



Field Experience from West Coast Research

Larry Myer

WESTCARB Technical Director
California Energy Commission
lrmyer@lbl.gov

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Public Workshop
Bakersfield, CA
September 25, 2009*

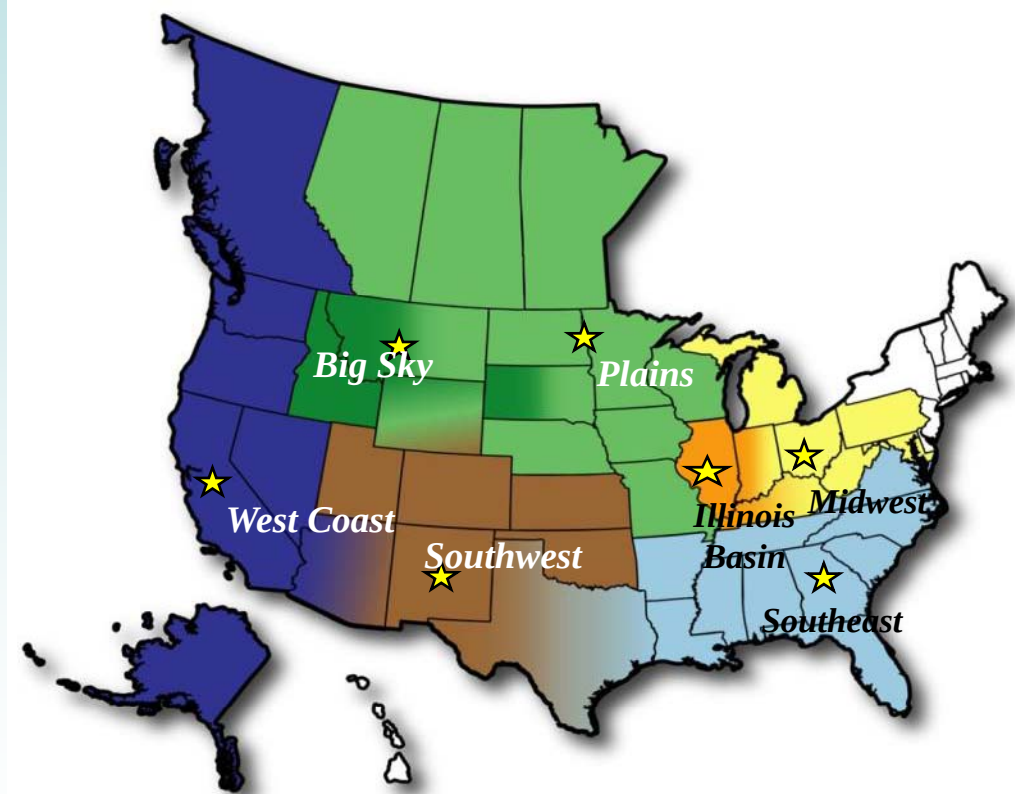


Outline

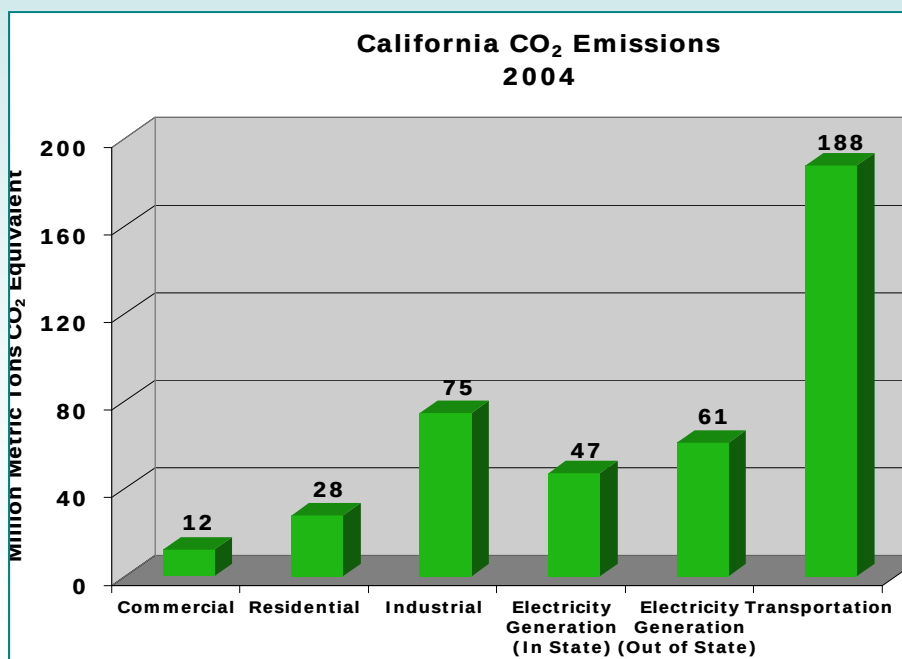
- WESTCARB project introduction
- Overview of California geologic sequestration opportunities
- WESTCARB field pilot projects – what we're doing and what we've learned
 - Institutional elements
 - Technical work

WESTCARB Is One of Seven DOE Regional Carbon Sequestration Partnerships

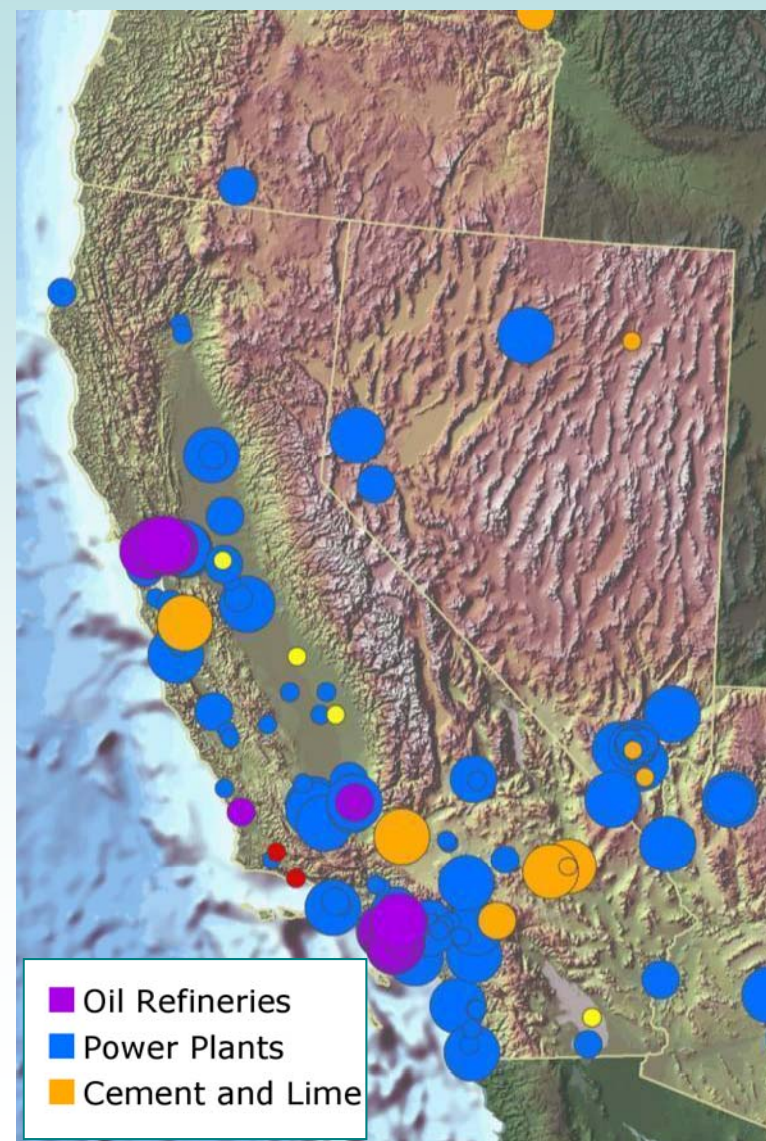
- Opportunities for terrestrial and geologic CO₂ storage are being evaluated
- DOE program represents 43 states, 4 provinces, and more than 350 organizations
- Phase I (complete) focused on regional characterization of CO₂ storage capacity and cost
- Phase II (under way) is focusing on CO₂ storage technology validation via small-scale field tests
- Phase III (beginning) is focusing on pre-commercial (large-scale) geologic CO₂ storage field tests



