

Well Construction and Reservoir Research Efforts of the United States Department of Energy National Laboratories



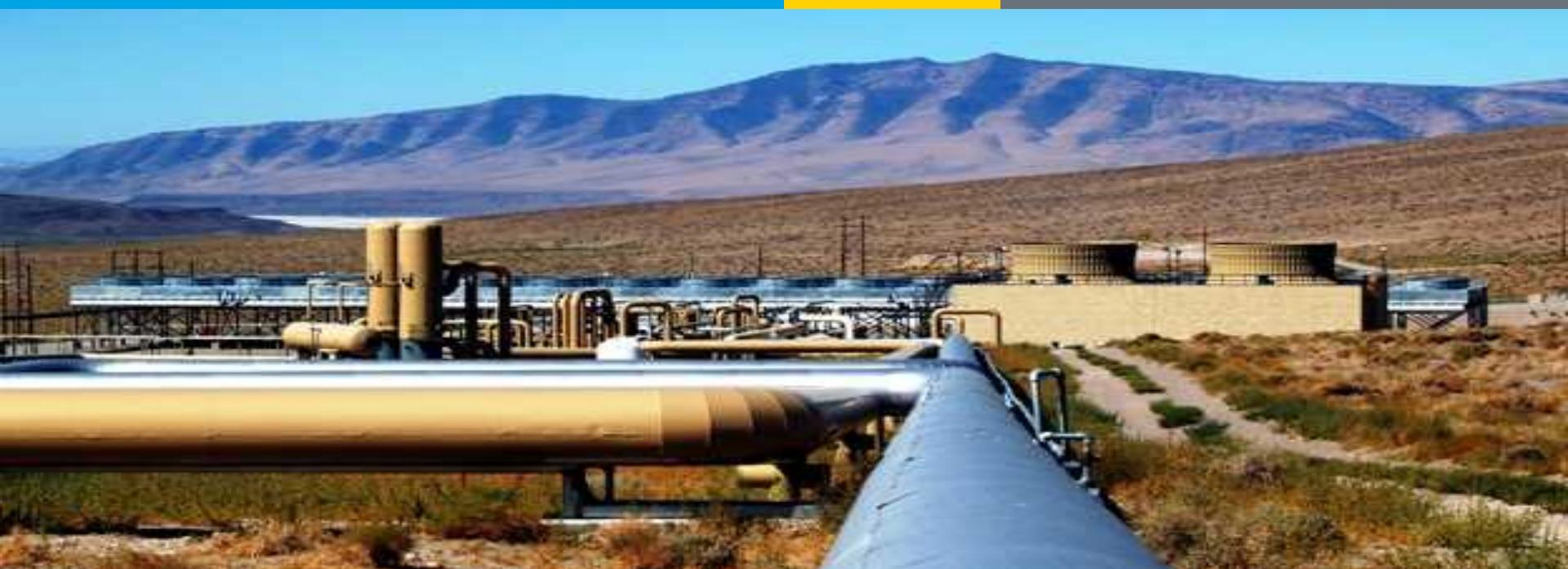
U.S.-Africa Geothermal Partnership Kickoff Meeting

