WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP
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WESTCARB Annual Business Meeting

Bakersfield, California
October 15-18, 2012

Geologic Characterization for CO_2 Storage in the Southwestern Sacramento Basin Based on Citizen Green Well Data

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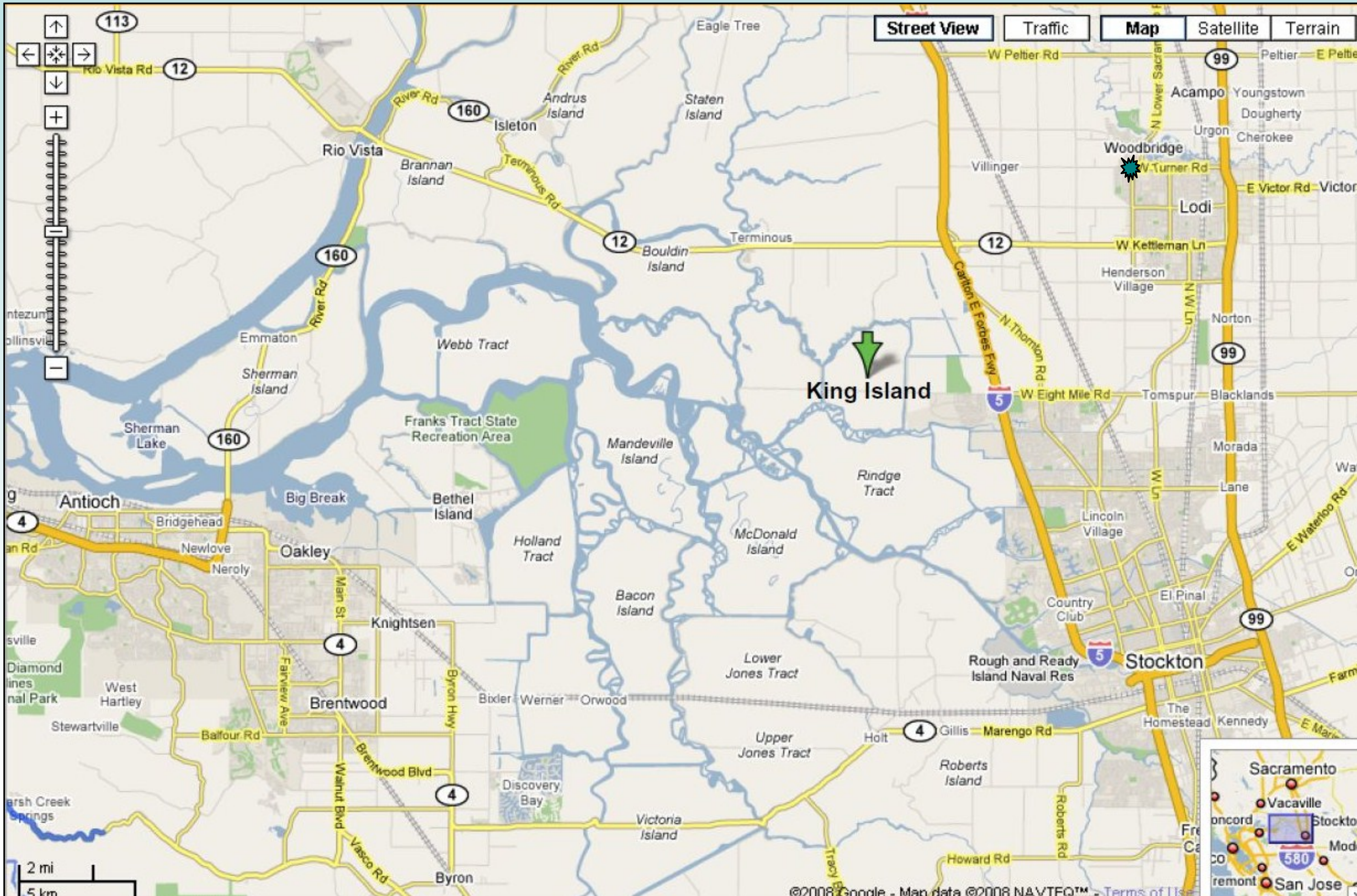
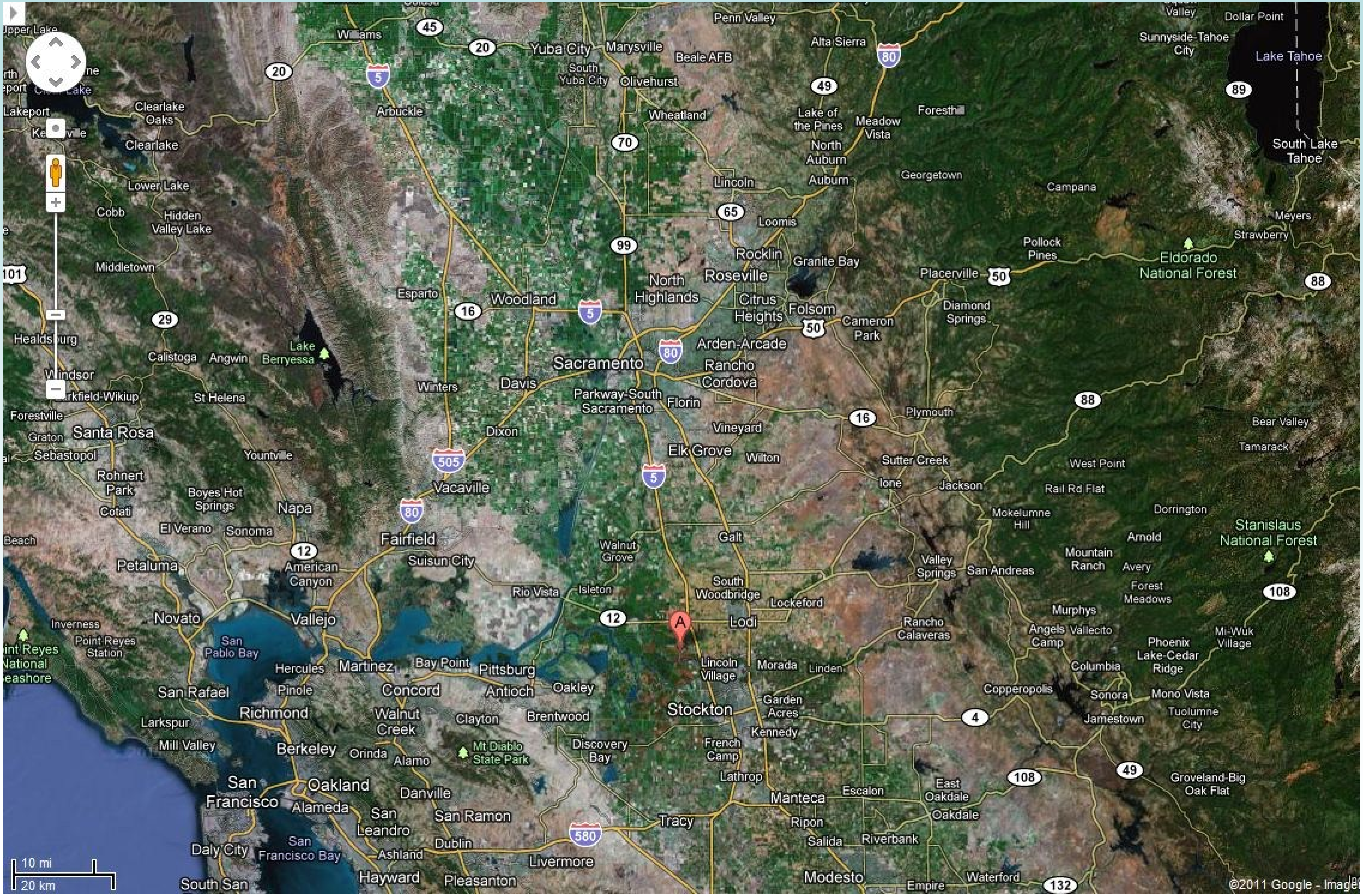
King Island Location in the Sacramento River Delta