California CO₂ Emissions by Sector and Major Source Type



(Source: U.S. EPA)

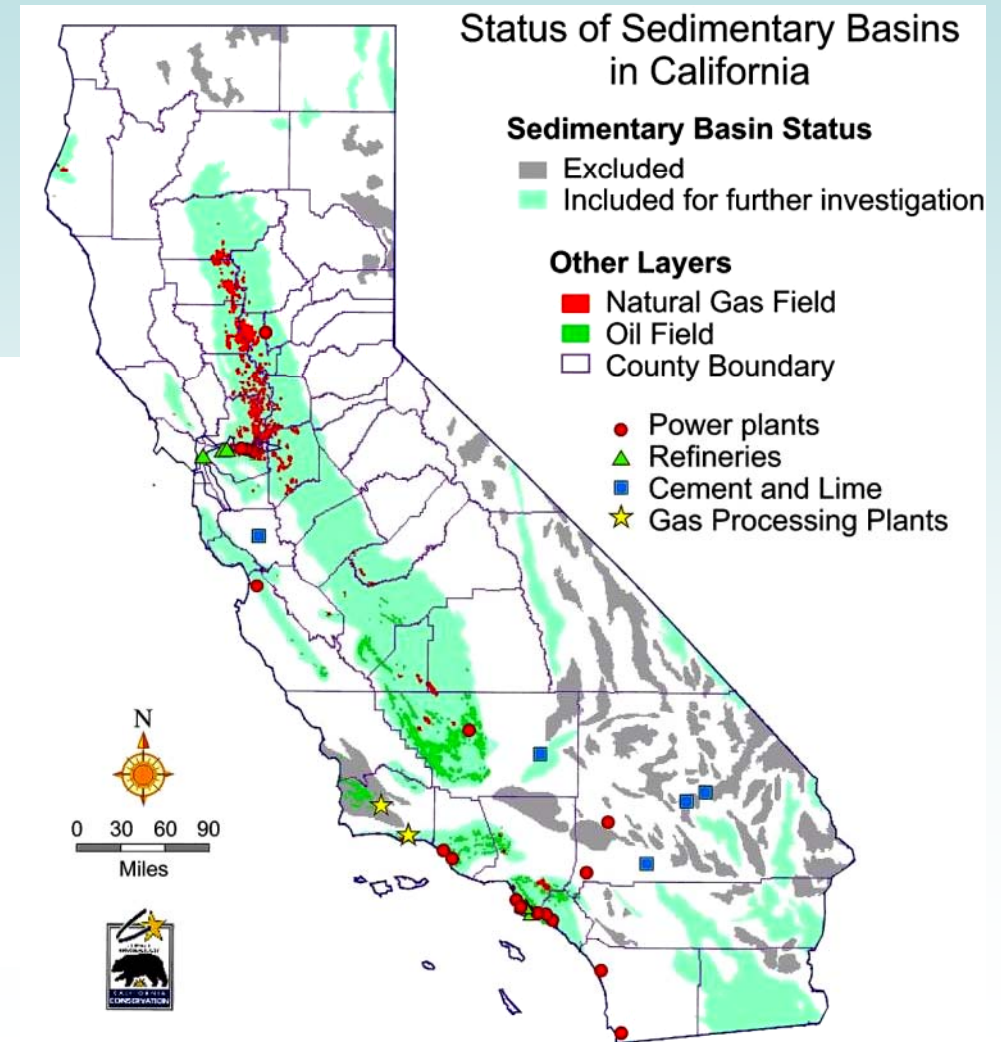
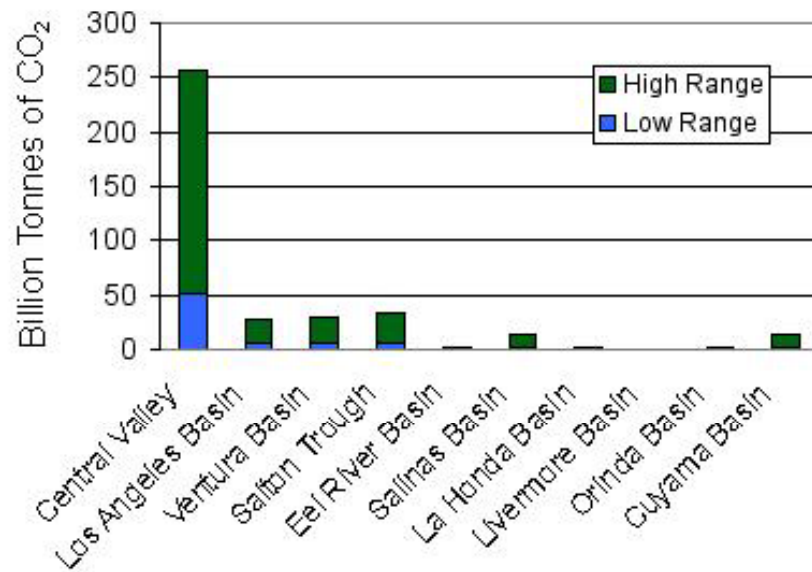


Primary Geologic CO₂ Storage Options for California

- Oil and gas reservoirs
 - Storage with Enhanced Oil Recovery (EOR) or Enhanced Gas Recovery (EGR)
 - Storage only
- Saline formations
 - Storage only

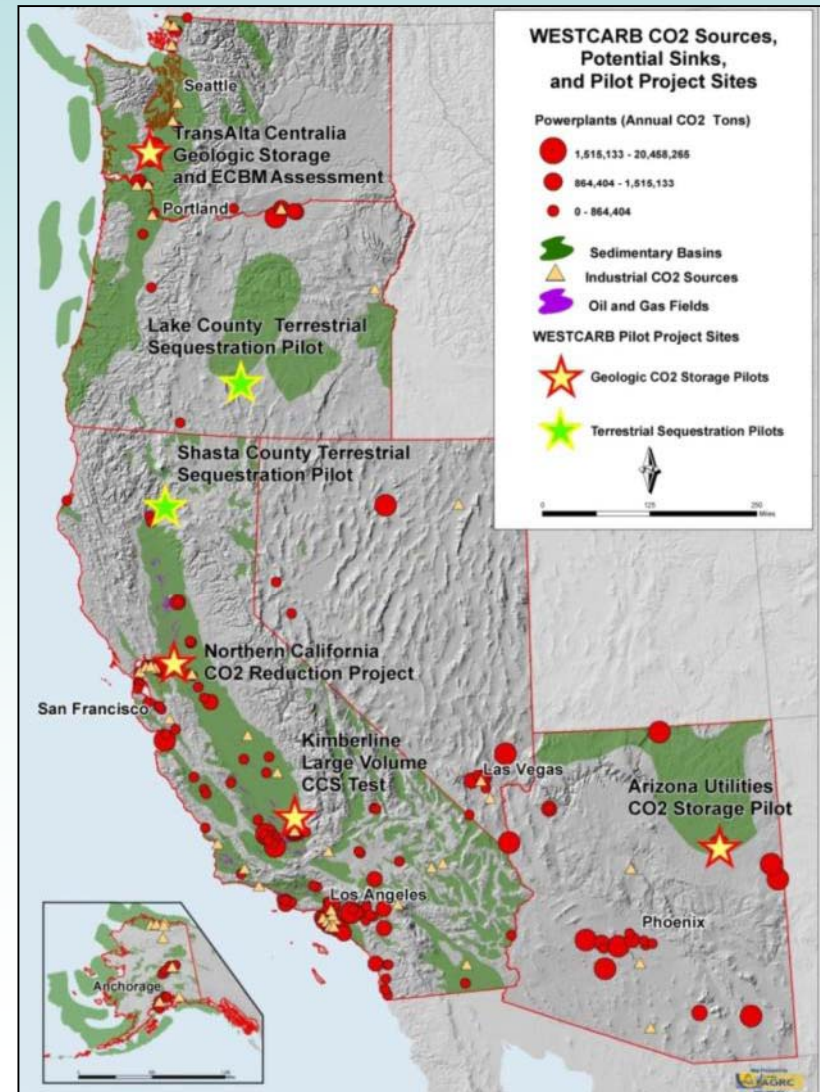
Major Geologic Storage Opportunities in California

