Field Experience from West Coast Research

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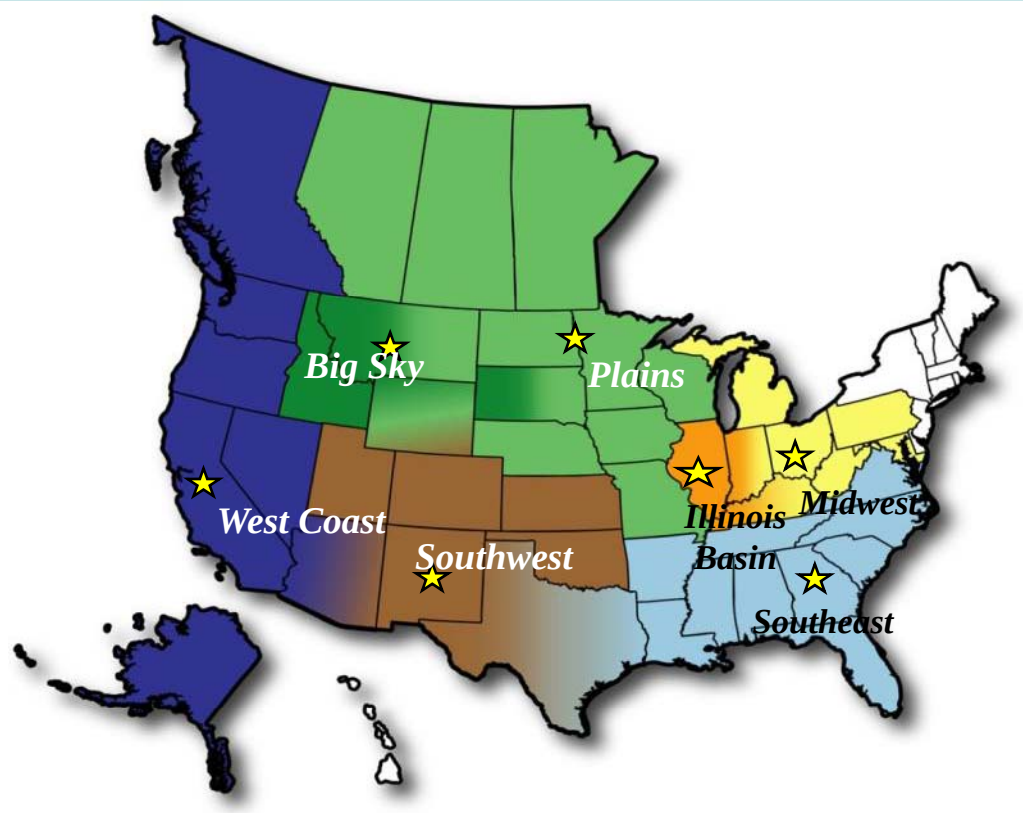
Carbon Capture & Sequestration
Public Workshop
Bakersfield, CA
September 25, 2009

Outline

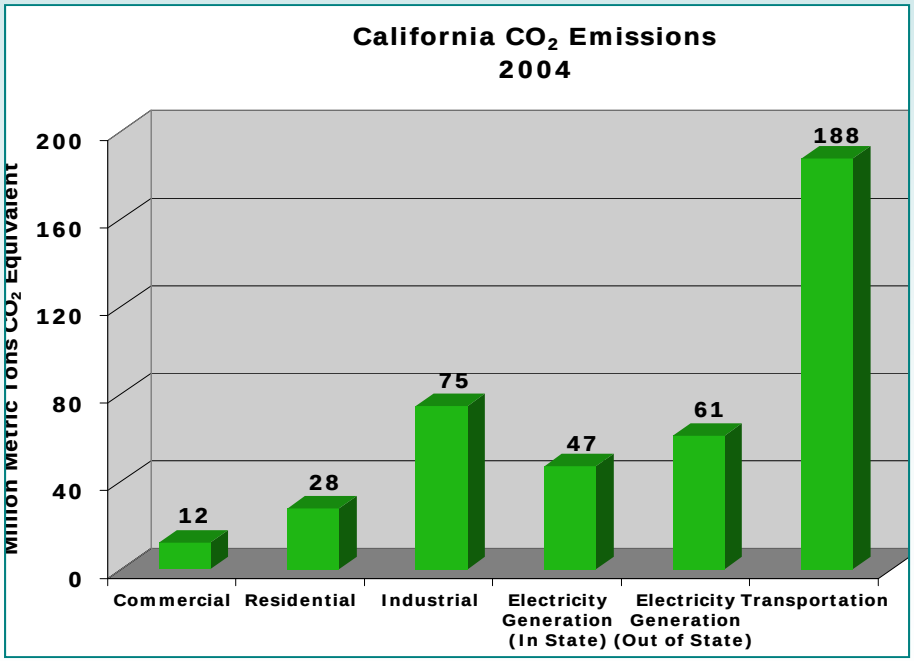
- WESTCARB project introduction
- Overview of California geologic sequestration opportunities
- WESTCARB field pilot projects – what we're doing and what we've learned
  - Institutional elements
  - Technical work

WESTCARB Is One of Seven DOE Regional Carbon Sequestration Partnerships

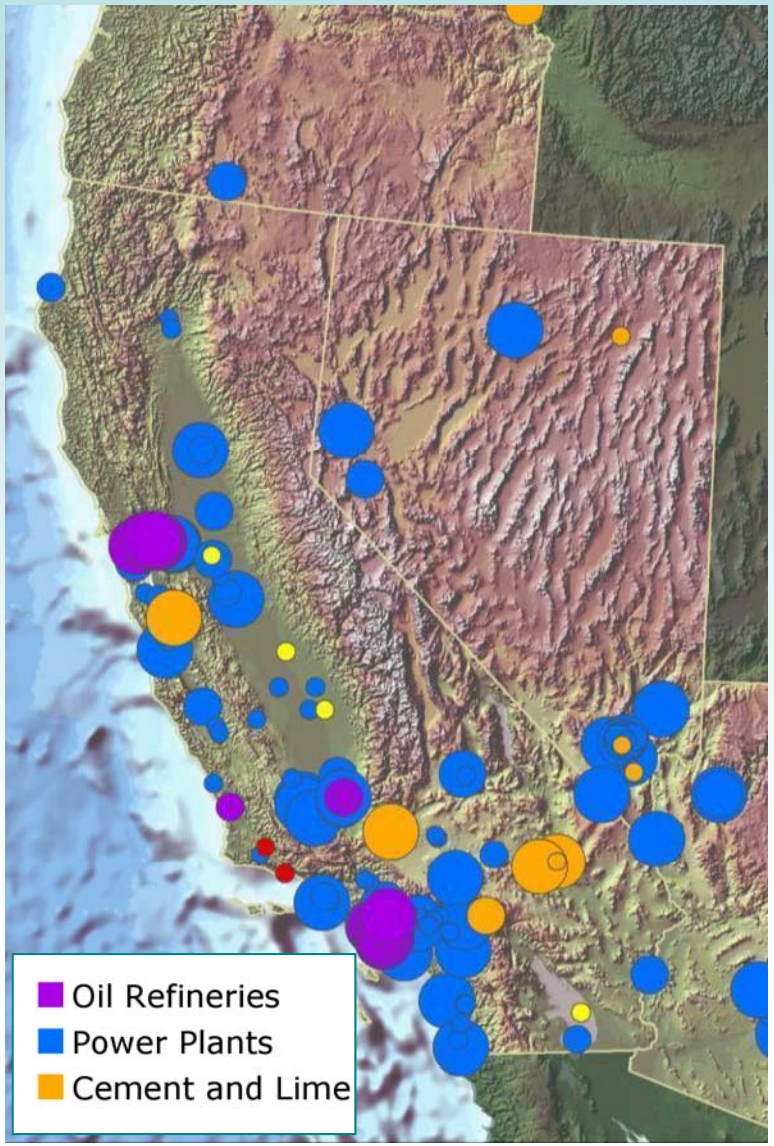
- Opportunities for terrestrial and geologic CO_2 storage are being evaluated
- DOE program represents 43 states, 4 provinces, and more than 350 organizations
- Phase I (complete) focused on regional characterization of CO_2 storage capacity and cost
- Phase II (under way) is focusing on CO_2 storage technology validation via small-scale field tests
- Phase III (beginning) is focusing on pre-commercial (large-scale) geologic CO_2 storage field tests