September 28, 2014

**Douglas Blankenship
Sandia National Laboratories**

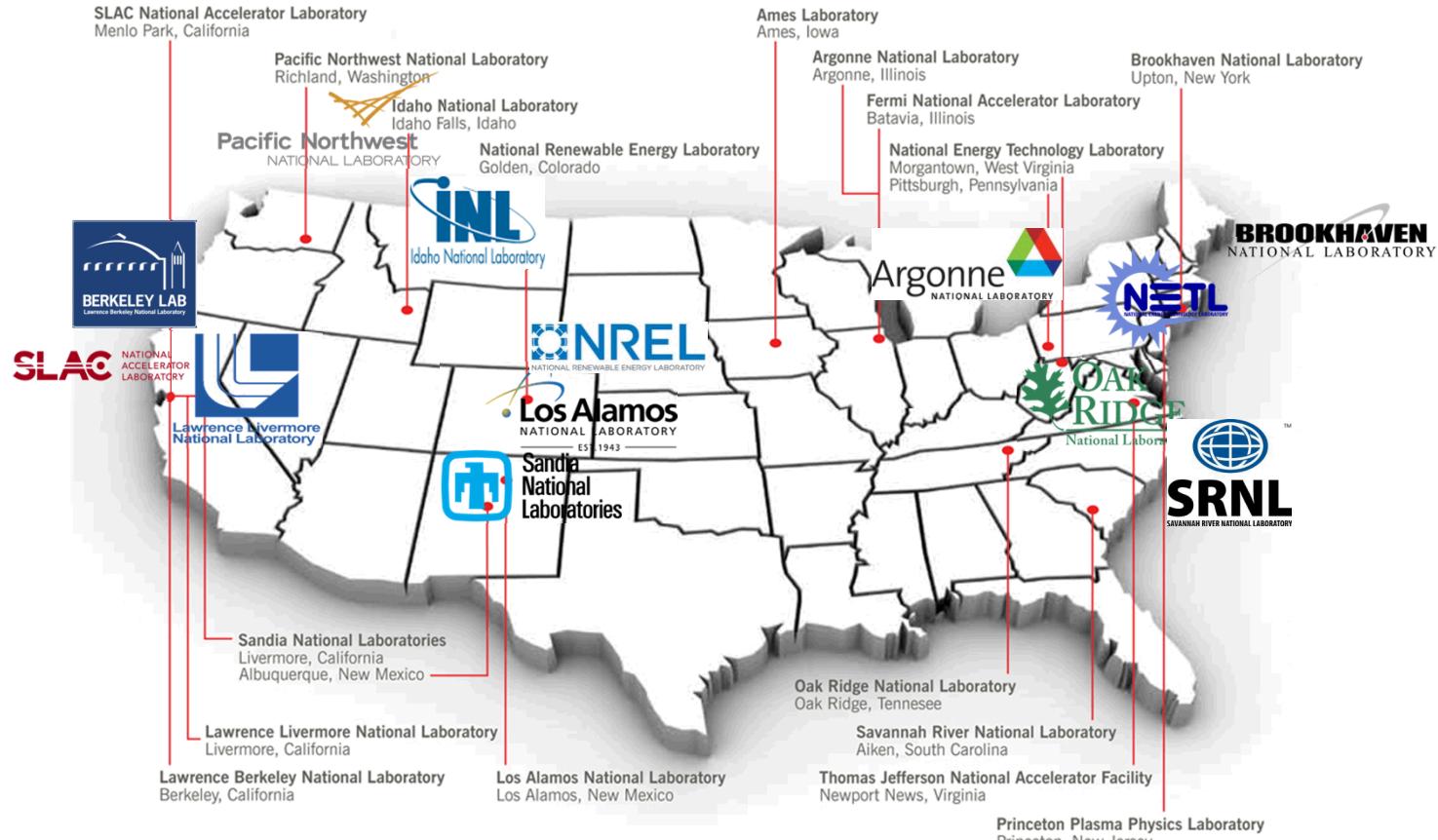


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- Provide an overview of US DOE National Laboratory capabilities related to resource development
- Broad portfolio – Description necessarily incomplete
- Examples are provided but biased by presenter's area of understanding

Department of Energy Laboratories

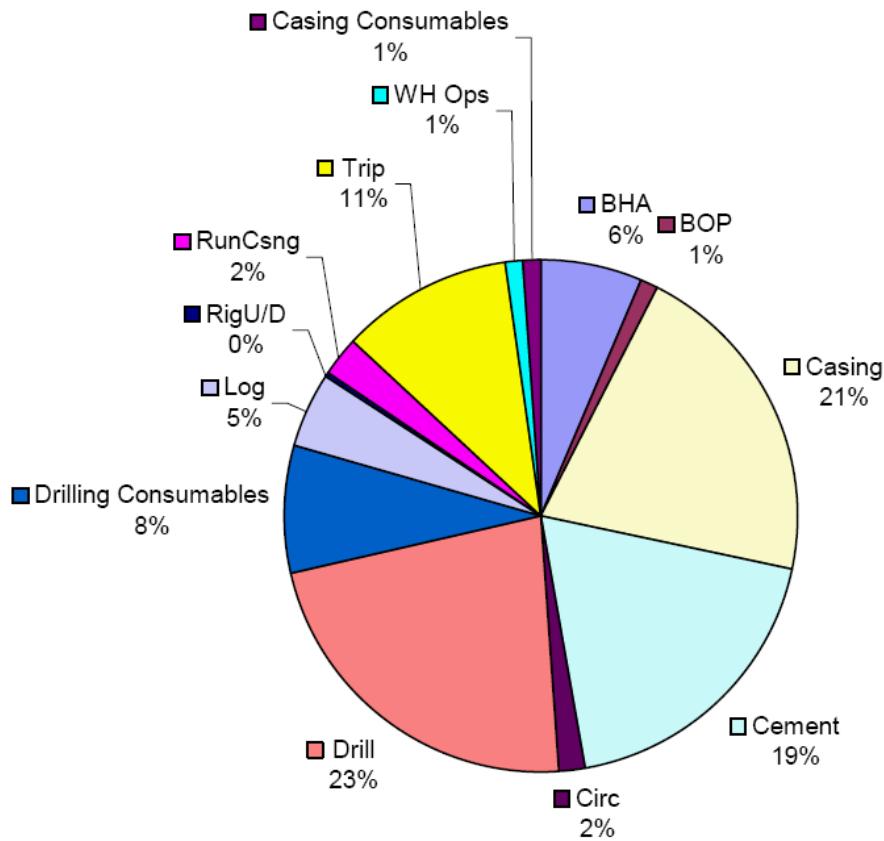


Material in this presentation contributed by many scientists across National Labs.

