsurface Working Team: 13 Laboratories

ANL: Mark Nutt
BNL: Martin Schoonen
INL: Earl Mattson, Hai Huang
LANL: Rajesh Pawar, Melissa Fox, Andy Wolfsberg
LBNL: Susan Hubbard (co-lead), Curt Oldenburg (deputy), Jens Birkholzer
LLNL: Roger Aines, Jeff Roberts, Rob Mellors
NREL: Charles Visser
NETL: Grant Bromhal, Cindy Powell
ORNL: Eric Pierce, Yarom Polsky
PNNL: Alain Bonneville, Dawn Wellman
SLAC: Gordon Brown
SNL: Marianne Walck (co-lead), Doug Blankenship (deputy), Susan Altman
SRNL: Lisa Oliver, Ralph Nichols



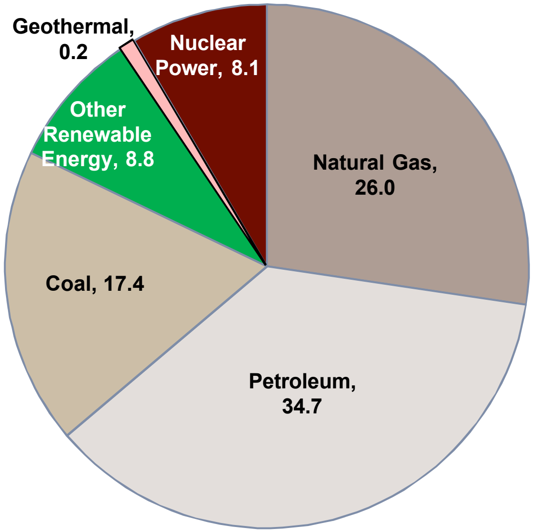
Subsurface Control for a Safe and Effective Energy Future

Sandia National Laboratories

Adaptive Control of Subsurface Fractures and Fluid Flow

Intelligent Wellbore Systems	Subsurface Stress & Induced Seismicity	Permeability Manipulation	New Subsurface Signals

Energy Field Observatories



Primary Energy Use by Source, 2012 Quadrillion Btu [Total U.S. = 95.1 Quadrillion Btu]

Energy Production

- Increase U.S. electrical production from geothermal reservoirs
- Increase U.S. unconventional oil and natural gas for multiple uses

Economic & Social Benefits

- Retain U.S. leadership
- Increased public confidence
- Increase revenues (taxes and royalty) to Federal, State, and local governments

Protect the Environment

- President's Climate Action Plan: Safely store CO_2 to meet GHG emissions reduction targets
- Safe storage/disposal of nuclear waste
- Reduced risk of induced seismicity
- Protect drinking water resources

Energy Security

- Increased recovery factors from tight formations can vastly increase the longevity of US energy security

Subsurface Control for a Safe and Effective Energy Future

Adaptive Control of Subsurface Fractures and Fluid Flow

Intelligent Wellbore Systems	Subsurface Stress & Induced Seismicity	Permeability Manipulation	New Subsurface Signals
Materials: adaptive cements, muds, casing	Stress state beyond the borehole	Physicochemical rock physics, including fluid-rock interactions	Diagnostic signatures of system behavior and critical thresholds
Real time, in-situ data acquisition and transmission system	Signal acquisition and processing and inversion	New approaches to remotely characterize in-situ fractures and to monitor fracture initiation/branching and fluid flow	Autonomous acquisition, processing and assimilation approaches
Diagnostics tools, remediation tools and techniques	Localized manipulation of subsurface stress	Manipulating (enhancing, reducing and eliminating) flow paths	Integration of different measurements collected over different scales to quantify critical parameters and improve spatial and temporal resolutions
Quantification of material/seal fatigue and failure	Risk assessment	Novel stimulation methods	
Advanced drilling and completion tools (e.g., anticipative drilling & centralizers)			
Well abandonment analysis/R&D			

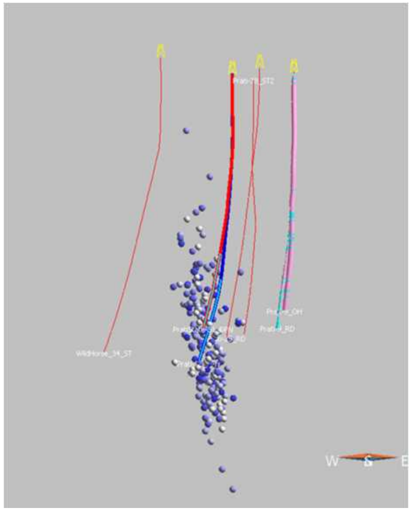
Energy Field Observatories (Wells, Ops and Logistics)

Fit For Purpose Simulation Capabilities

What Is Unique About the SubTER Proposal?