California Saline Formation Resource Estimate

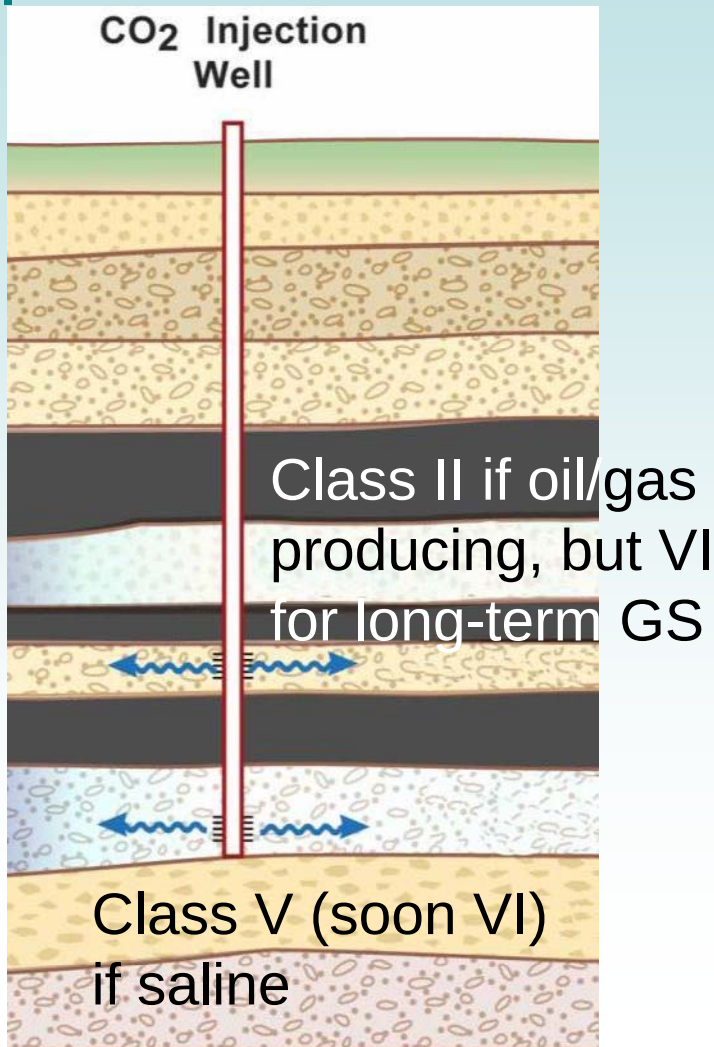


Field Tests Provide Regional Knowledge Base Essential for Implementation

- Field tests examine prime CO₂ storage locations
- Pilot projects involve site-specific focus for:
 - Demonstrating storage security of the geologic formations
 - Demonstration of safe operations without adverse environmental impact
 - Assessing injectivity and storage capacity
 - Validating and demonstrating monitoring methods
 - Establishing regulatory procedures
 - Assessing institutional issues



WESTCARB Projects Establishing Working Relationship With Federal and State Regulators



- In California and Arizona, both federal and state regulators have jurisdiction over underground injection permits
- WESTCARB partners have filed three “Class V” UIC permits with U.S. EPA Region 9 for CO₂ injection, and one with ADEQ
- WESTCARB experience has shown that state agencies have been communicative with EPA Region 9, and vice versa
- EPA’s proposed “Class VI” rule for long-term storage wells draws upon DOE partnership data

CCS Researchers and Project Developers Are Helping Inform Policymakers on Key Issues

- Legal issues for long-term CO₂ storage
 - Pore space ownership and severability unclear, especially for saline formations; subsurface trespass law also unclear
 - Long-term liability for stored CO₂ unresolved in non-EOR applications
- Financial uncertainty
 - Project financing and investor risk—clarity needed on legal issues, incentives for early action, insurance
 - Value of CO₂



Outreach and Education

- Public meetings, teacher workshops, and presentations at conferences
- Project-specific pages and drilling coverage on www.westcarb.org
- IEPR and AB 1925 reports to Legislature
- “Best practices” manual with other DOE partnerships





PUBLIC MEETING

Storing Carbon Dioxide to Fight Global Warming: Arizona Utilities CO₂ Storage Pilot Project

Holbrook, Arizona, August 1, 2007, 6:30-8:00 p.m.

Purpose

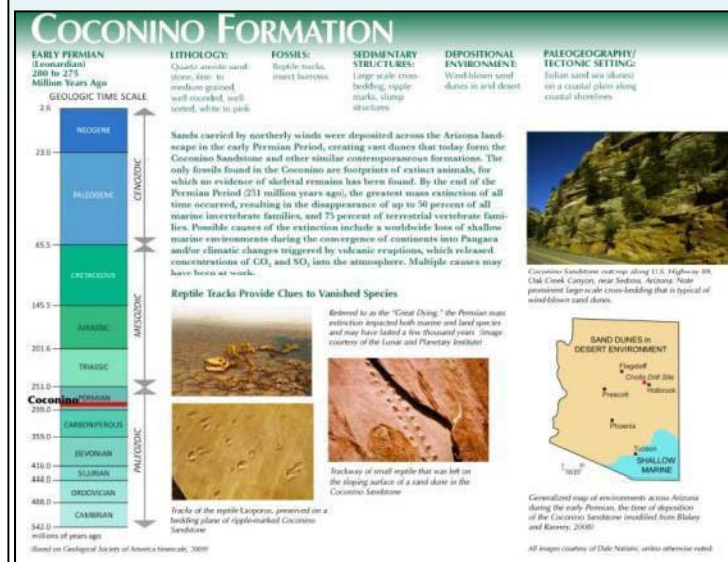
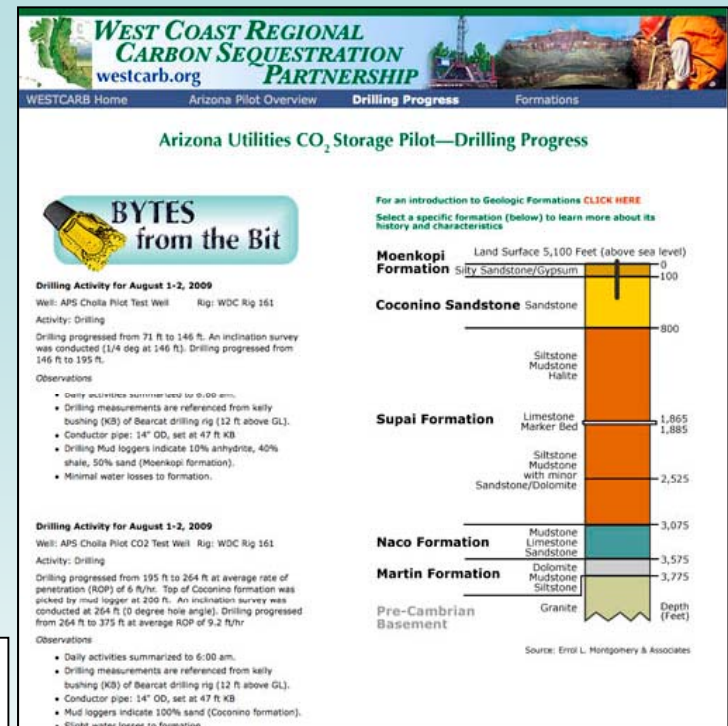
This international meeting is being held to discuss plans for a research project to test “carbon sequestration,” a promising new technology that can keep carbon dioxide (CO₂) away from the atmosphere to curb global warming. The known CO₂ storage, carbon sequestration involves injecting CO₂ about 1 mile underground into porous geologic formations suitable for secure long-term storage. In Arizona, well-sorted, deep-laying formations such as limestone, mudstone, and sandstone are excellent candidates for CO₂ storage. The depth and high salinity of the water in these formations rule out the possibility of using it for human consumption or agriculture. The proposed

CO₂ storage test in northeast Arizona will inject a small amount of commercial-grade CO₂ into a dedicated well equipped with sensitive monitoring instrumentation. This will allow researchers to “see” the CO₂ as it is absorbed into the porous rock. Successful subsurface geologic tests would help confirm the feasibility of ultimately storing CO₂ captured from nearby power plants, which could be required by future regulations.