California CO_2 Emissions by Sector and Major Source Type



(Source: U.S. EPA)

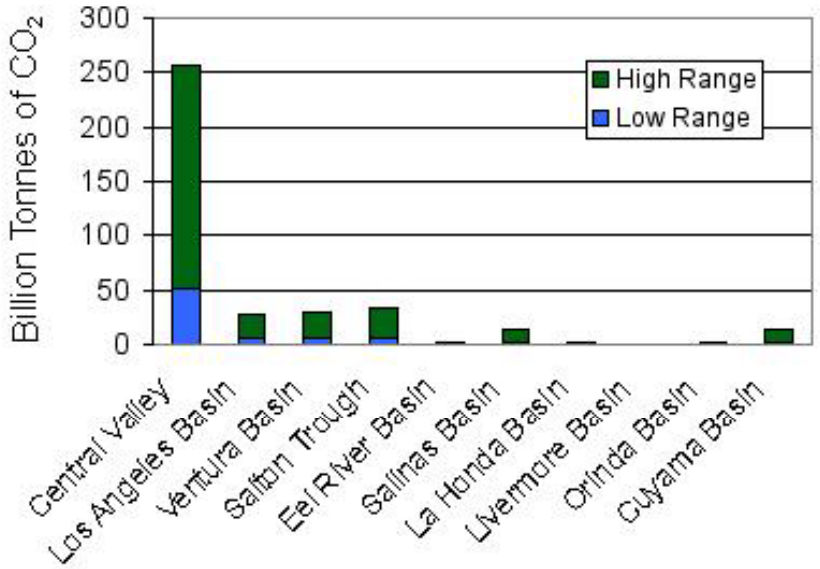


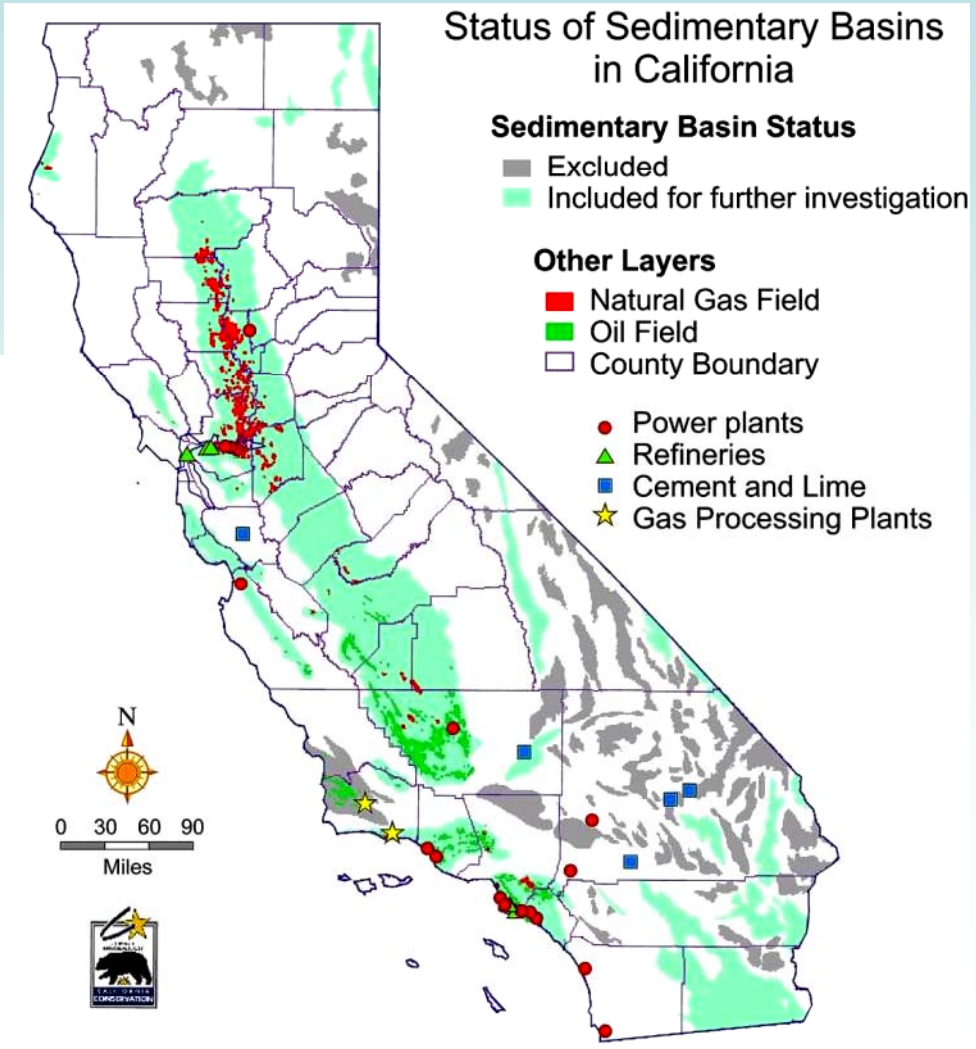
Primary Geologic CO_2 Storage Options for California

- 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

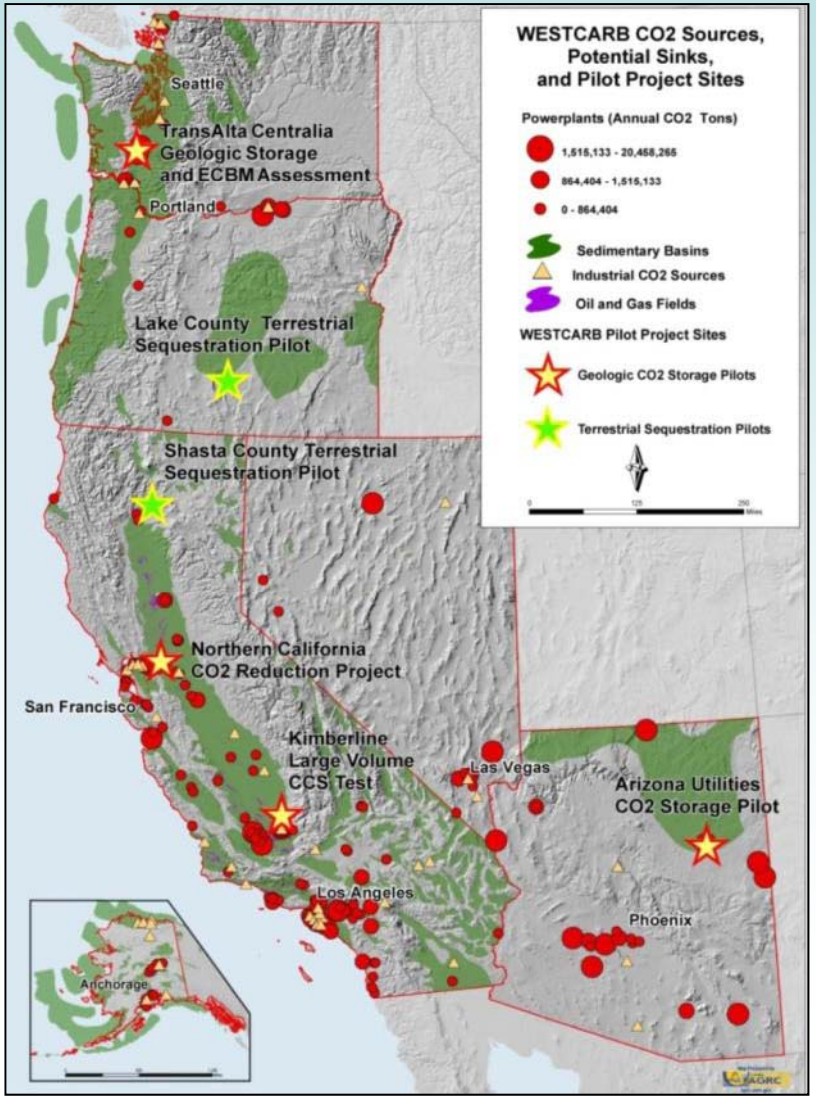
California Saline Formation Resource Estimate