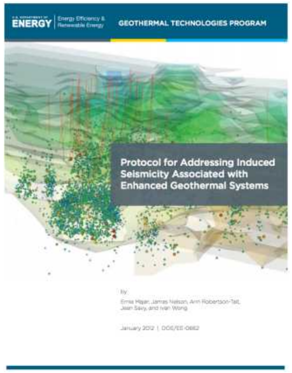
- Facilitates innovation to address **climate change** and reduce greenhouse gas emissions
  - Safe storage of CO_2
  - Increased deployment of renewable energy (geothermal)
  - Reduction of fugitive methane emissions through improved wellbore technologies, etc.
- Addresses challenges and opportunities with **water** management
- Drives innovation to improve **safety** associated with subsurface energy operations
- Advances new concepts for safe and responsible disposal of **nuclear waste**
- Increased recovery factors from tight formations can vastly increase the longevity of US **energy security**
- Implementation of a **new collaborative model** to tackle an energy “grand challenge” faced by multiple sectors

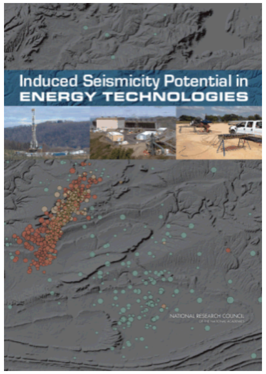
Criticality of Core Themes
Subsurface Stress and Induced Seismicity



Induced Seismicity at The Geysers Geothermal Field (Calpine)

Approach to Date: Geothermal sector has proactively developed its own induced seismicity management protocol. CO_2 storage developing new risk assessment tools through NRAP.





Increasing societal relevance of induced seismicity as EGS deployment and CO_2 storage grow, akin to oil and gas today

***Subsurface Stress and Induced Seismicity Program*:**

- Improved stress measurements
- Broader data acquisition and sharing
- Advanced risk assessment tools

Permeability Manipulation and ***New Subsurface Signals*** are also critical components of overall effective reservoir management that are essential for scaling up EGS and CO_2 storage safely and effectively

Outcomes:

- Improved understanding of the subsurface
- Mitigation and reduced risk
- Safe scale up
- Improved resource identification and development

Criticality of Core Themes
Wellbore Integrity

Sandia National Laboratories

New Study Published in the Proceedings of the National Academy of Science Highlights Wellbore Integrity as a Critical Issue

--Darrah et al. PNAS- *September 15, 2014*

Deep borehole disposal provides an alternative approach.

*"We document fugitive gases in eight clusters of domestic water wells overlying the Marcellus and Barnett Shales, including declining water quality through time over the Barnett. Gas geochemistry **data implicate leaks through annulus cement** (four cases), **production casings** (three cases), and **underground well failure** (one case) rather than gas migration induced by hydraulic fracturing deep underground."*

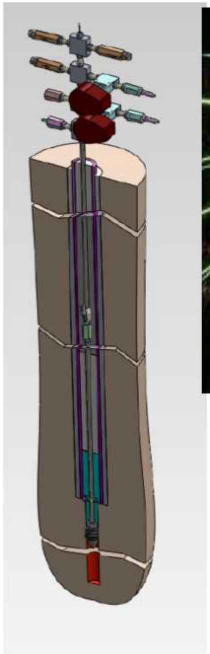
Quarrels Continue Over Repository for Nuclear Waste –New York Times, June 27, 2013

Approach: New Ways to Control Permeability and Flow

Precise control over fracturing and fluid flow is critical for efficient extraction of energy resources, as well as for containment of CO_2 and waste streams.