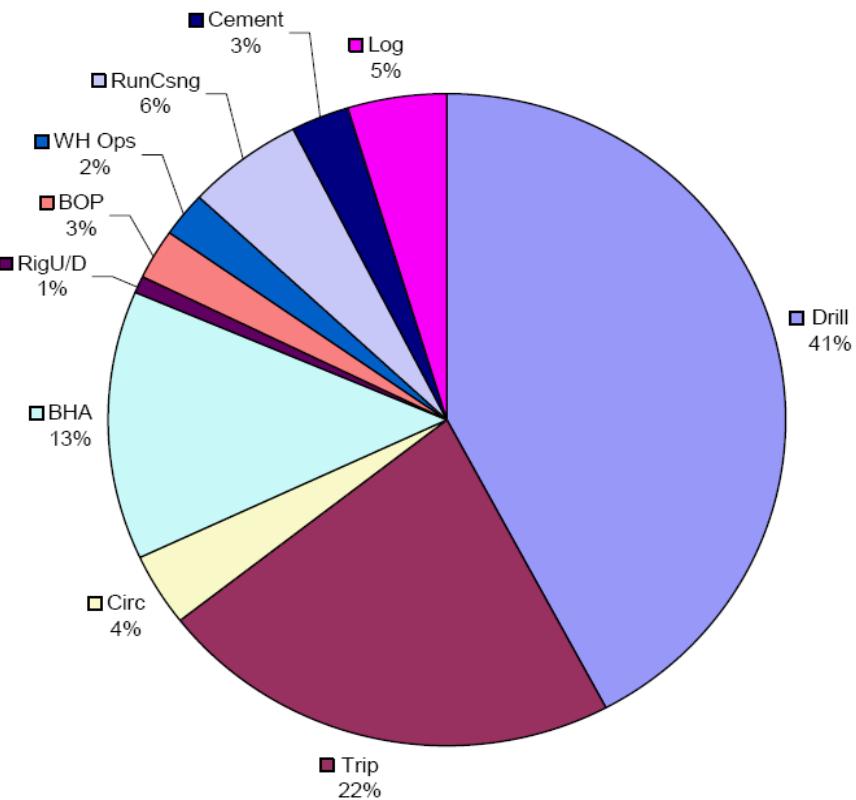
Mark Nutt (ANL); Martin Schoonen (BNL); Earl Mattson, Hai Huang (INL); Rajesh Pawar, Melissa Fox, Andy Wolfsberg (LANL); Susan Hubbard (co-lead), Curt Oldenburg (deputy), Jens Birkholzer (LBNL); Roger Aines, Jeff Roberts, Rob Mellors (LLNL); Charles Visser (NREL); George Guthrie, Grant Bromhal (NETL);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

Well Construction

Well Construction Costs



Well cost (%) breakdown by task.



Well construction task time percentages.

Well Construction Research Portfolio Intended to Address Major Cost Drivers

- Pressure/Temperature Gradient Induced Drilling
- Wear-Resistant NanoComposite Coatings
- Field Trials of Drilling Systems
- HT Auto Indexers for DTHH
- HT Downhole Motors
- Casing Material Corrosion/Erosion Studies
- Multi-Function Cement For Geothermal Wells – Self Degrading and Expandable Cements
- Temporary Sealer to Address Fluid Loss
- Geopolymer Sealing Materials
- Drilling Cost Reduction Opportunities
- Controlled Rapid Wellbore Pressurization
- Advance Bit Deployment



PDC Bit



Motor Evaluation

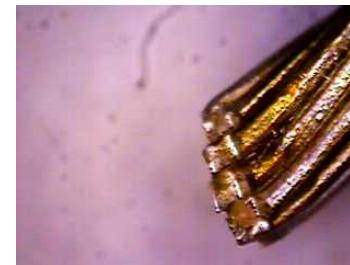


Down the Hole Hammer

- HT MWD Components
- HT Borehole Seismic Monitoring Tool
- HT Fiber Optic Data Transmission System
- Distributed Acoustic Temperature Sensing
- MCM Development for HT Accelerometer Measurements
- SiC Sensor Technologies
- HT Circuit Boards
- HT Neutron Imaging
- Acoustic Sensors for Fluid Monitoring
- Far Field Downhole EM



SEM image for $Mg(OH)_2$ crystal grown in the expanded alkali activated cement sealers