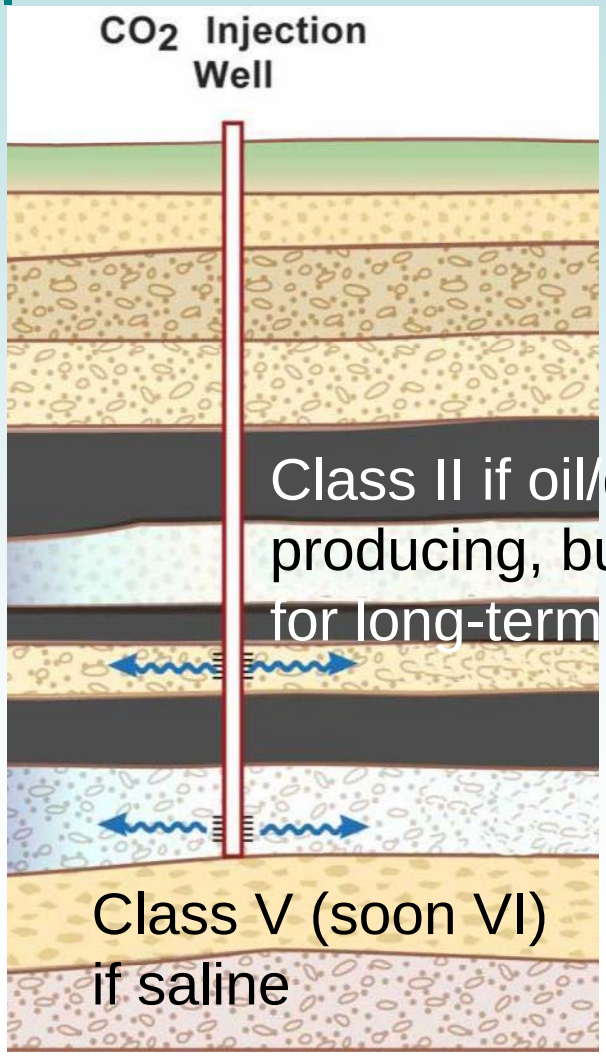


Field Tests Provide Regional Knowledge Base Essential for Implementation

- Field tests examine prime CO_2 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



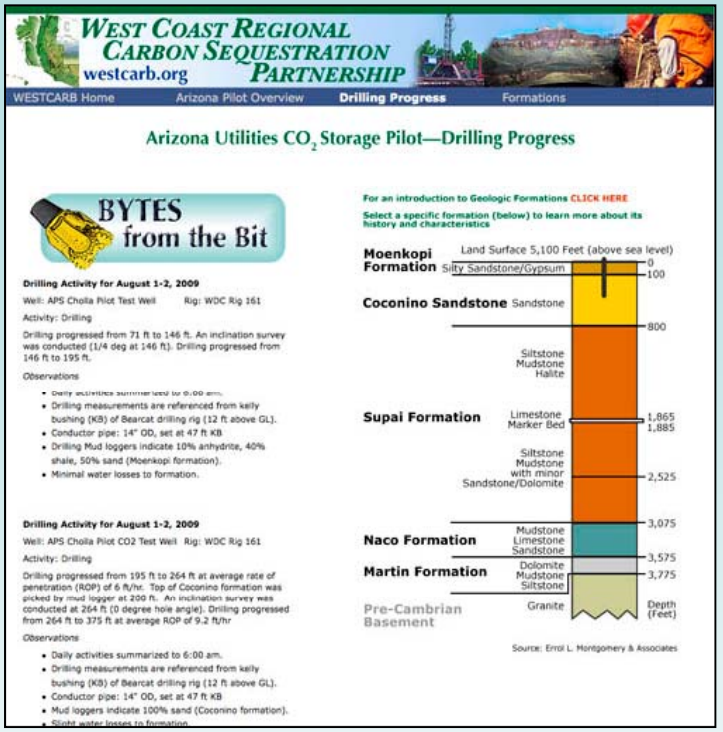
- In California and Arizona, both federal and state regulators have jurisdiction over underground injection permits
- WESTCARB partners have filed three “Class V” UIC permits with U.S. EPA Region 9 for CO_2 injection, and one with ADEQ
- WESTCARB experience has shown that state agencies have been communicative with EPA Region 9, and vice versa
- EPA’s proposed “Class VI” rule for long-term storage wells draws upon DOE partnership data

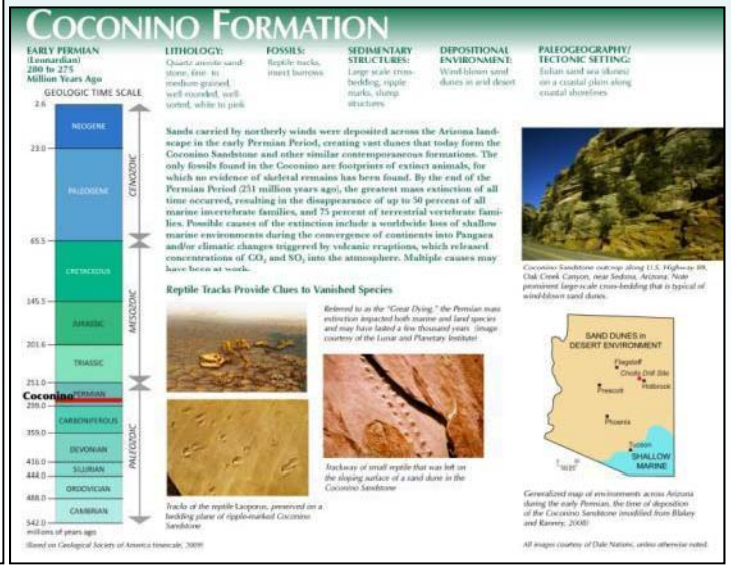
CCS Researchers and Project Developers Are Helping Inform Policymakers on Key Issues

- Legal issues for long-term CO_2 storage
  - Pore space ownership and severability unclear, especially for saline formations; subsurface trespass law also unclear
  - Long-term liability for stored CO_2 unresolved in non-EOR applications
- Financial uncertainty
  - Project financing and investor risk—clarity needed on legal issues, incentives for early action, insurance
  - Value of CO_2