Approach to Date:

- Geometry-based approaches
- Chemical manipulation
- Incomplete physical treatment in models



Gas phase bi-propellant energetic stimulation design (Sandia National Laboratories)

SubTER Permeability Manipulation Objectives:

- Novel stimulation techniques (e.g., water-free energetics, shape-memory alloys)
- Advances in reservoir and seal performance mechanisms for contaminant flow and trapping
- In-situ, real time imaging, modeling, and analysis of flow

Outcomes:

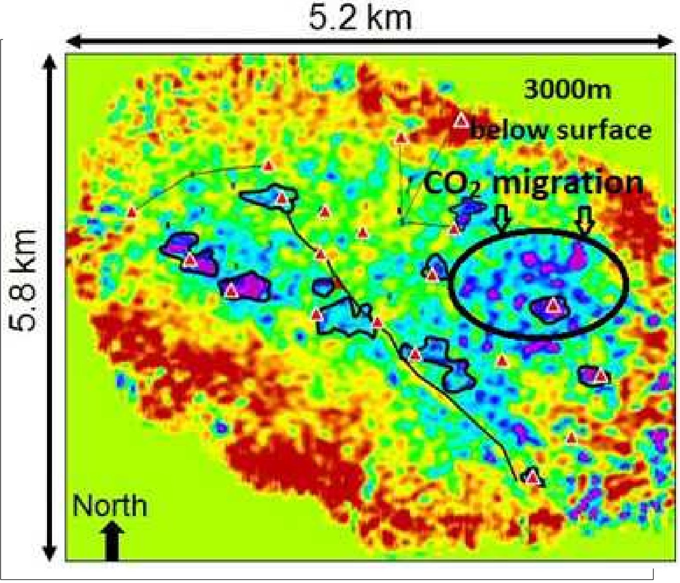
- Improved control over fluid migration and reservoir integrity
- Mitigation and reduced risk
- Safe scale up of EGS, carbon storage, and high-level waste disposal

Approach: New Ways to Acquire and Integrate Subsurface Signals

High fidelity characterization of subsurface environments is critical to successful subsurface engineering efforts.

Approach to Date:

- Seismic, electromagnetic, and gravity methods from the surface and the wellbore.



High resolution inverted seismic images of CO_2 migration at the Cranfield injection site

***SubTER Subsurface Signals Objectives*:**

- R&D on small-scale deployable sensors
- Autonomous acquisition, processing and assimilation
- Identification of critical system transitions

Outcomes:

- New ways to "see" subsurface fractures and fluid pathways.
- Acquisition of data necessary for adaptive control of subsurface fractures and fluid flow.

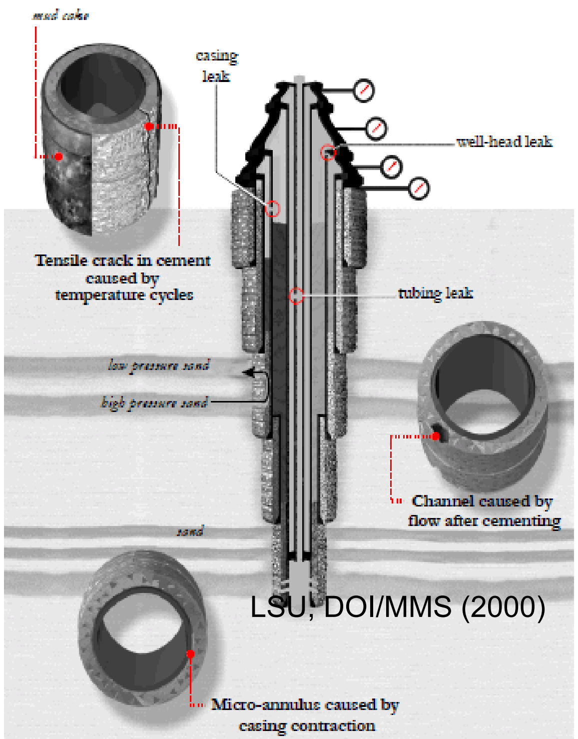
Approach: Intelligent Wellbore Systems R&D

Sandia National Laboratories

Intelligent Wellbores: Self-healing cements and integrated-casing monitoring systems for enhanced wellbore performance assurance

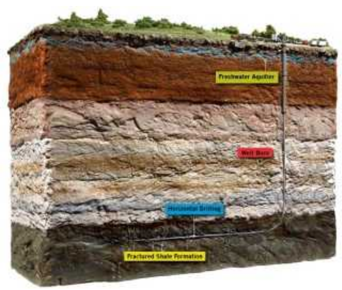
wide band gap semiconductors + advanced manufacturing + HT electronics and sensors + materials science
industry + national labs + academia

Casing/cement failure modes

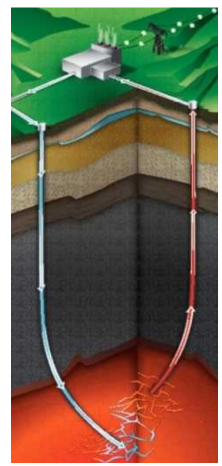


LSU, DOI/MMS (2000)