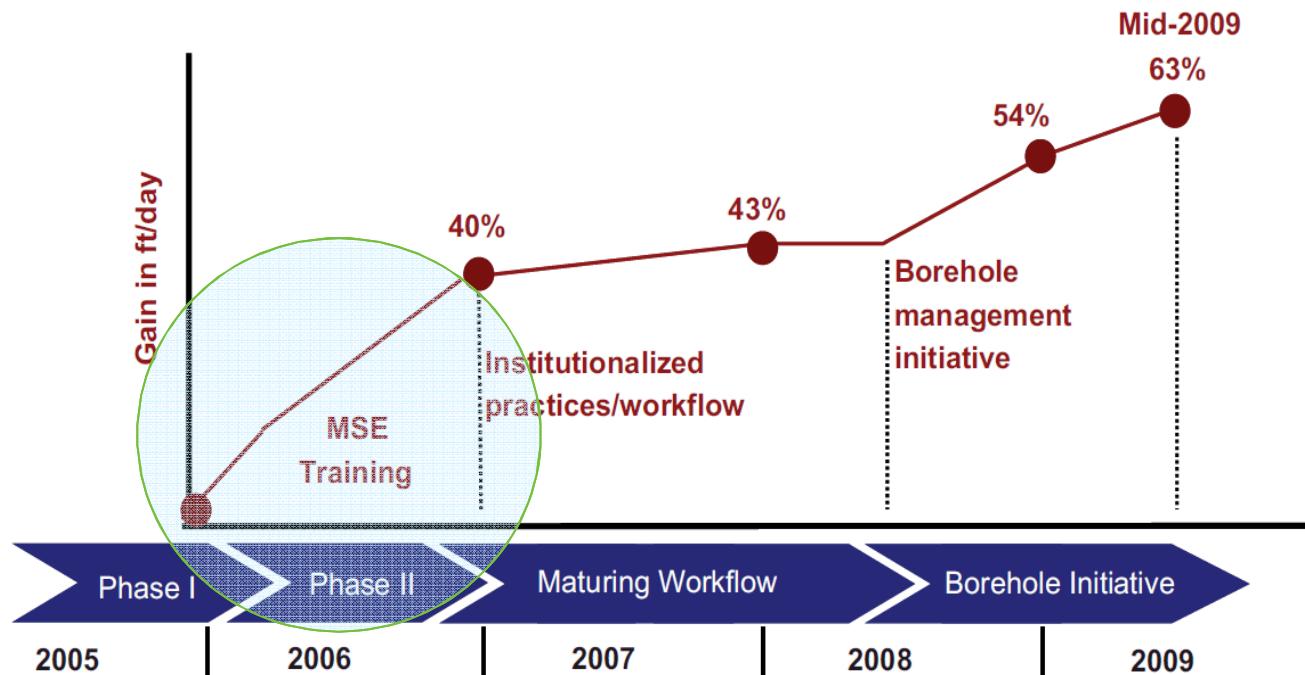
HT Solder Evaluation



HT Seismic

- Processes
 - Shell, “Drilling the Limit”
 - ExxonMobil, “FastDrill” / “Limiter Redesign”
 - 40% increase in ft/day in one year using drilling efficiency measures