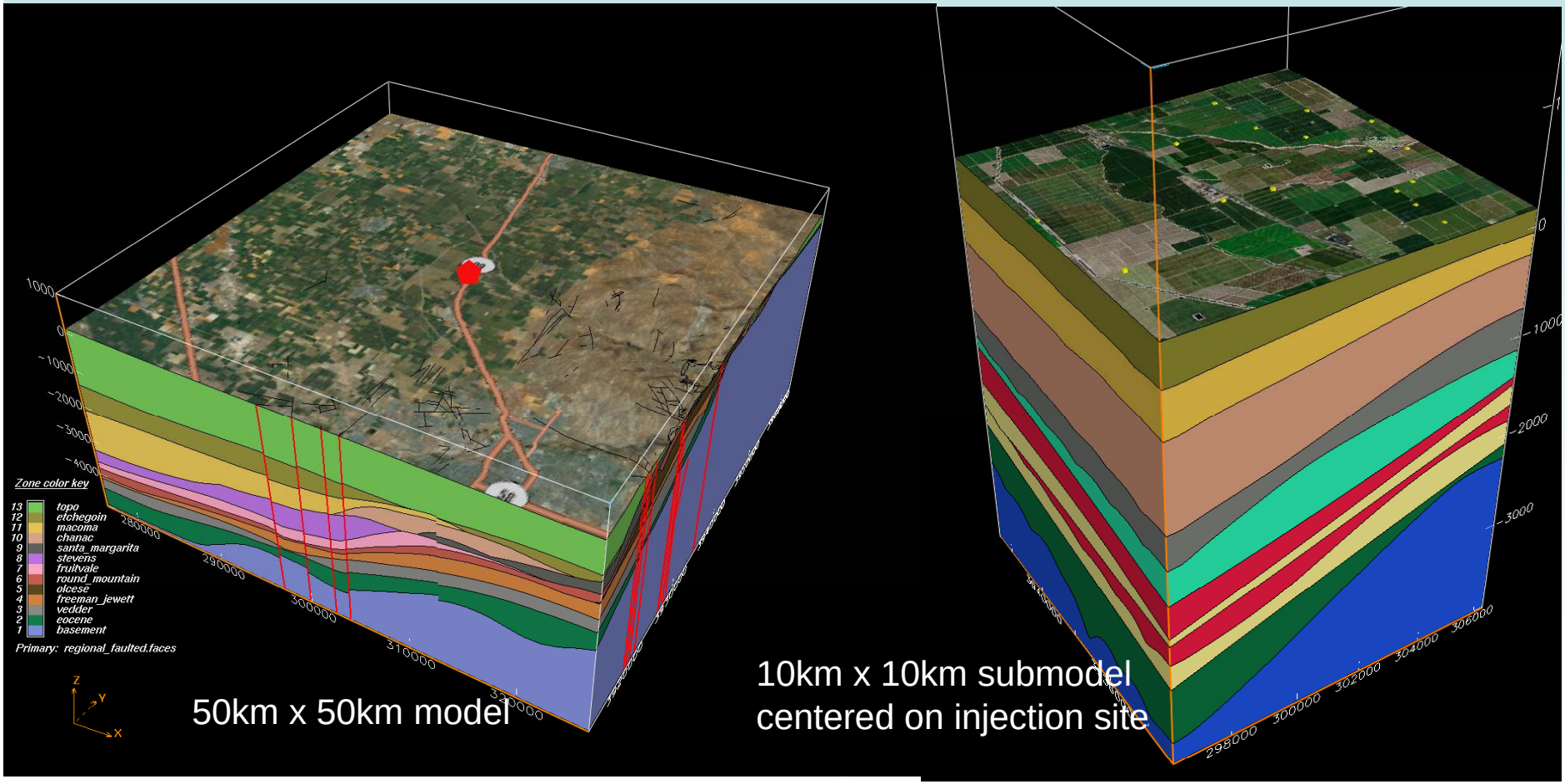
Outreach and Education

- 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





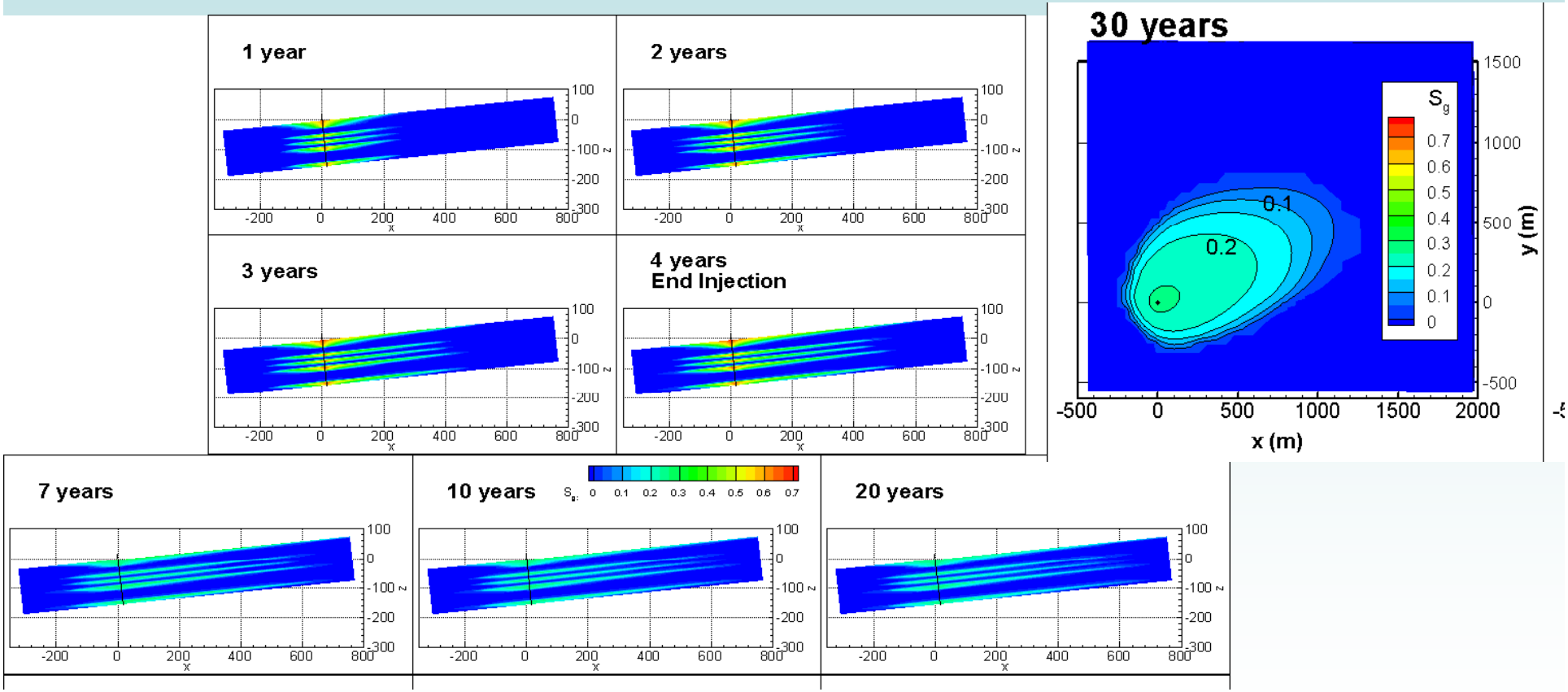
Existing Wells Provide Data for Initial Geologic Model



Initial geologic model centered on proposed Kimberlina project site near Bakersfield