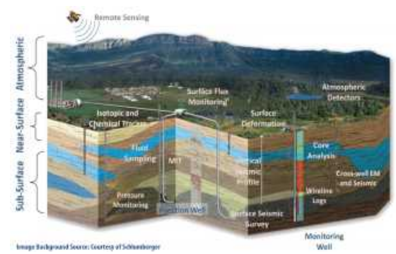
multi-decadal — REQUIRED LIFETIME → millennial



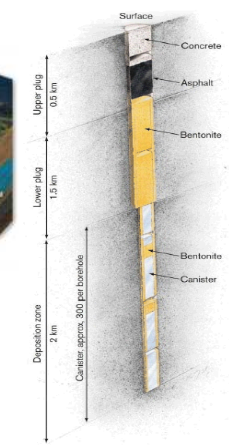
Oil and Gas



Geothermal



CO_2 Storage



Nuclear Waste Deep-Borehole Disposal

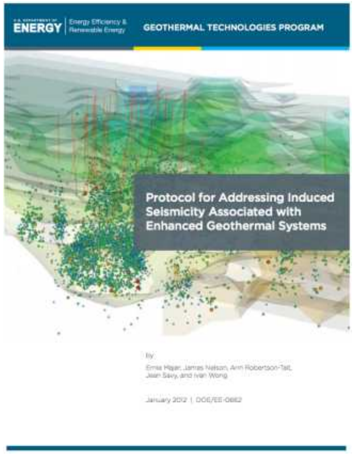
Class VI permit process, used-fuel disposition regulatory framework,…

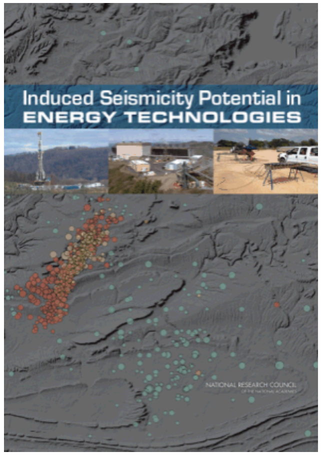
Approach: “Virtual” Field Observatory

Increasing societal relevance of induced seismicity as wastewater injection associated with natural gas extraction continues to expand and as EGS deployment grows.

Approach to Date:

- Induced seismicity management protocol





***SubTER Subsurface Stress and Induced Seismicity Program*:**

- Improved stress measurements
- Broader data acquisition and sharing
- Advanced risk assessment tools

Permeability Manipulation and New Subsurface Signals are also critical components of overall effective reservoir management that are essential for ensuring safe and effective subsurface operations.

Outcomes:

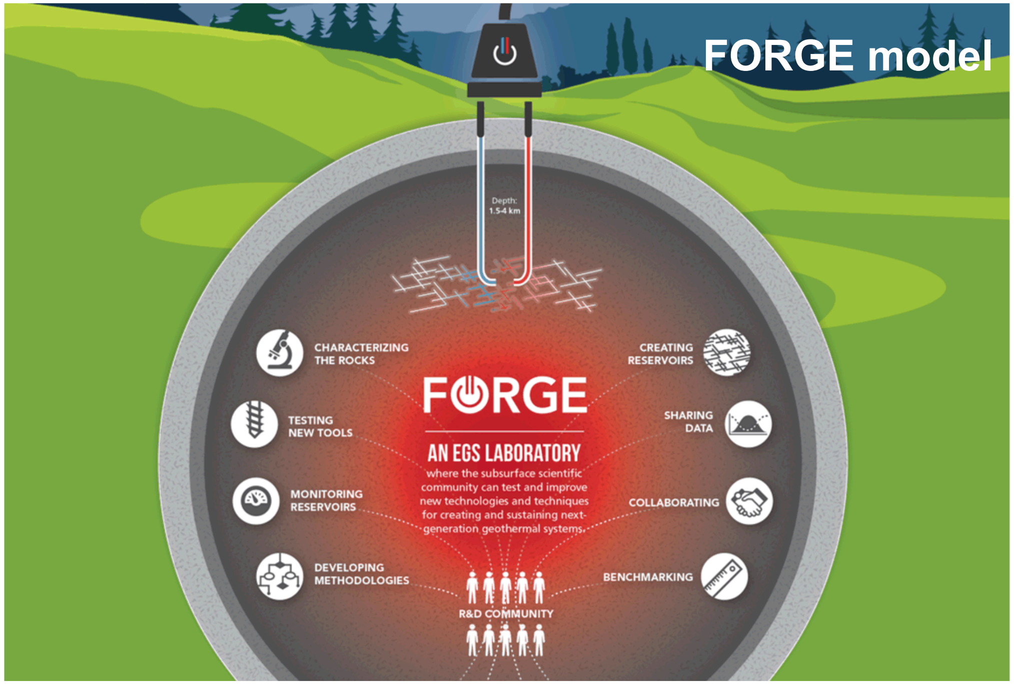
- Improved understanding of the subsurface
- Mitigation and reduced risk
- Safe scale up of EGS and carbon storage
- Improved resource identification and development