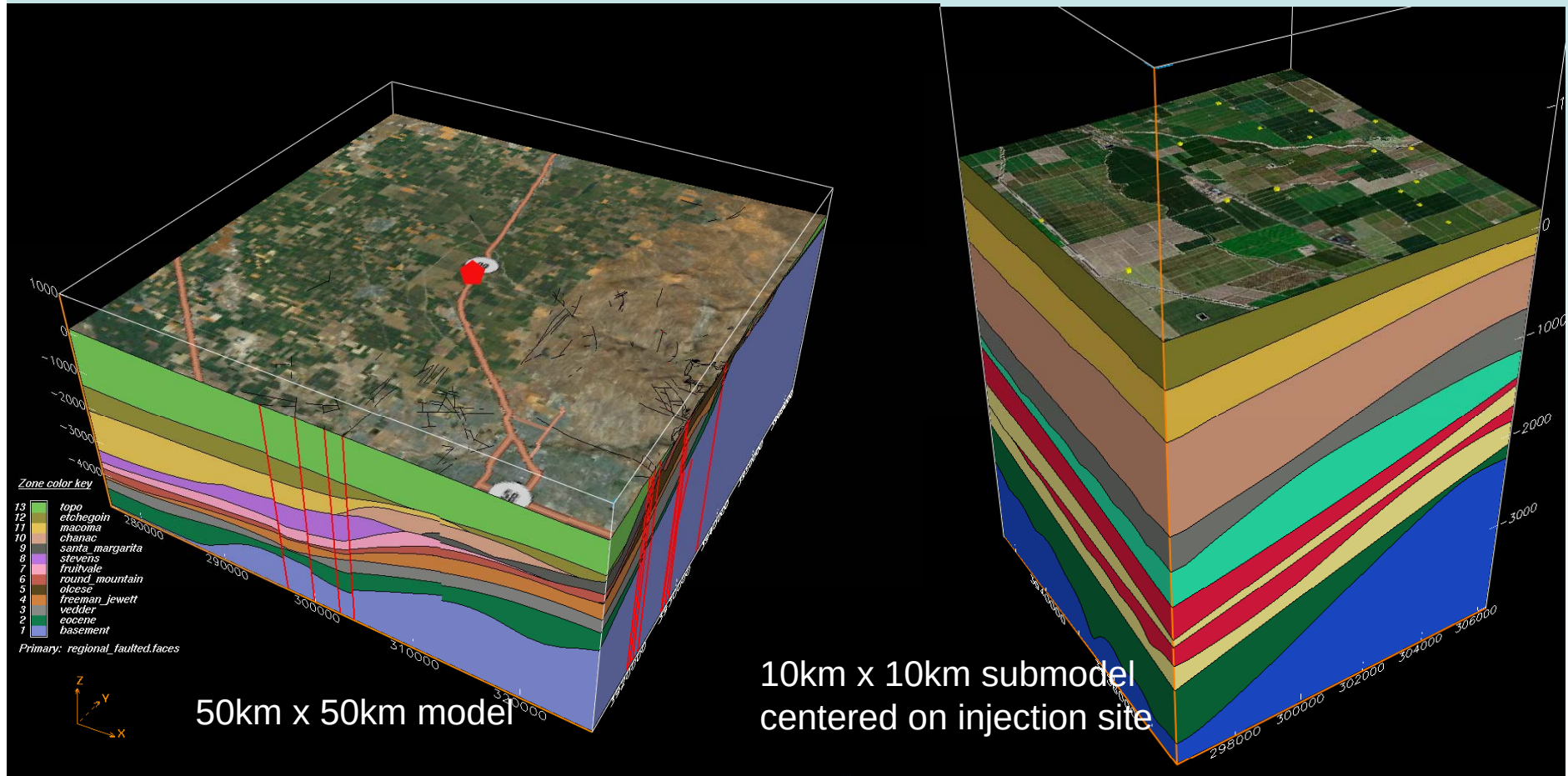
Everyone is welcome to attend the meeting to learn and ask questions about our proposed project. (Please see our Q & A section on the back of this announcement.)

MEETING LOCATION

Northland Power College
Fines Center Building
2201 N. Nevada Boulevard
Holbrook, AZ 86001
Meeting Contact: Danny Grady, APS-Cholla Power Plant
Telephone: 928-280-1341; Email: Danny.Grady@aps.com



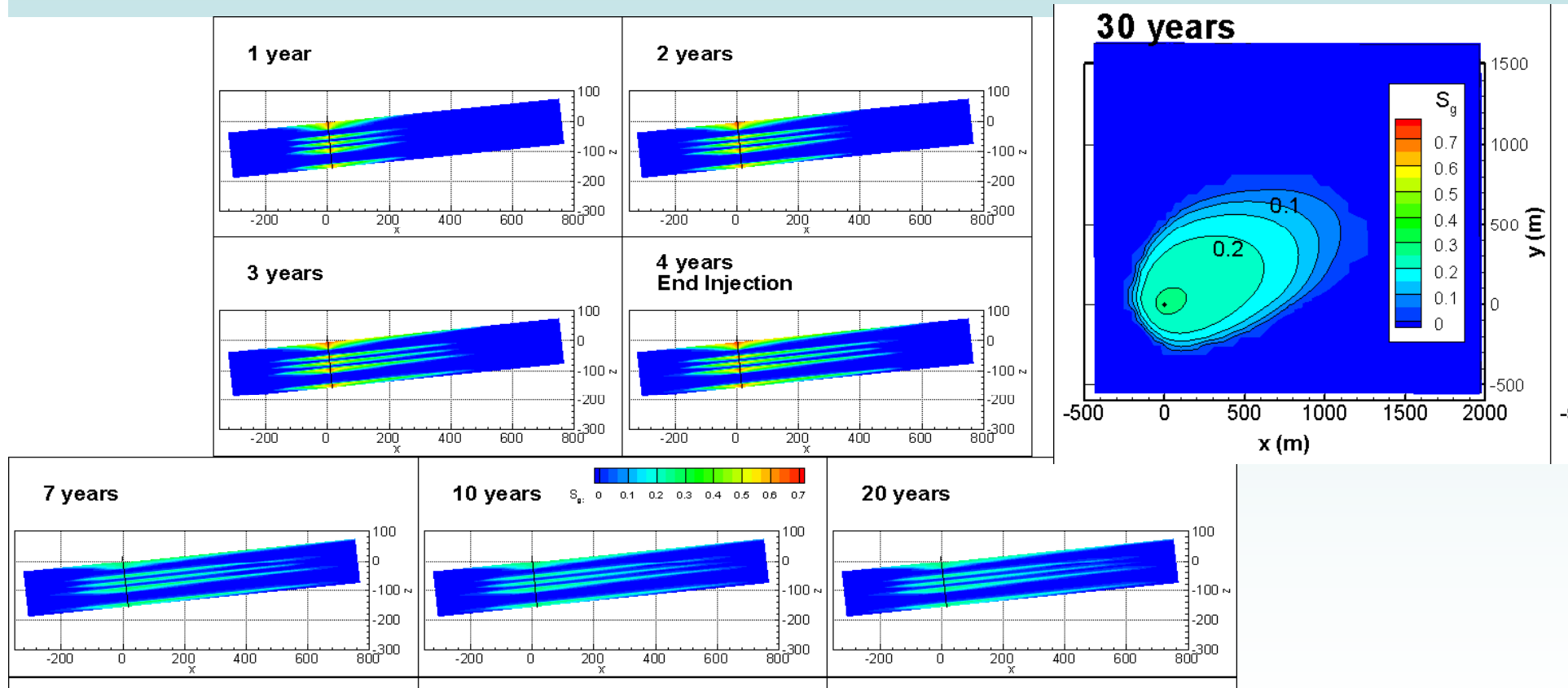
Existing Wells Provide Data for Initial Geologic Model