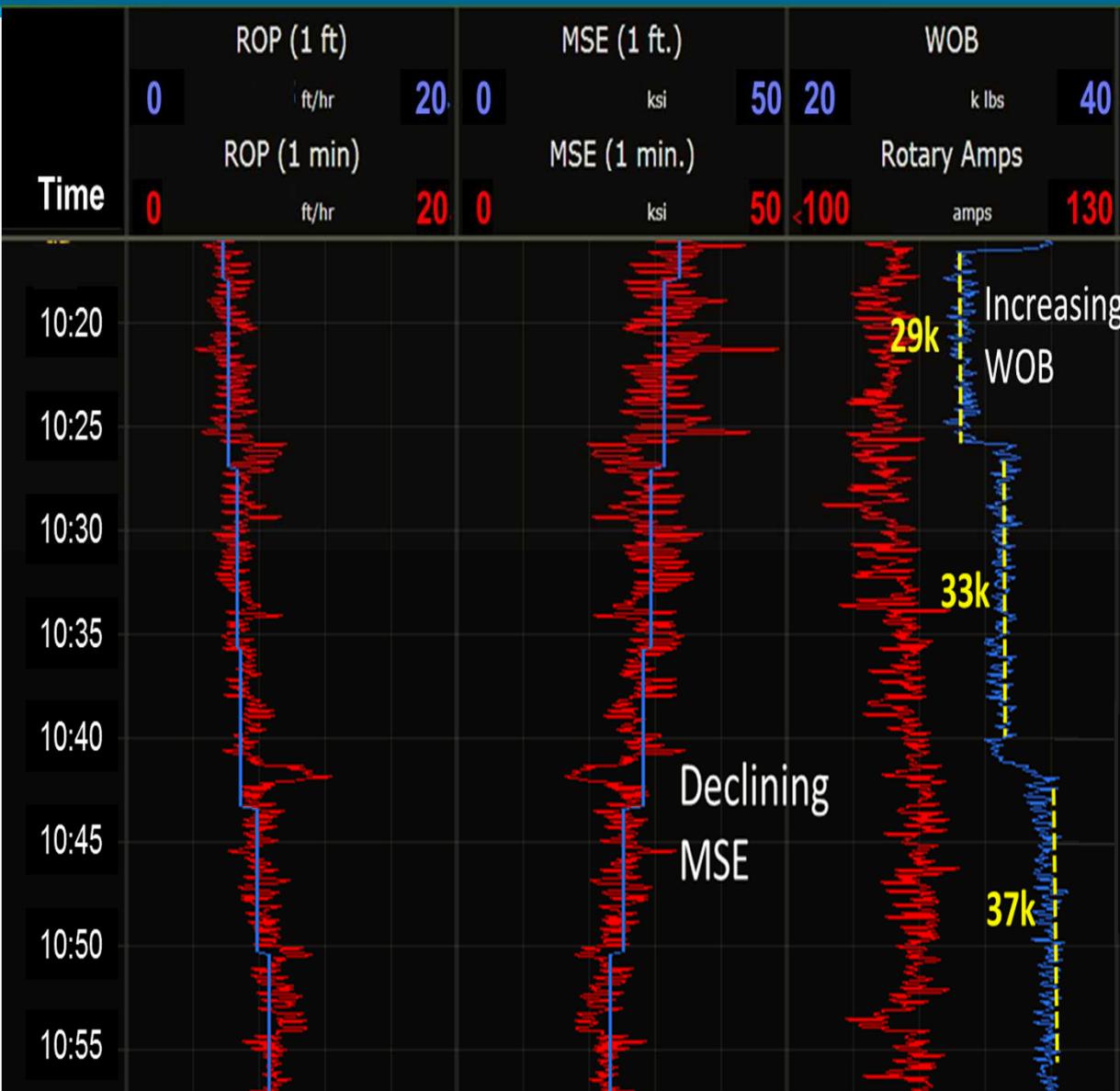
Dupriest F., et al.,
Borehole-quality design and drilling practices to maximize drill-rate performance, in SPE Annual Technical Conference and Exhibition 2011: Florence, Italy.



- Apply mature/proven rock penetration systems used in Oil & Gas/Minerals industry to improve geothermal drilling technology
- Partner with
 - Ormat Technologies
 - Navy Geothermal Program
 - Barber Drilling
 - National Oilwell Varco Reed Hycalog
 - Baker Hughes
- Doubled ROP and Reduced Costs with PDC Bits



Use Mechanical Specific Energy (MSE) to Maximize WOB – Geothermal Example



- **WOB step tests show declining MSE (reduce whirl).**
- **Workflow to maximize performance is to raise the WOB in steps:**
- **If MSE declines, continue raising WOB**
- **If MSE increases, stop and go the other way**
- **Run inclination survey at normal intervals, or when new WOB exceeds prior experience**

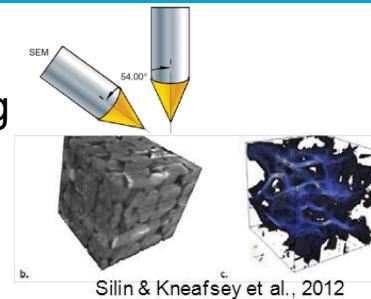
Reservoir Capabilities

Capabilities related to Exploration and Production PETROPHYSICS

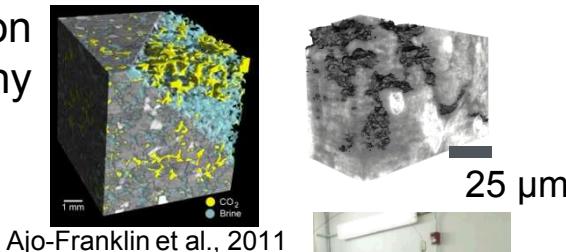
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Energy Efficiency &
Renewable Energy

FIB/SEM imaging



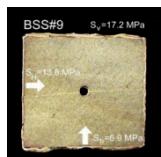
Synchrotron microtomography



Neutron diffraction- based strain (Polsky, 2013)

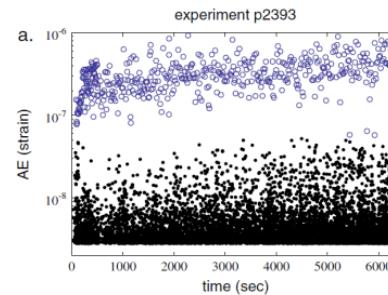
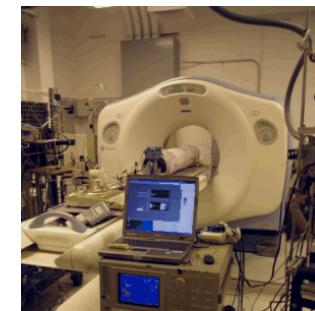