Approach: Field Observatories are Critically Important to SubTER Efforts

Sandia National Laboratories

Required for fundamental subsurface progress:

- Validation through monitoring/production
- Site-specific conditions
- Strong industry engagement
- Multiple business models:
    - Fit-for-purpose, dedicated site (FORGE, RMOTC)
    - Isolated, targeted effort (Frio CCS pilot)
    - Opportunistic (Weyburn)
- Expensive: individual sites = $10-35M/year commitment

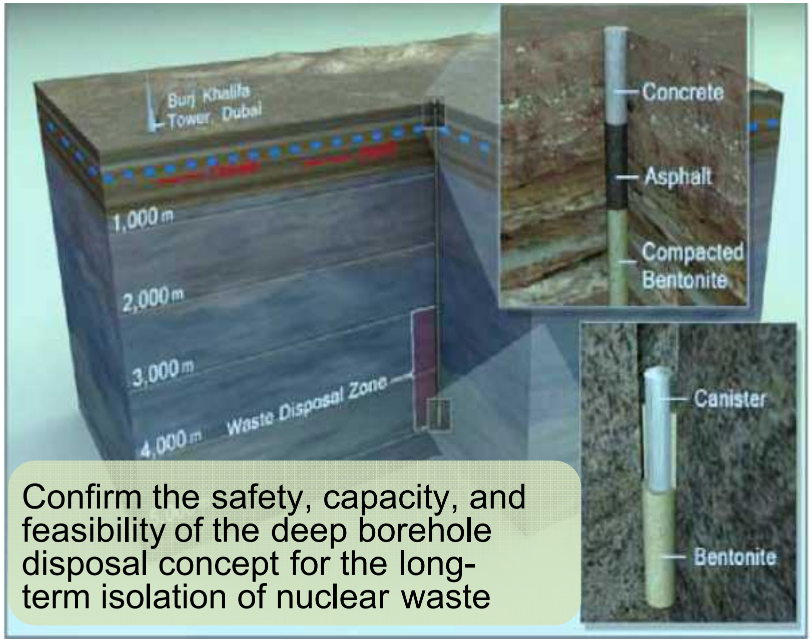


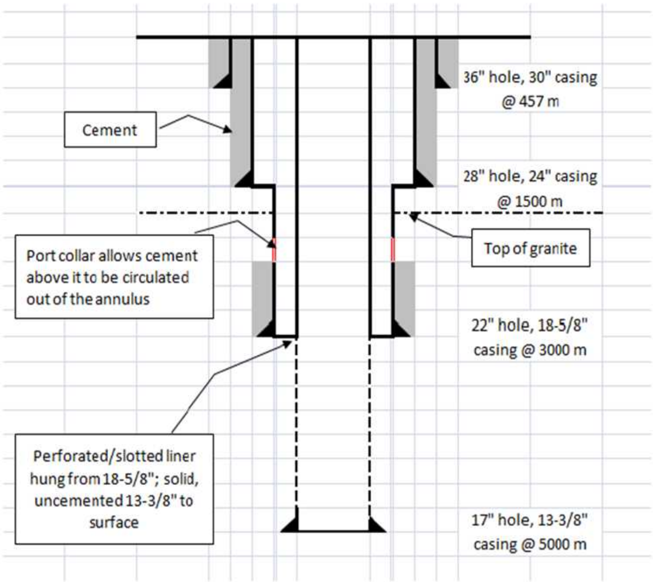
Phase 1	Phase 2	Phase 3	
$2 M	$29 M		
Site Selection	*Site preparation & characterization*	*R&D testing, monitoring, innovative drilling, advanced stimulation, sustainability testing*	*Decommission/ Transfer site*
PHASE 1	**PHASE 2**	**PHASE 3**	**Closeout**

Validation of new results and approaches at commercial scale;
Road-test monitoring, stimulation, and permeability- and flow-control tools