Initial geologic model centered on proposed Kimberlina project site near Bakersfield

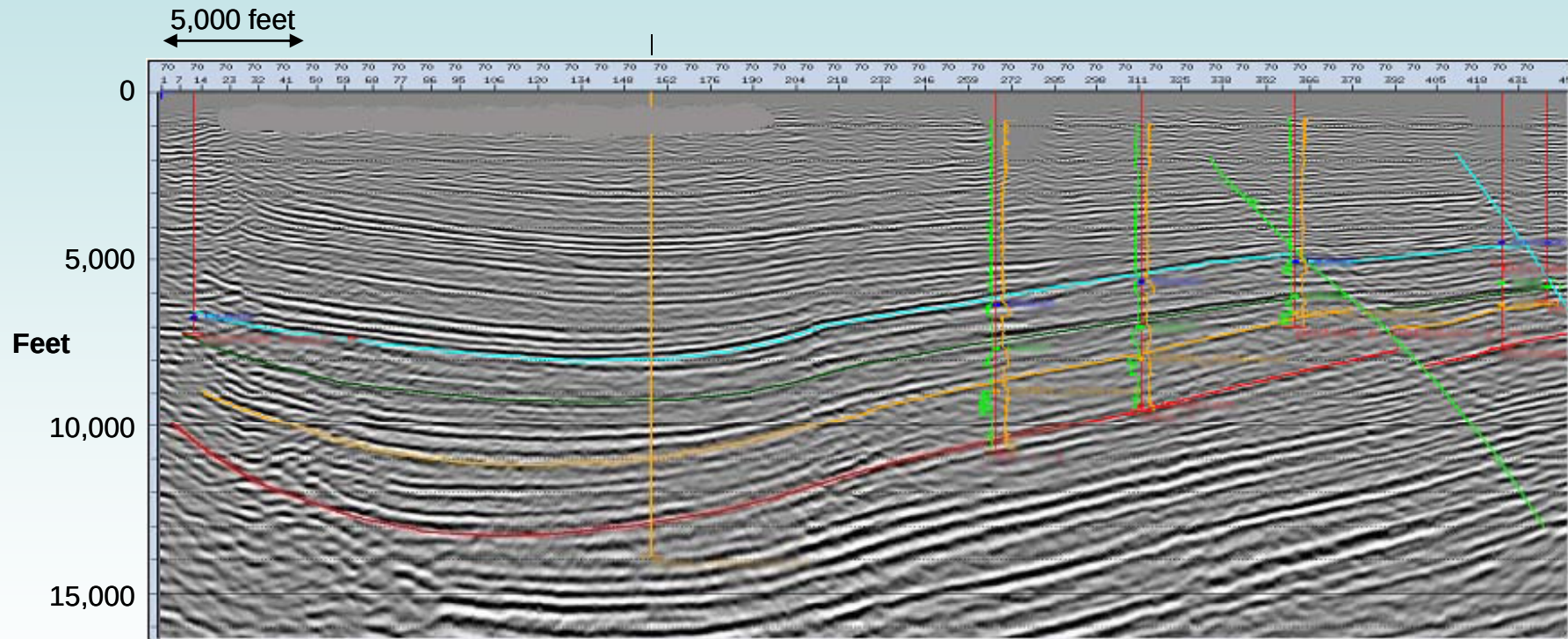
Source: Jeff Wagoner, LLNL

Simulations Show CO₂ Extent and Immobilization Over Time in Subsurface



Results of computer simulations of CO₂ in subsurface at Kimberlina project site
(Source: C Doughty, LBNL)

Seismic Data Provides Data on Geology Between Wells

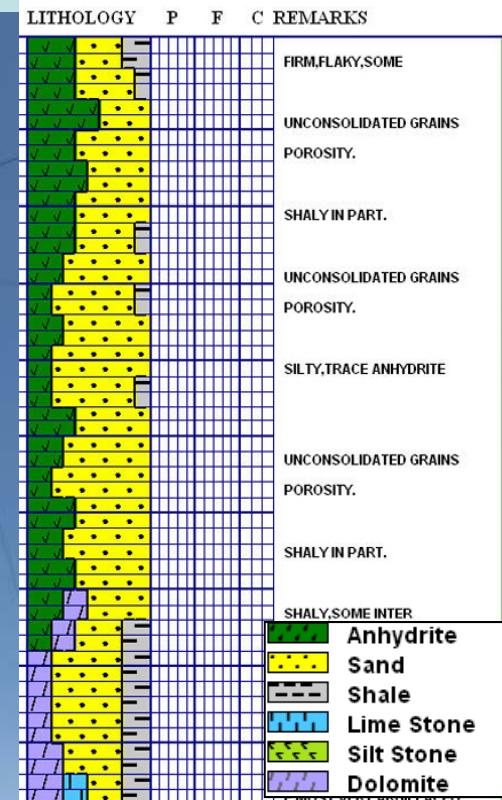
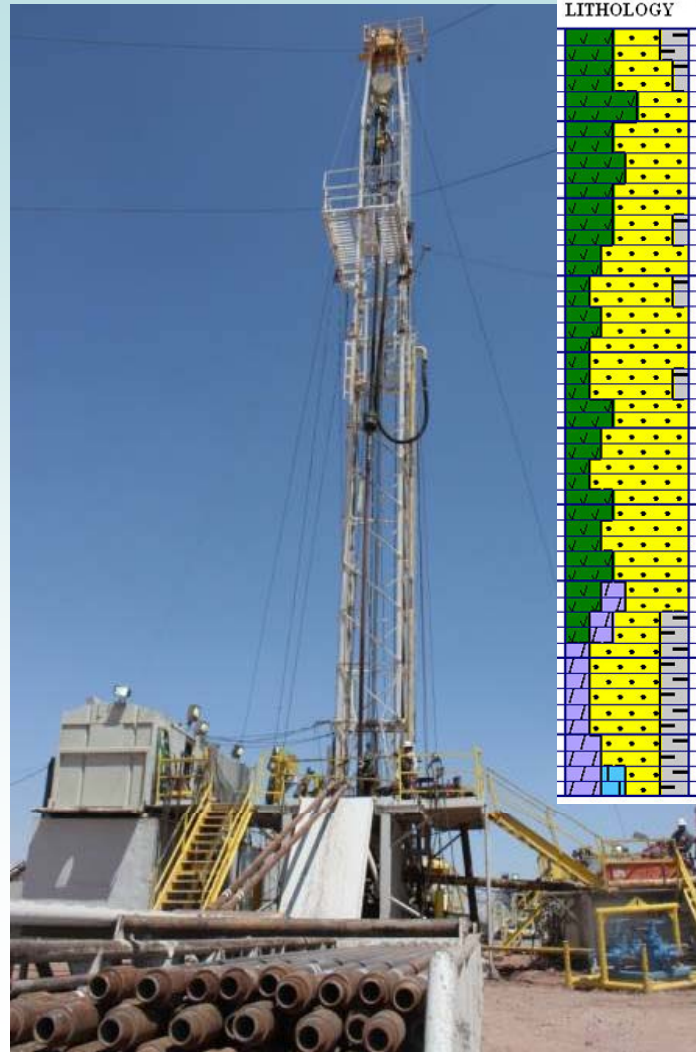


Source: Shell

**Seismic reflection data from northern California (Sacramento Basin)
pilot project area**

Wells at Project Site Provide Detailed Characterization Information

- Data during drilling validates geologic model, detailed information on overburden, seal, and reservoir
 - Cuttings inspected
 - Cores taken
 - Fluid salinity monitored
- Geophysical well logs and initial injectivity assessment in open hole
- Well cased and completed for additional characterization and monitoring measurements