Triaxial lab experiments and associated measurements



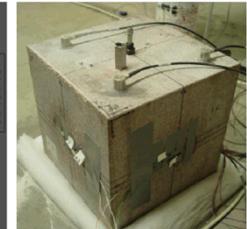
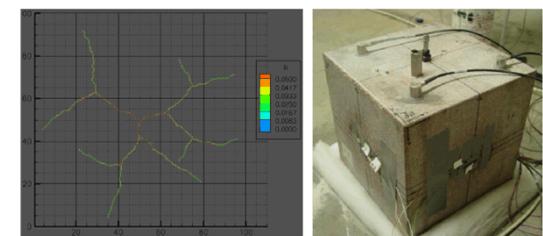
- Investigate heterogeneous rock responses to stress across scales
- Quantify stress/material property relationships and resulting effects on reservoir performance
- Improve interpretation of subsurface responses

Medical CT Scanners



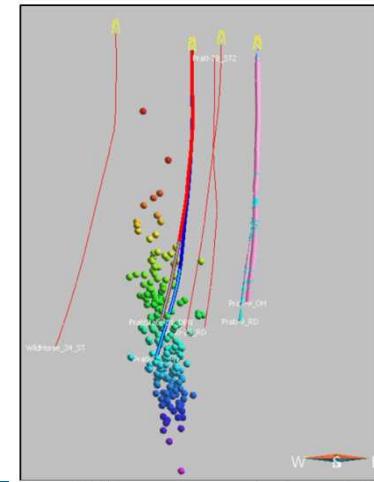
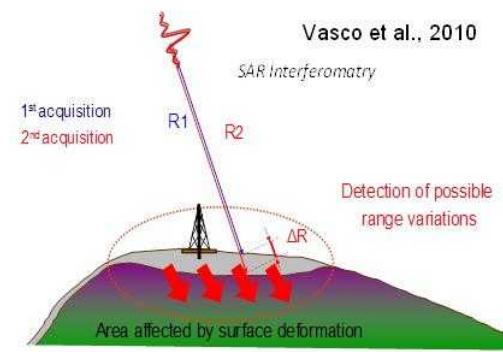
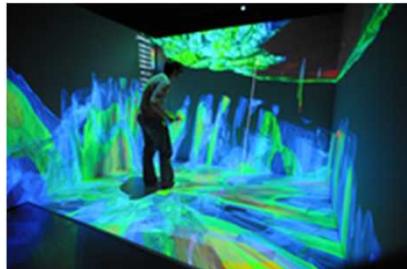
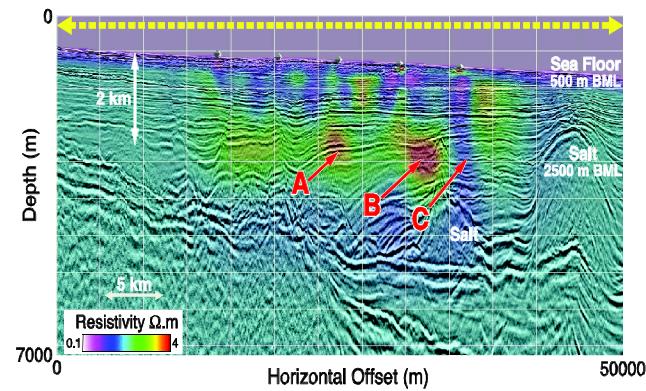
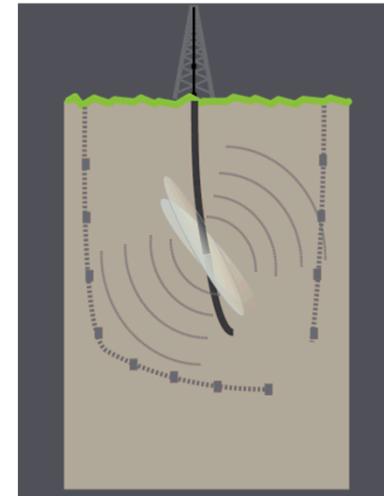
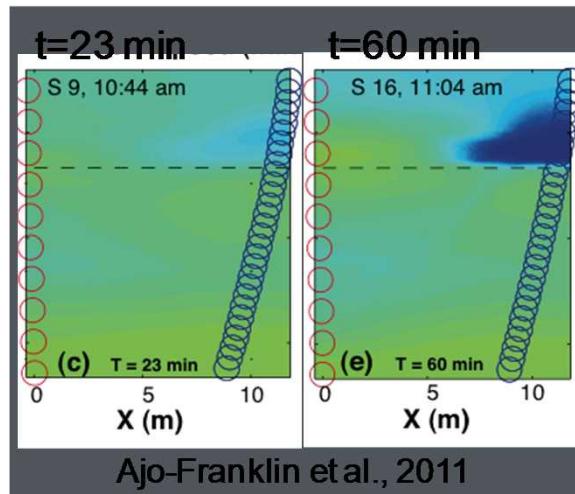
Acoustic emissions
Johnson et al., 2013