Approach: Deep Borehole Field Test

- Demonstrate the feasibility of characterizing and engineering deep boreholes (no actual waste disposal)
- Demonstrate safe processes and operations for safe waste emplacement downhole





***Crosscut Benefit*:** Drilling technology, well construction and integrity, and subsurface characterization.

Clear Alignment with Industry and Stakeholder Priorities

Sandia National Laboratories

HALLIBURTON

- Nanotechnology
- Photonics
- ***Interfacial Chemistry***
- ***Complex Fracture Modeling in Real-time***
- Spectroscopy at the Bit
- Green Chemistry

Society of Petroleum Engineers

JPT

- ***Higher Resolution Subsurface Imaging***
- Challenges in Reusing Produced Water
- ***In-Situ Molecular Manipulation***
- Increasing Hydrocarbon Recovery Factors
- ***Carbon Capture and Sequestration***

the Bernard M. Gordon Center for Subsurface Sensing & Imaging Systems

- ***Subsurface Sensing and Imaging***
- ***Physics-Based Signal Processing and Image Understanding***

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

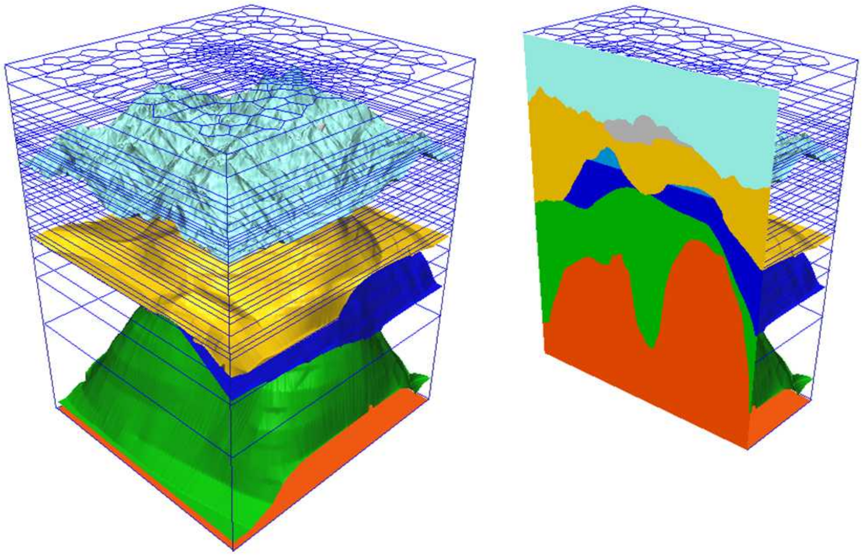
Grand Challenges for Earth Resources Engineering

- ***Make the earth transparent***
- ***Understand engineering control of coupled subsurface processes***
- ***Minimize environmental footprint***
- ***Protect people***

USGS science for a changing world

- Recognizing the signal within the natural variability
- ***Identifying feedback between natural and perturbed systems***
- Quantifying consequences, impacts, and effects
- ***Effectively communicating uncertainty and relative risk***

Moving Forward



Stakeholder engagements (DOE/Labs)

- NAS/NRC COGGE Capability Presentation: April 29, 2014; NAS/NRC meeting October 23, 2014
- JASON kickoff: June 20, 2014 – JASON report now available online: funding from 7 DOE Offices
- USEA: July 22, 2014, October 30, 2014
- Shell Rock and Fluid Physics Conference (Amsterdam): September
- QTR engagement – assistance to DOE (ongoing)

Upcoming events

- AGU: Town Hall (December 15), special sessions
- Lab Workshop: November 18-19
- Industry engagement – workshop planned for Spring 2015

DOE: 6 small FY14 projects initiated

Seed funding to these projects will kick-start efforts in FY15, FY16 and beyond . . .

Summary and Vision

- **The need for dramatic improvements in subsurface capabilities is both well documented and urgent.**
  - Improved recovery factors, CO_2 and energy storage, disposal
  - Subsurface characterization, high resolution imaging, manipulation and management of all subsurface activities
  - Safety, reliability, mitigation of environmental effects, and significant policy impacts
- **The DOE Program Offices have worked together and with the National Labs since mid 2013 to identify key approaches and tasks (4 pillars).**
  - Actively engaging external stakeholders, including USGS, NSF, industry, additional sectors: RFI, consultations, Jason's study, facilitated meetings
- **Field Observatories play an important role in validation of new technologies and approaches.**