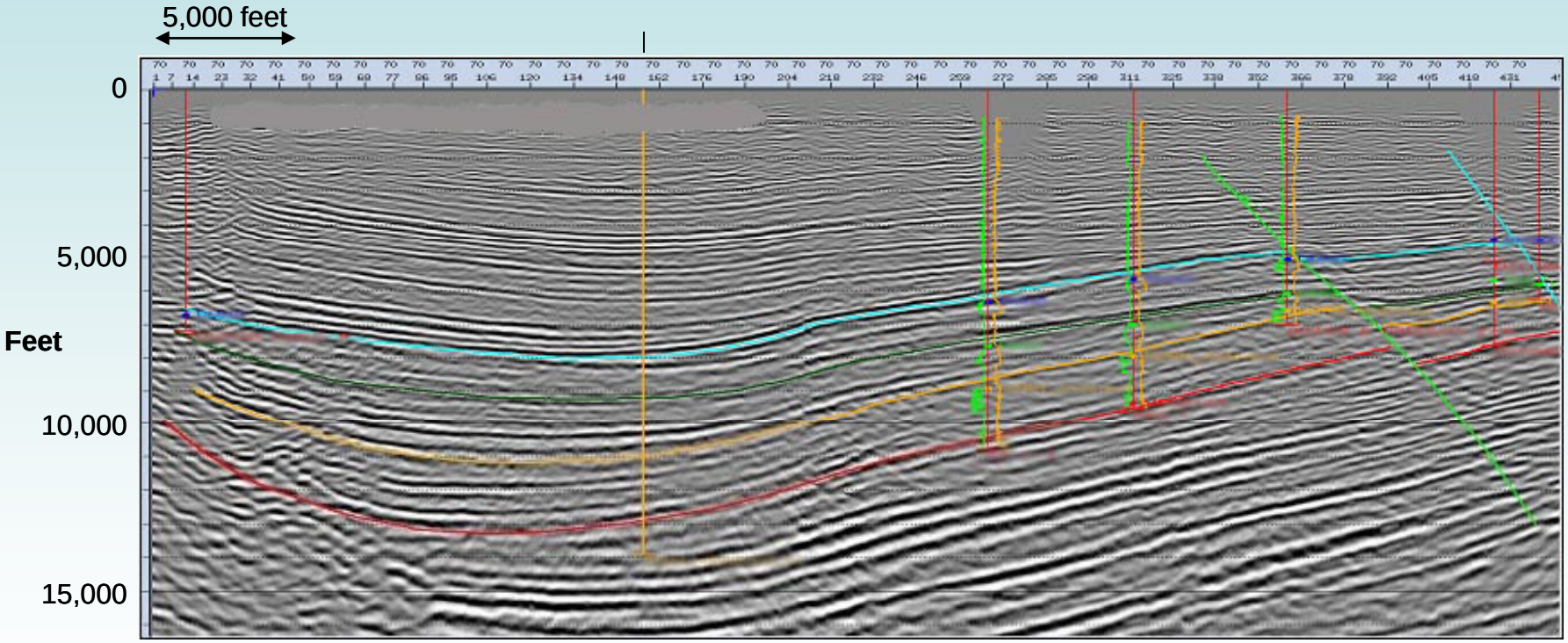
Source: Jeff Wagoner, LLNL

Simulations Show CO_2 Extent and Immobilization Over Time in Subsurface



Results of computer simulations of CO_2 in subsurface at Kimberlina project site
(Source: C Doughty, LBNL)

Seismic Data Provides Data on Geology Between Wells

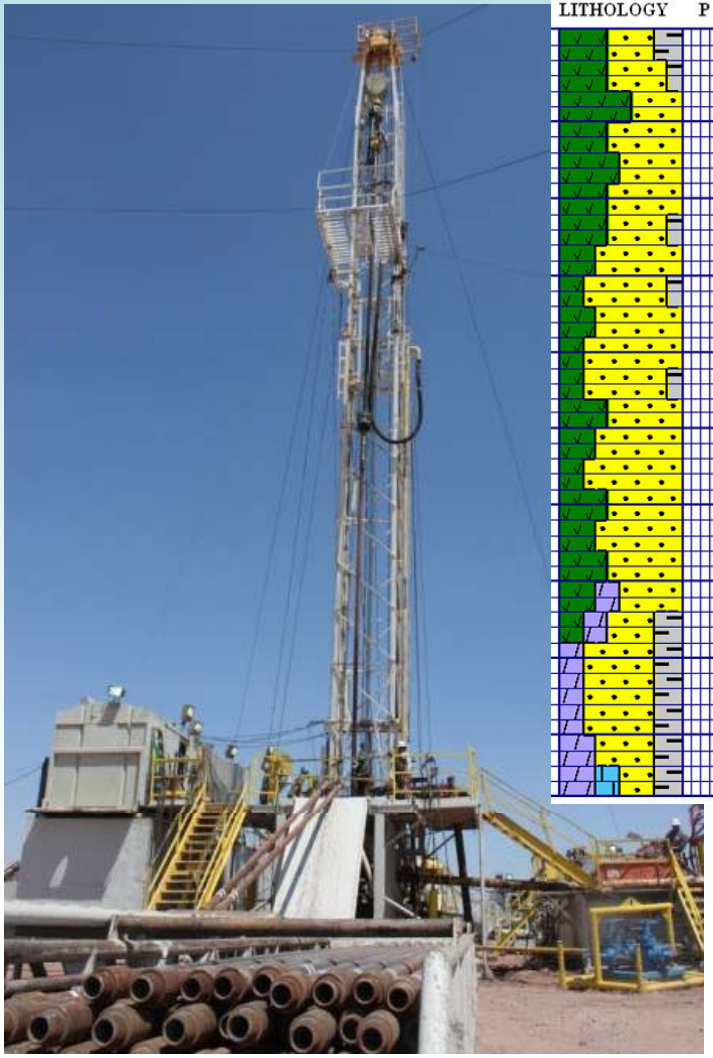


Source: Shell

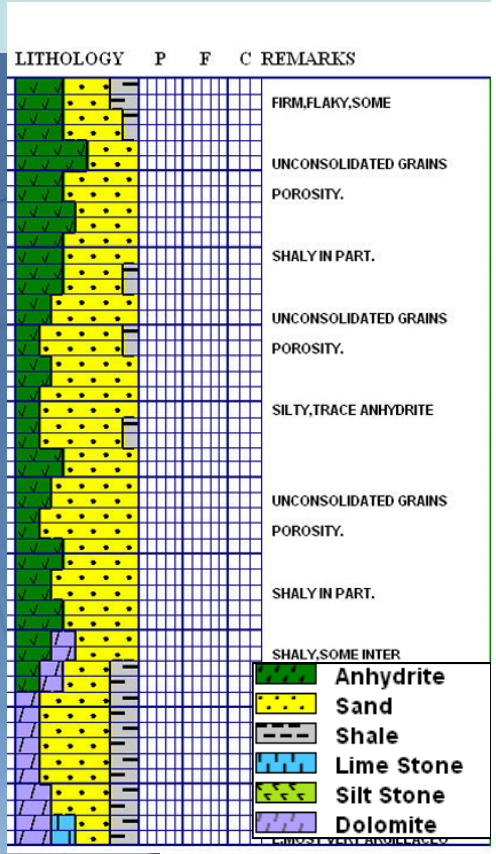
Seismic reflection data from northern California (Sacramento Basin) pilot project area

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



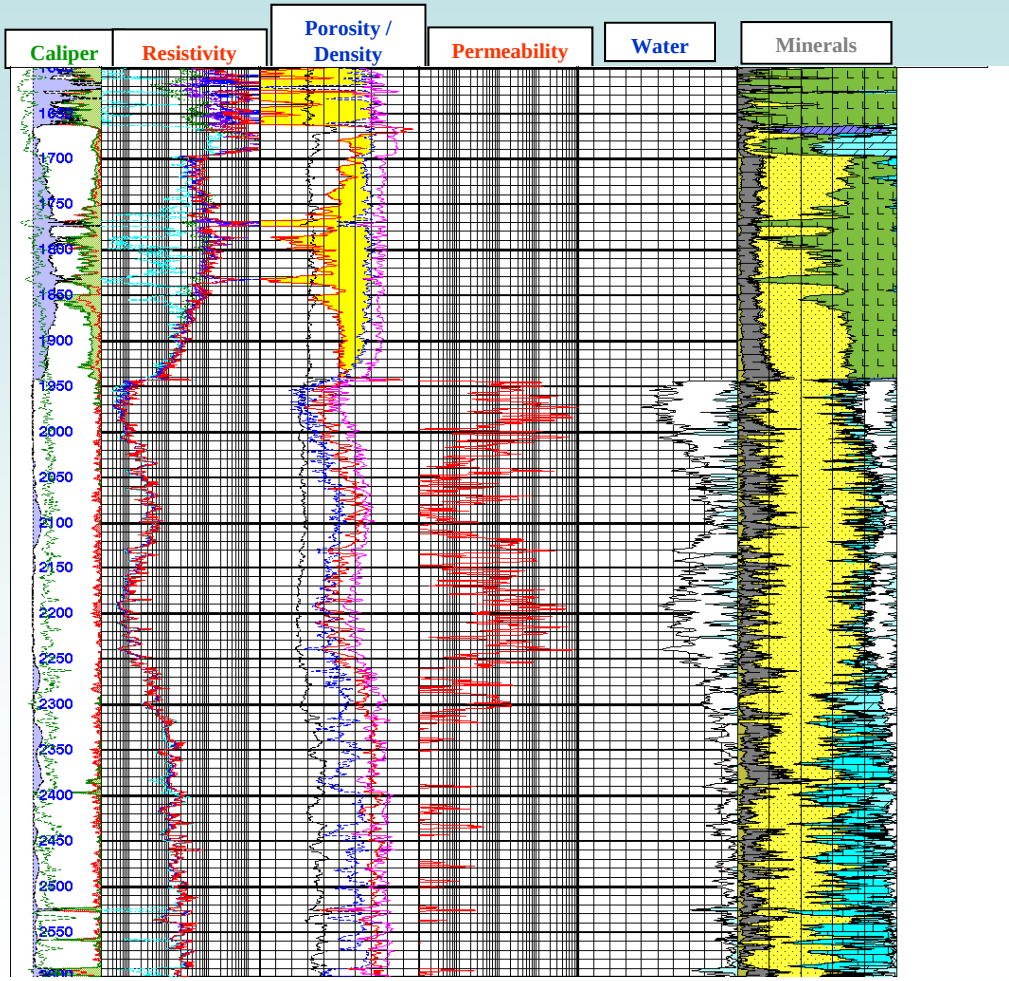
Well drilling at Arizona pilot site



"Mud Log"