Block manipulations

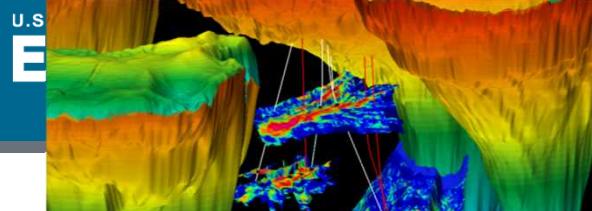


SUBSURFACE IMAGING & SENSING

- Many methods (including seismic, electromagnetic, InSar)
- New sensor developments (fiber optics, high temperature sensors)



THMC SIMULATION CAPABILITIES



Usability

Geomodel Construction

- Data Readers
- Meshing
- Property Mapping

Postprocessing

- Visualization
- Analysis Tools

Physics

Constitutive Models

- Rock Models
- Fluid Models
- Frac Propagation Criteria

Benchmarks

- Analytical Solutions
- Field Tests

Numerics

Discretizations

- Finite Element / Volume
- Mimetic Methods
- Boundary Element

Fracture Tracking

- Mesh Adaptation
- Embedded Discontinuities
- Static Mesh Methods

Coupled Solvers

- Multigrid / Multiscale
- Nonlinear Solvers

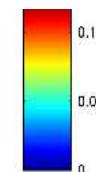
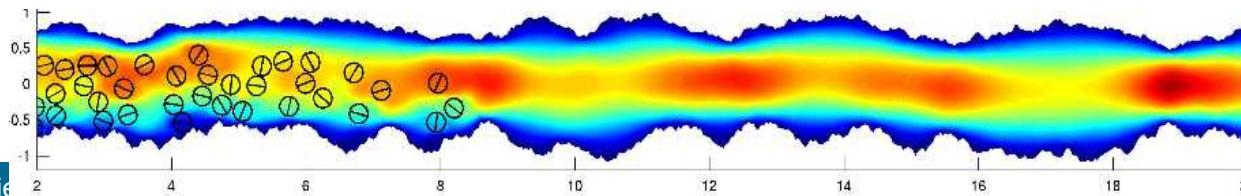
HPC