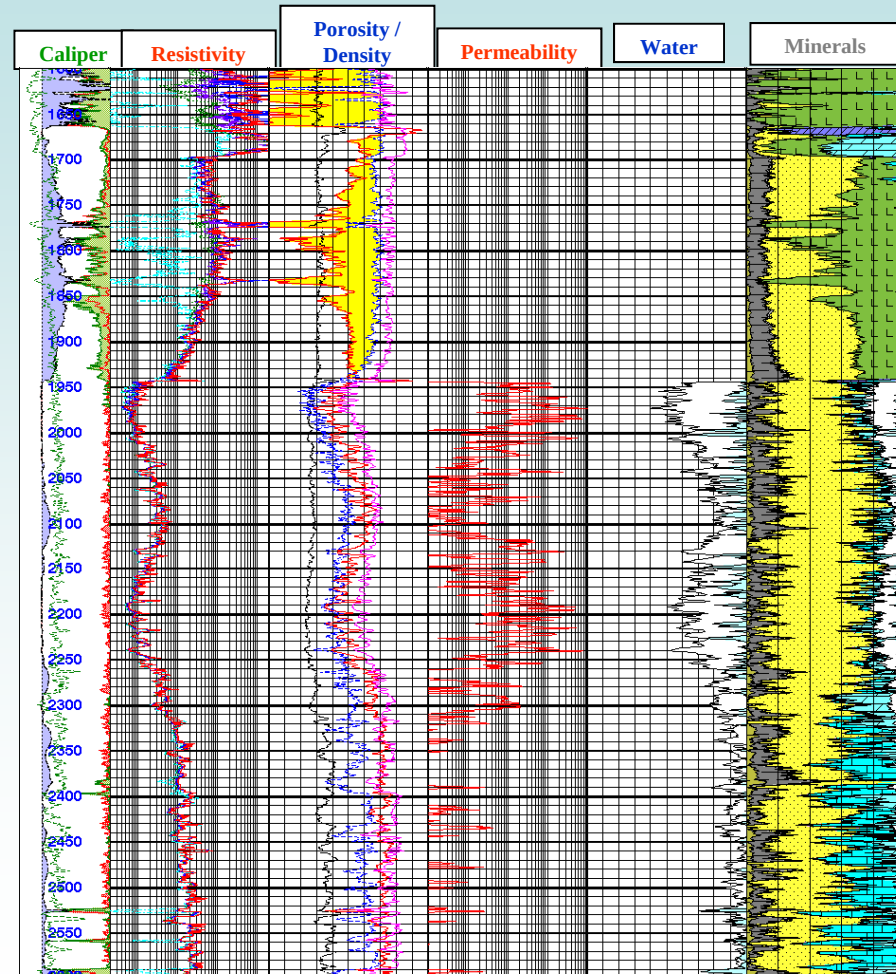
“Mud Log”

Well drilling at Arizona pilot site

Geophysical Well Logs Provide Formation and Fluid properties



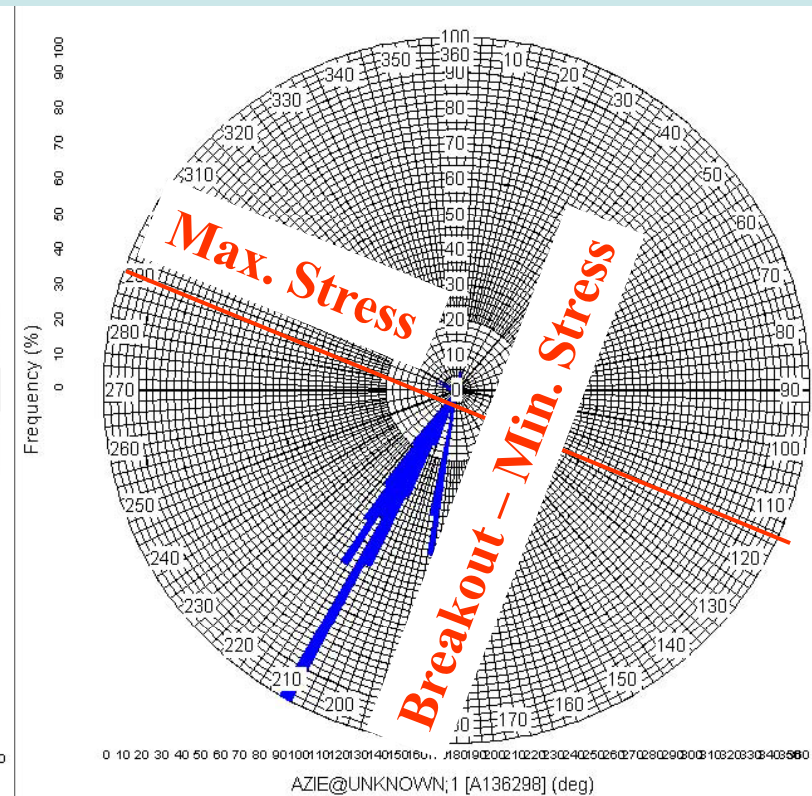
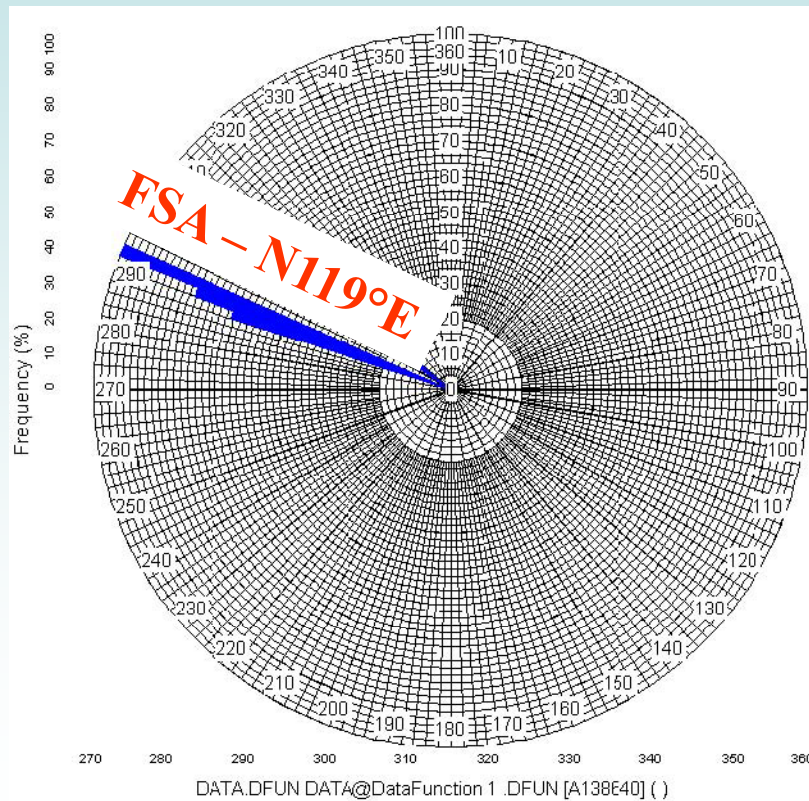
Schlumberger well log processing truck on location in Arizona (Photo: R. Trautz, EPRI)



Example section of well logging results, Arizona well (Source: Schlumberger)