Geophysical Well Logs Provide Formation and Fluid properties

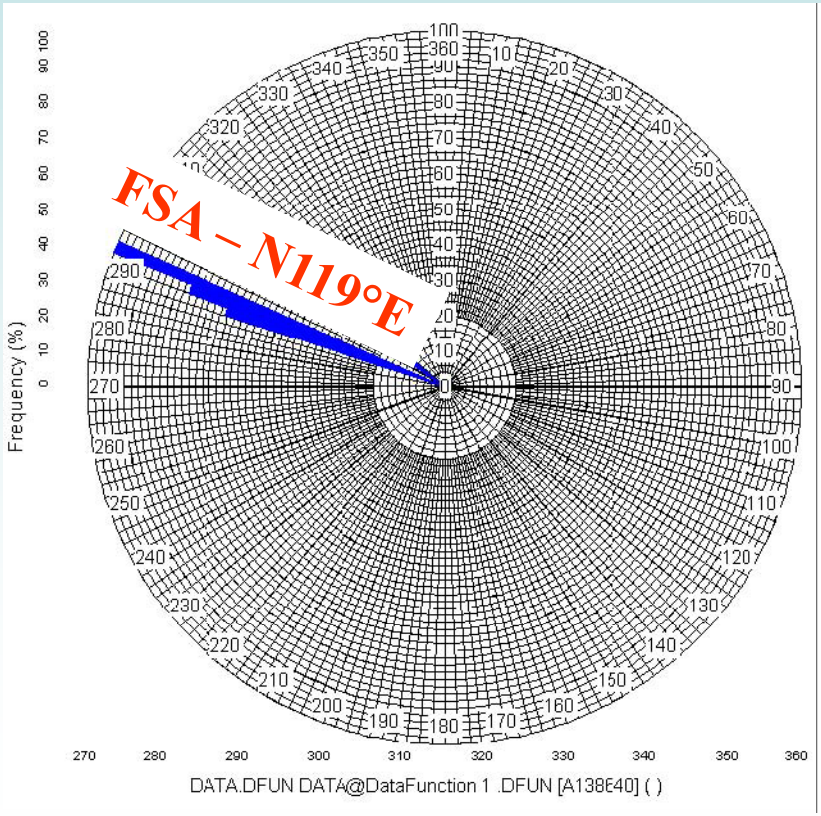
Schlumberger well log processing truck on location in Arizona (Photo: R. Trautz, EPRI)



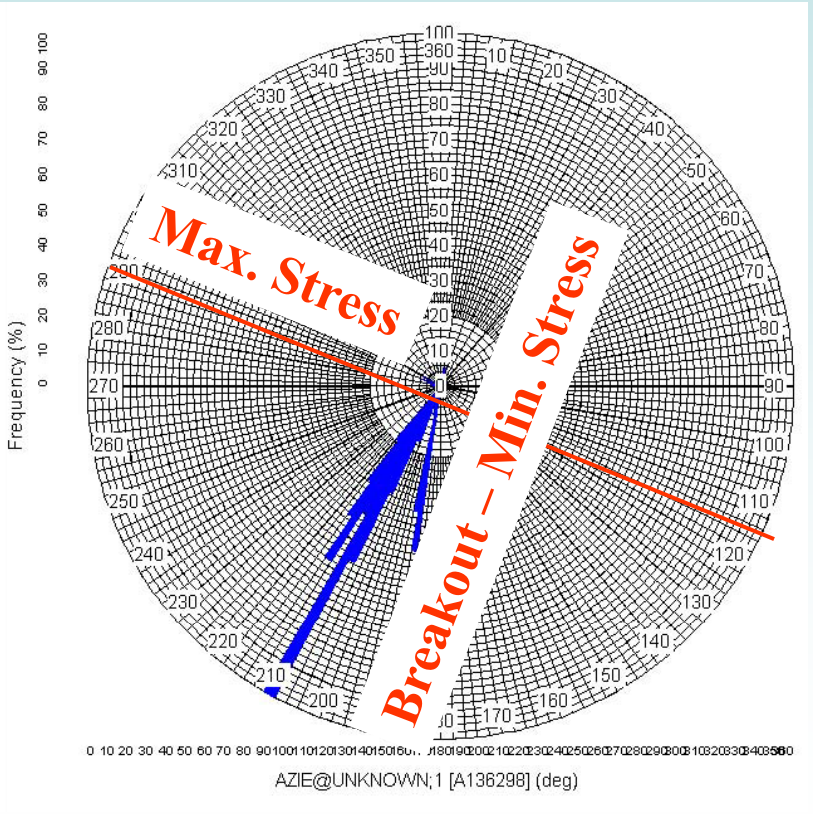
Example section of well logging results, Arizona well (Source: Schlumberger)