Data Assimilation & Uncertainty Quantification

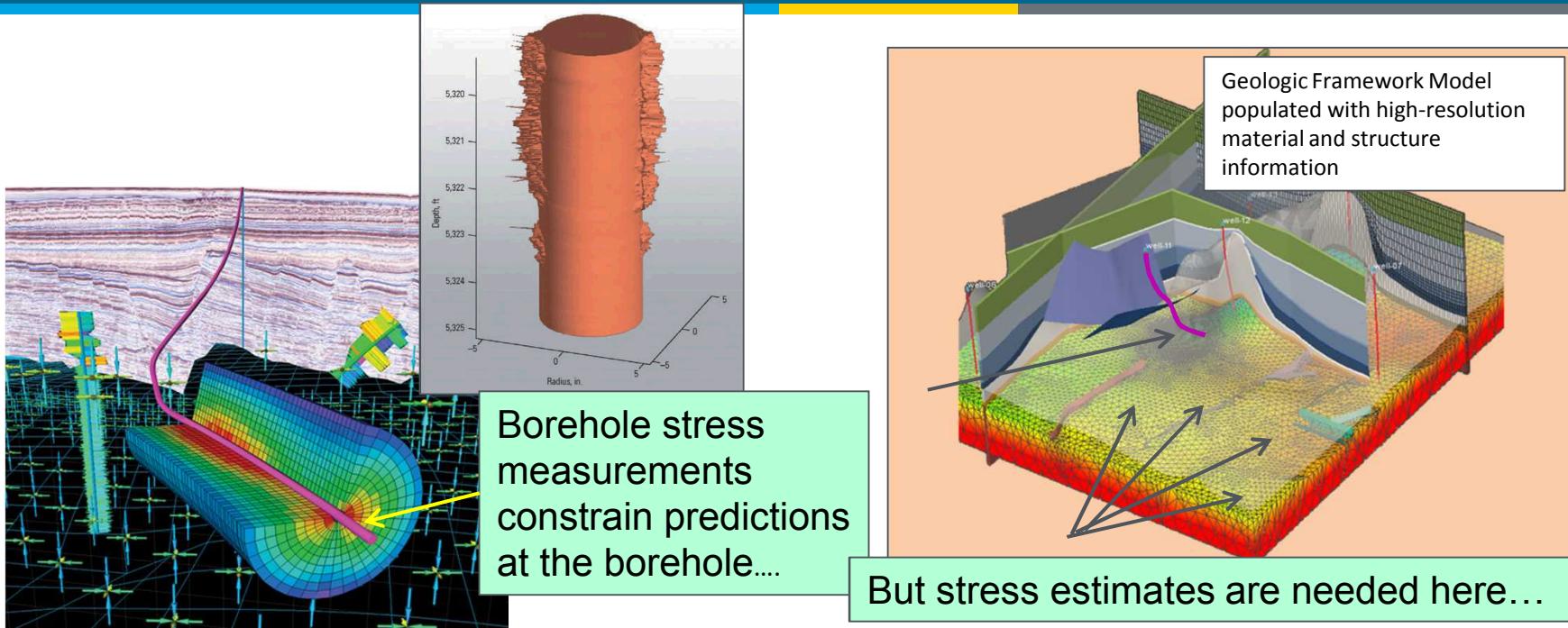
- Inverse Methods
- (Non-)Invasive UQ

High Performance Computing

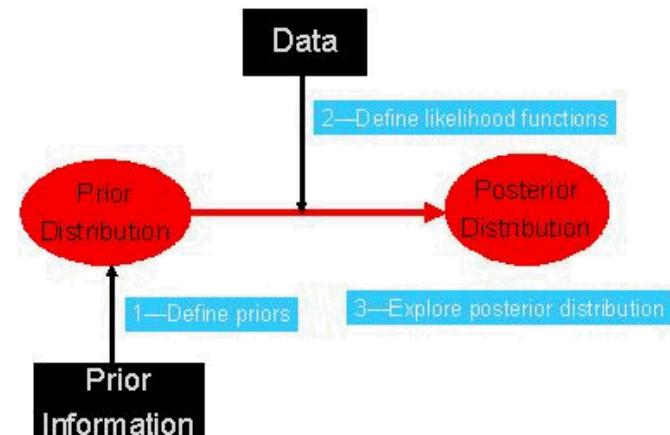
- Load Balancing
- Hardware Tuning



INTEGRATION & JOINT INVERSION



- Joint consideration of direct measurements, indirect measurements, knowledge of geologic framework, and theory
- Opportunity to estimate away from borehole, account for heterogeneities and inelastic behaviors, and to quantify uncertainty
- Needed to guide subsurface manipulations with confidence



FIELD OBSERVATORY & EXPERIMENTS

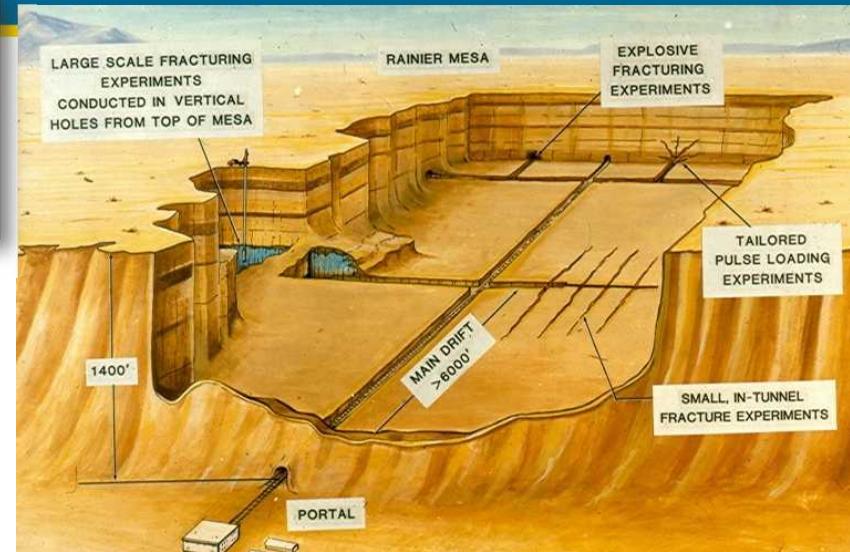
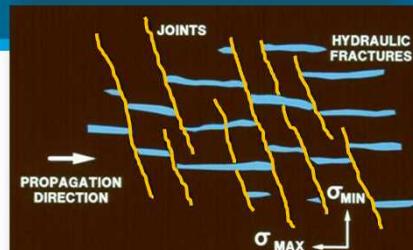
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Energy Efficiency &
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- **Nevada Test Site, 1976-1985**

- Extensive characterization driven by coalbed methane:

- Direct observation of fractures, cores, seismic, tiltmeters, geology



- **Multiwell Experiments, Rifle CO. 1981-1988**
- Stimulation experiments using 3 closely-spaced vertical wells to improve production from “tight” sands
- Results
 - Stress measurement techniques developed
 - Geology matters – extensive rock core collected
 - Fracture-height growth controlled by stress contrasts
 - Effectiveness of PDC bits for coring
 - Monitoring technologies initiated

Thank You