Data on Earth Stresses Derived from Well Logs

Rose diagram fast shear (FSA) direction Rose diagram borehole enlargement



Source: Schlumberger

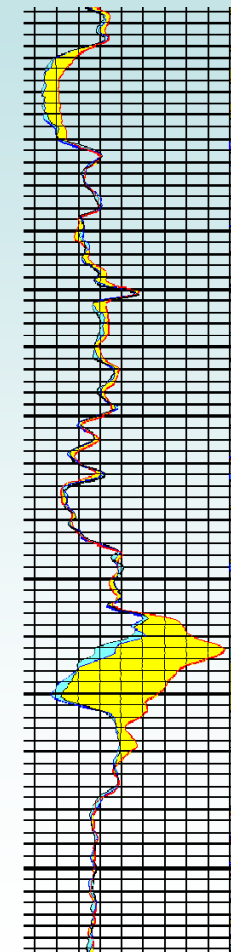
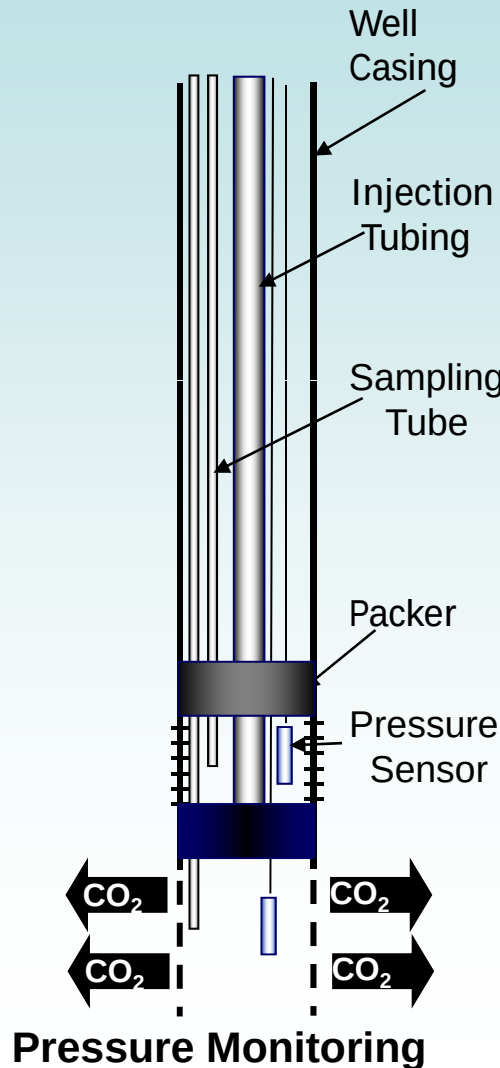
Multiple Methods Provide Data Monitoring Needs

- Worker EH&S
- Assurance monitoring – shallow groundwater; atmospheric levels; seismicity
- Storage security – seal and wellbore integrity; plume movement; brine movement; capacity/trapping

	Wellhead pressure, temperature	Annulus pressure	CO2 surface sensors	Eddy covariance tower	Flux chamber	Groundwater sampling	Well logs	Seismic survey, 3D/VSP	Measurements on core	Microseismic	Formation pressure, temperature	Overburden fluid sampling	Overburden fluid pressure	Tracers	Electrical / Electromagnetic	Active source thermal	Synthetic Aperture Radar
Worker Health Safety	X	X	X														
Shallow groundwater					X						X						
Atmospheric CO2			X	X	X												
Seismicity							X	X									
Seal and wellbore integrity	X					X	X	X			X	X	X	X			
CO2 plume						X	X			X			X	X	X	X	
Formation pressure / brine movement						X	X		X								X
Storage capacity / trapping mechanism						X	X	X	X	X			X	X	X		

Pilot Tests Assess Geologic Seal Integrity to Assure Secure Storage

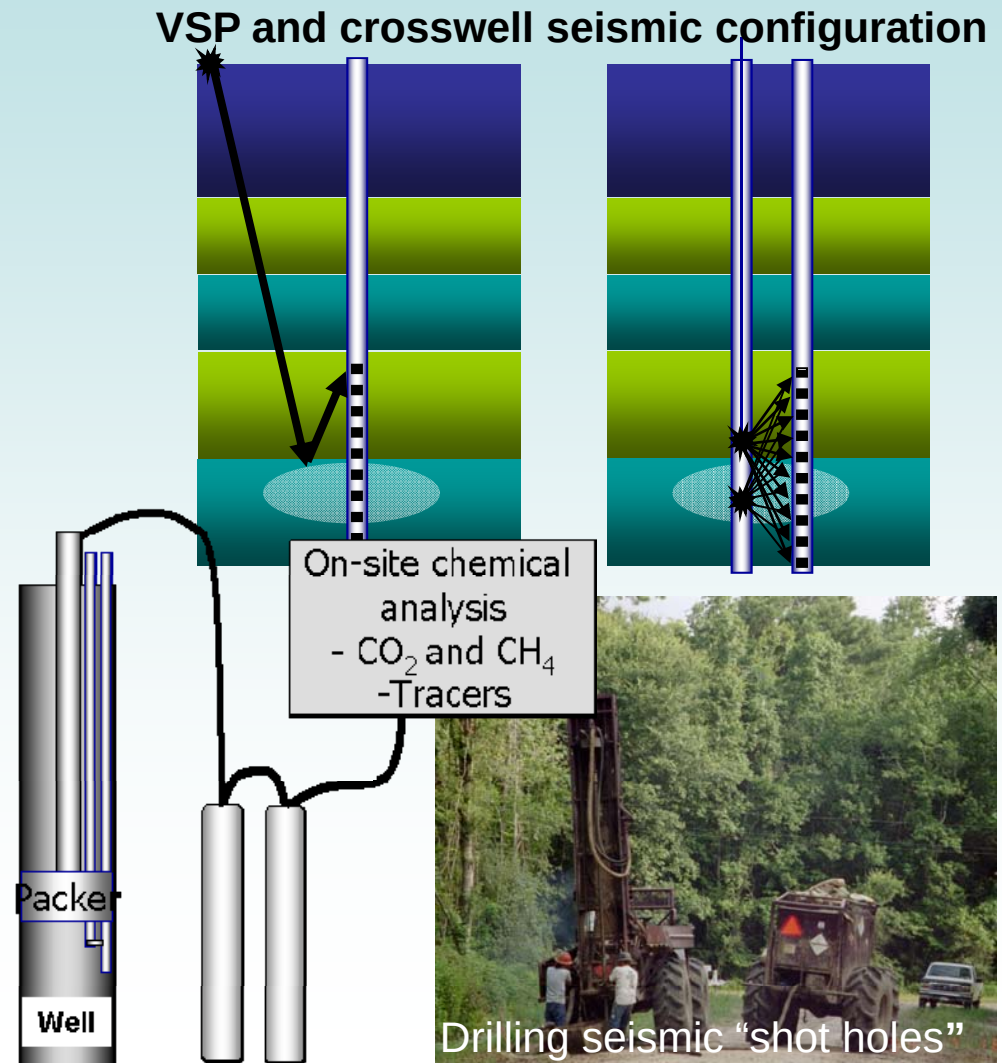
- Geomechanical analysis
 - Safe injection pressure
- Monitor pressure and water quality in a shallow formation above the injection zone (for early detection of any leaks)
- Obtain geophysical well logs from injection and observation wells before and after CO₂ injection



"RST" Log

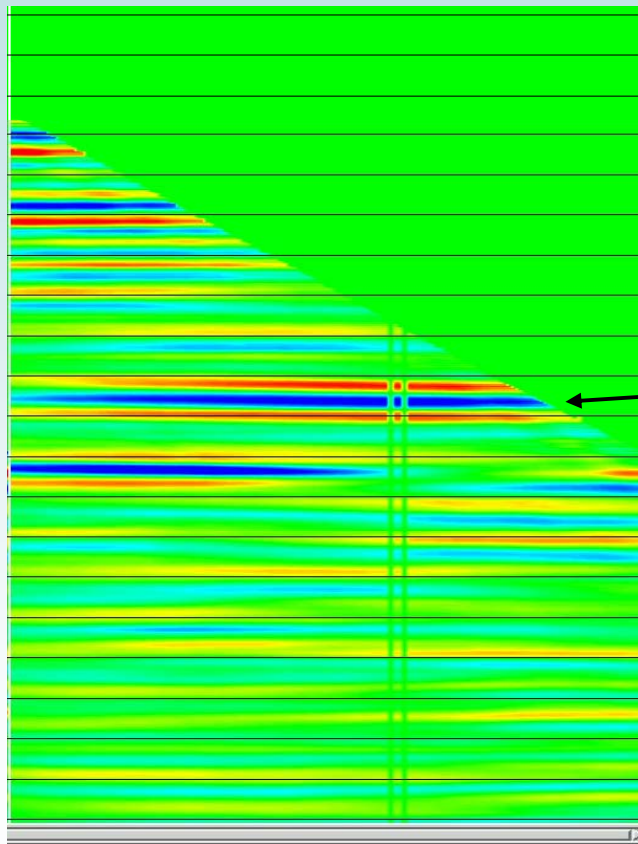
Pilot Tests Will Map the Underground Spread of Injected CO₂ Within Intended Storage Zone

- Repeat, “time lapse”, seismic
 - surface, VSP, crosswell
- Other geophysical methods
- Well logs in monitoring wells before and after injection
- Fluid sampling in monitoring wells – CO₂ arrival, fluid chemistry, tracers
- Comparison with computer predictions