Data on Earth Stresses Derived from Well Logs

Rose diagram fast shear (FSA) direction



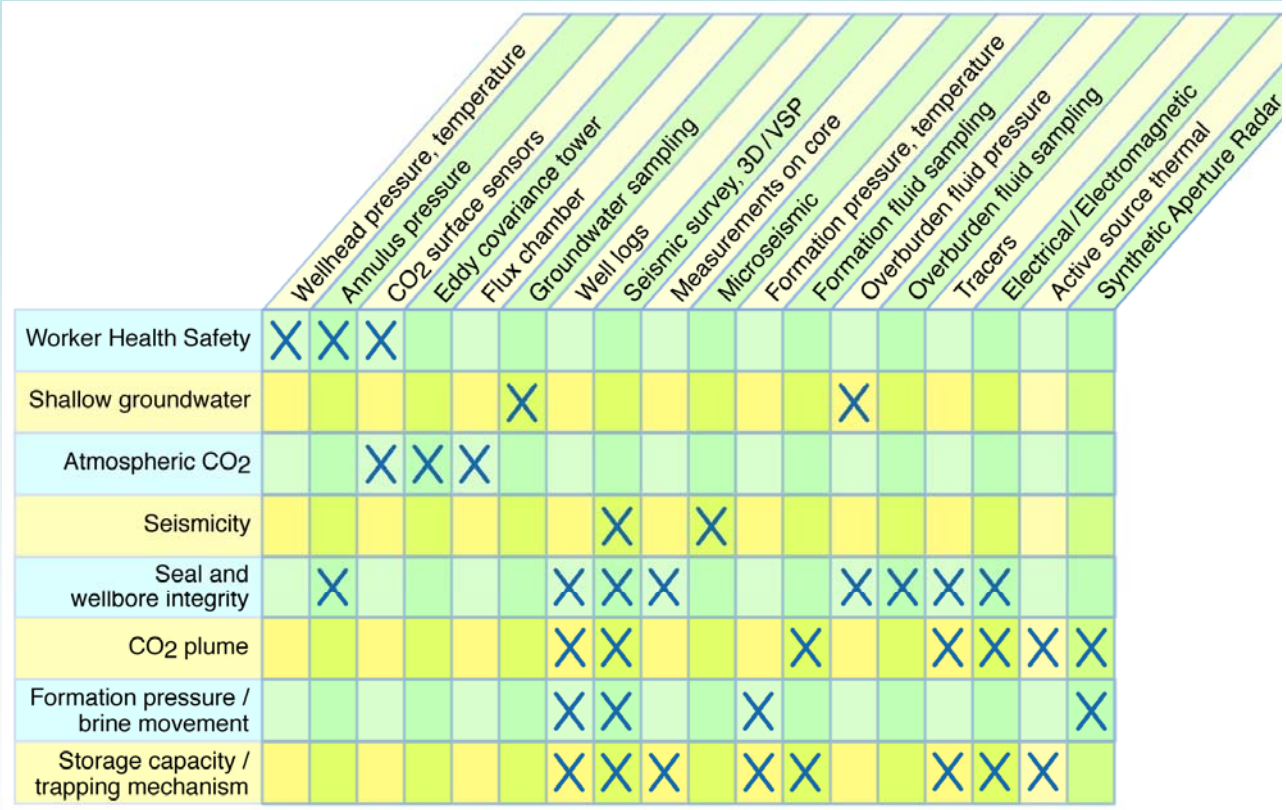
Rose diagram borehole enlargement



Source: Schlumberger

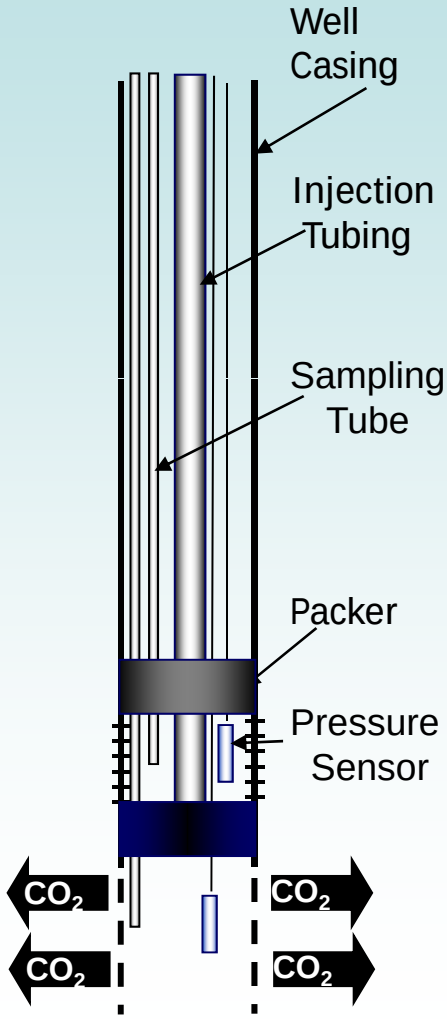
Multiple Methods Provide Data Monitoring Needs

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

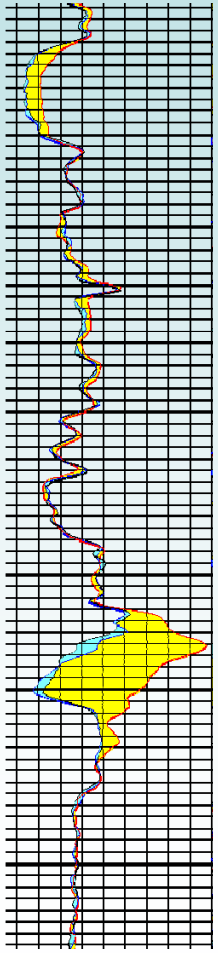


Pilot Tests Assess Geologic Seal Integrity to Assure Secure Storage

- 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 CO_2 injection



Pressure Monitoring

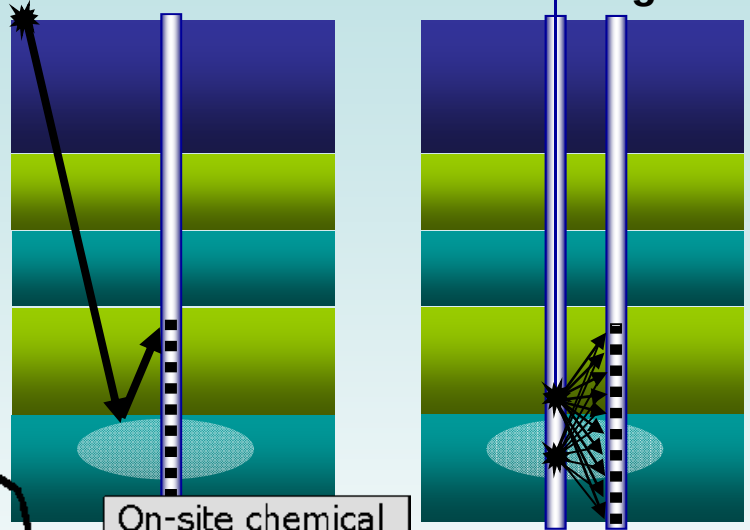


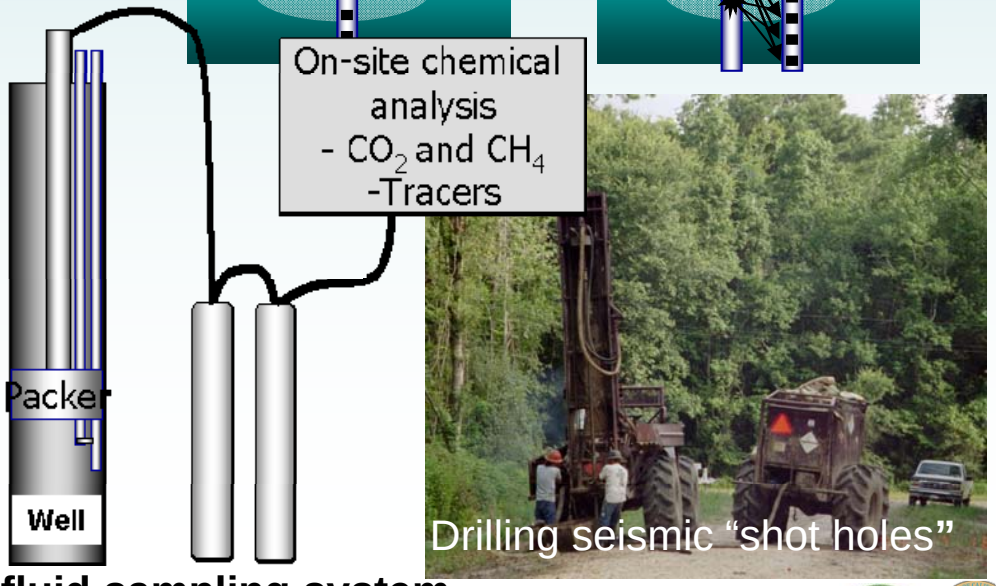
"RST" Log

Pilot Tests Will Map the Underground Spread of Injected CO_2 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 – CO_2 arrival, fluid chemistry, tracers
- Comparison with computer predictions