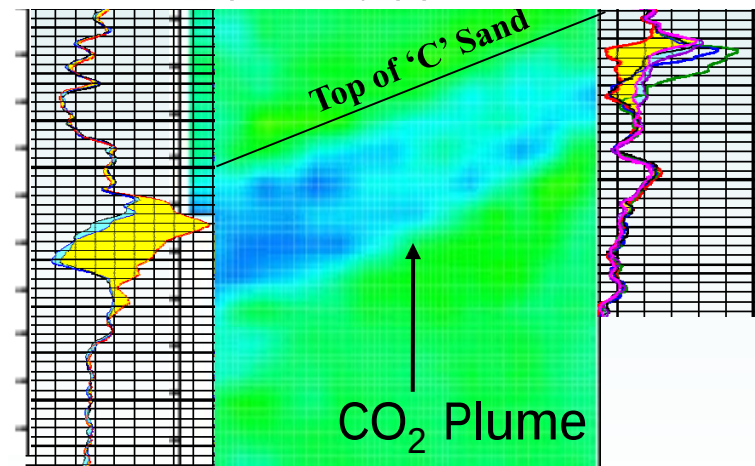
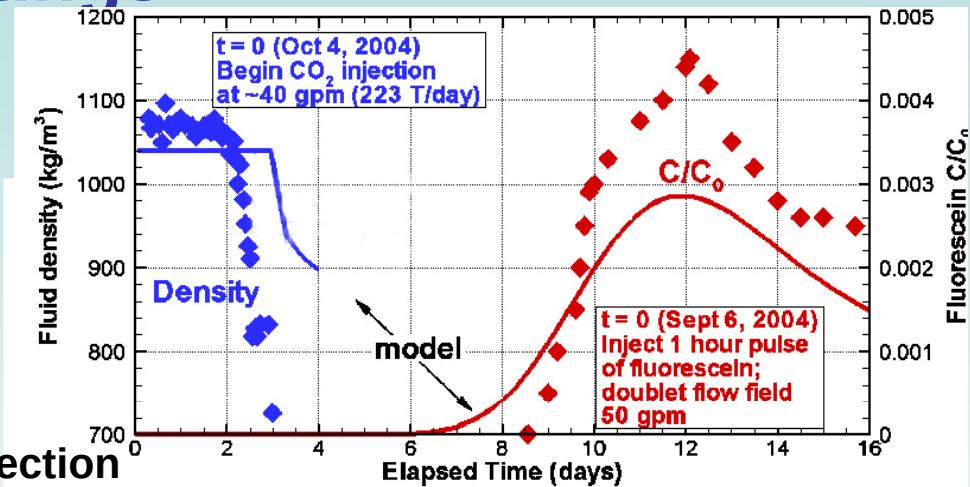
“U-tube” fluid sampling system

Pilots Test Methods Successfully Used in Other Geologic Settings

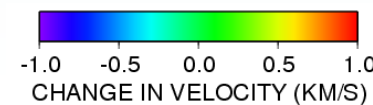


Reflection from layer containing CO₂

VSP, crosswell, and U-tube results from Frio pilot test (Doughty et al, 2006)



Injection Well

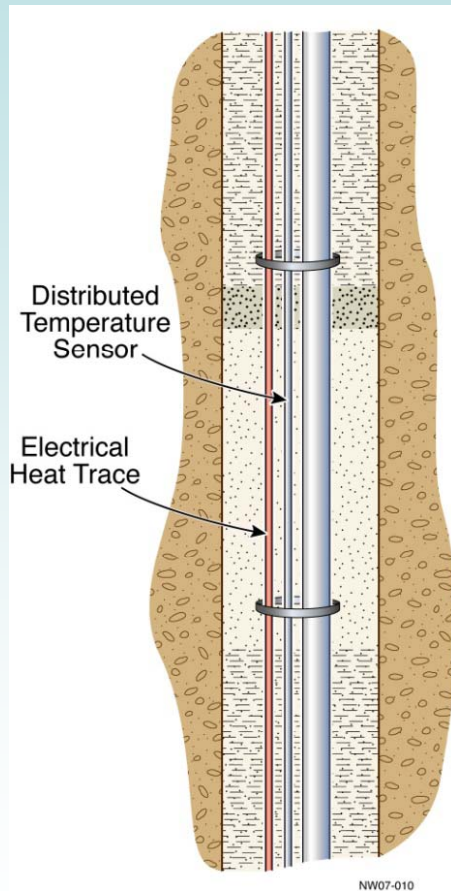


Monitoring Well

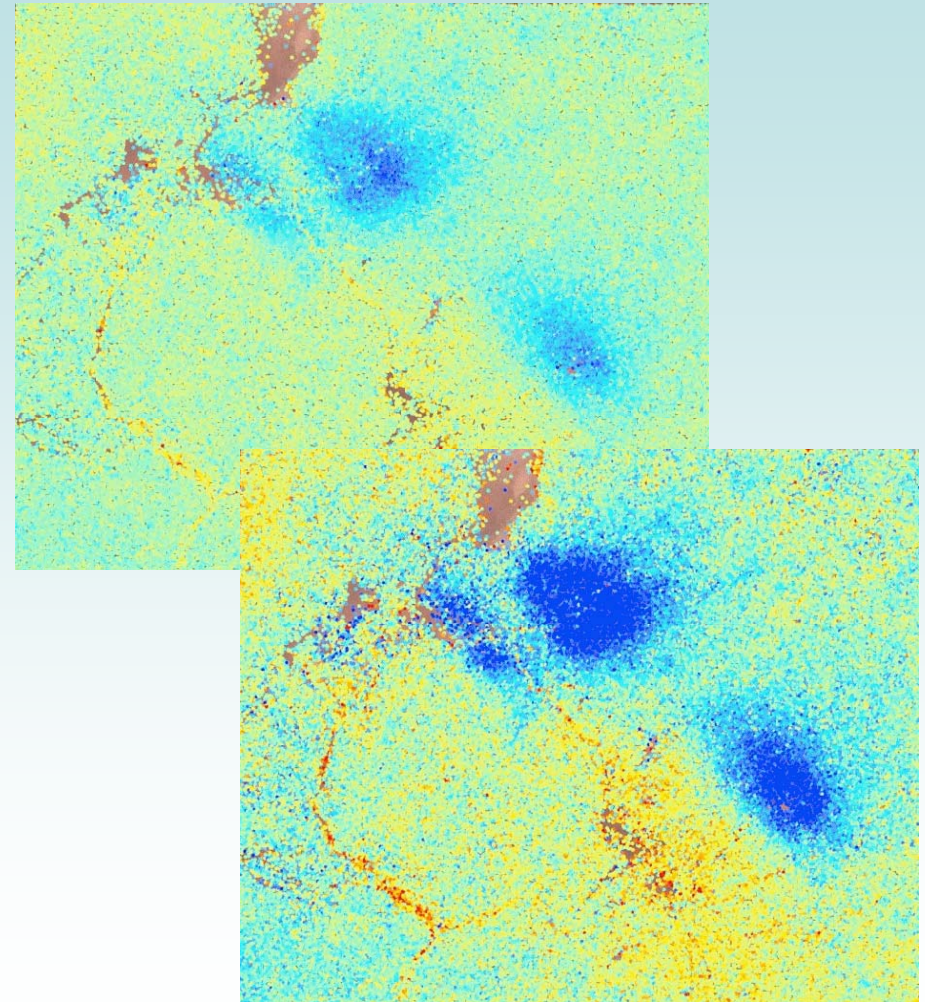
Summary

- California has a large geologic storage resource
- WESTCARB pilot projects provide important knowledge base for regional CCS implementation
- Experience with institutional issues highlight were policy needed; pave the way for larger scale projects
- Technical work is providing additional data on suitability of particular formations for sequestration, and validation and demonstration of monitoring technologies

Research-Stage MMV Methods Will Be Explored



Using detailed measurement of thermal Transients to derive CO₂ saturation
(B. Freifeld LBNL)



Use of minute surface displacements to monitor subsurface pressure changes

Source: D. Vasco, LBNL