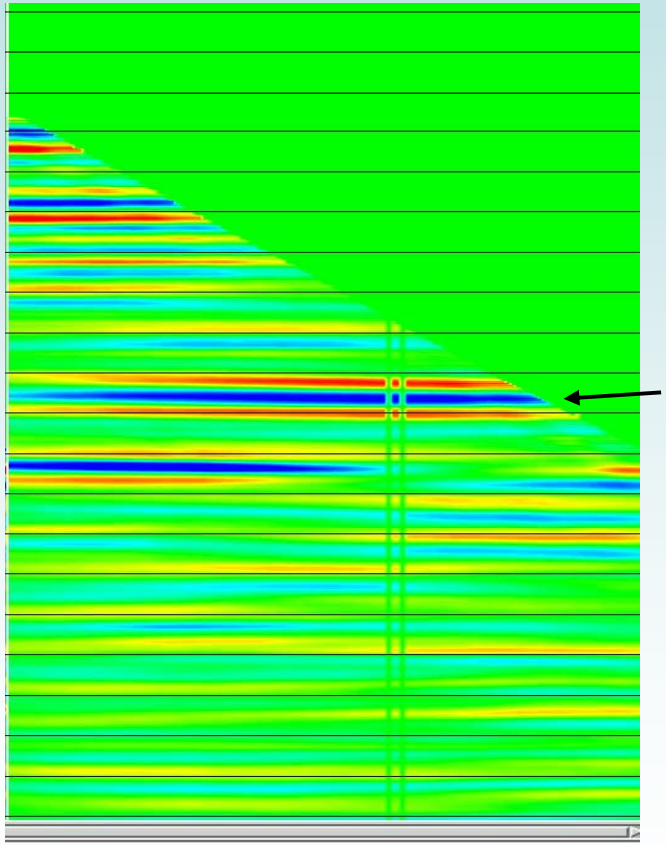
VSP and crosswell seismic configuration



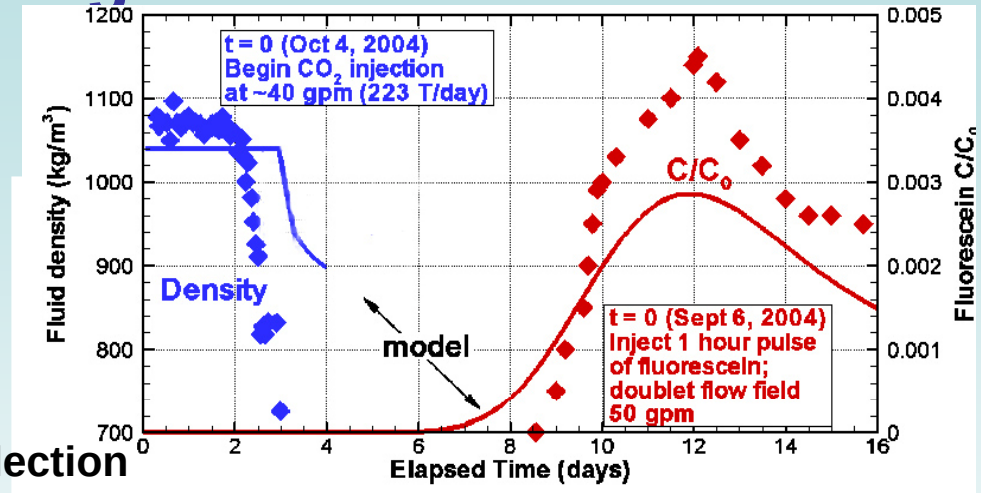


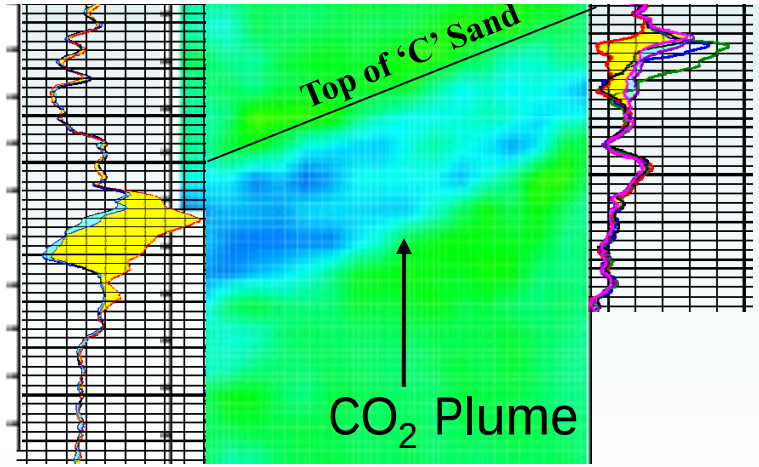
“U-tube” fluid sampling system

Pilots Test Methods Successfully Used in Other Geologic Settings



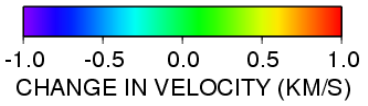
Reflection from layer containing CO_2





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

Injection Well

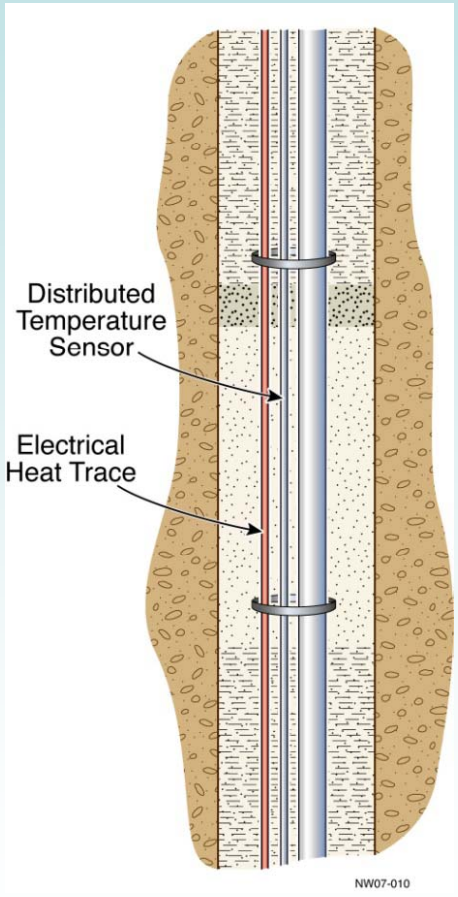


Monitoring Well

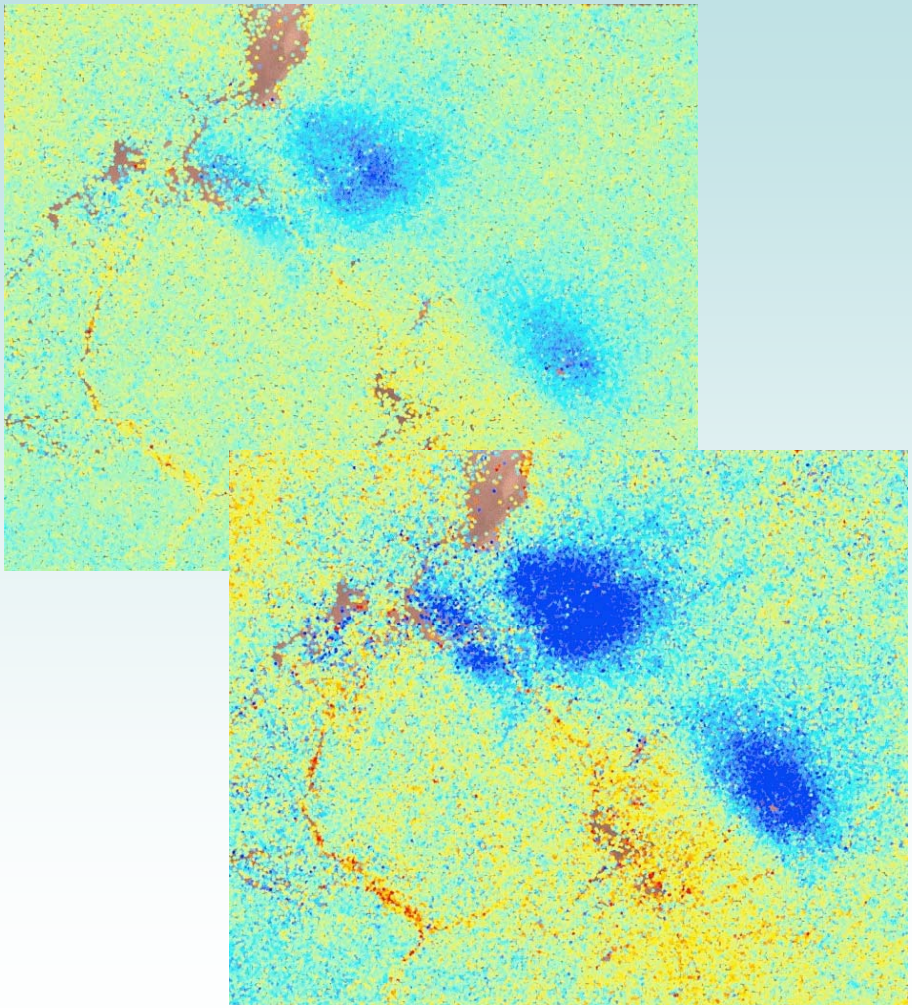
Summary

- 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 CO_2 saturation
(B. Freifeld LBNL)



Use of minute surface displacements to monitor subsurface pressure changes

Source: D. Vasco, LBNL