Penn Valley
Dollar Point
Williams
Yuba City
Marysville
Beale AFB
Alta Sierra
Sunnyside-Tahoe City
Lake Tahoe
South Yuba City
Olivehurst
Clearlake Oaks
Arbuckle
Wheatland
Lake of the Pines
Meadow Vista
Foresthill
Lakeport
Clearlake
North Auburn
Auburn
South Lake Tahoe
Lower Lake
Lincoln
Georgetown
Campana
Cobb
Hidden Valley Lake
Loomis
Meyers
Strawberry
Rocklin
Granite Bay
Pollock Pines
Middletown
Roseville
Placerville
Eldorado National Forest
North Highlands
Esparto
Woodland
Citrus Heights
Folsom
Diamond Springs
Cameron Park
Calistoga
Angwin
Lake Berryessa
Arden-Arcade
Sacramento
Rancho Cordova
Windsor
Winters
Davis
St Helena
Parkway-South Sacramento
Florin
Forestville
Santa Rosa
Plymouth
Graton
Sebastopol
Dixon
Vineyard
Bear Valley
Elk Grove
Wilton
Tamarack
Yountville
Rohnert Park
Vacaville
Sutter Creek
West Point
Ione
Jackson
Rail Rd Flat
Boyes Hot Springs
Napa
Cotati
Mokelumne Hill
Dorrington
El Verano
Sonoma
Fairfield
Galt
Arnold
Stanislaus National Forest
Petaluma
Suisun City
Walnut Grove
Mountain Ranch
Avery
American Canyon
Valley Springs
San Andreas
South Woodbridge
Rio Vista
Isleton
Forest Meadows
Lockeford
Inverness
Novato
Vallejo
Murphys
Lodi
Rancho Calaveras
Angels Camp
Vallecito
Mi-Wuk Village
Point Reyes Station
San Pablo Bay
Phoenix Lake-Cedar Ridge
Hercules
Martinez
Bay Point
Pittsburg
Lincoln Village
Morada
Linden
Columbia
San Rafael
Pinole
Concord
Antioch
Oakley
Copperopolis
Sonora
Mono Vista
Richmond
Walnut Creek
Clayton
Brentwood
Stockton
Garden Acres
Larkspur
Jamestown
Tuolumne City
Mill Valley
Kennedy
Berkeley
Orinda
Alamo
Mt Diablo State Park
Discovery Bay
French Camp
San Francisco
Oakland
Lathrop
East Oakdale
Groveland-Big Oak Flat
Alameda
Danville
Manteca
Escalon
Oakdale
San Leandro
San Ramon
Tracy
Ripon
San Francisco Bay
Dublin
Salida
Riverbank
Daly City
Ashland
Livermore
Hayward
Pleasanton
Modesto
Empire
Waterford
South San
10 mi
20 km
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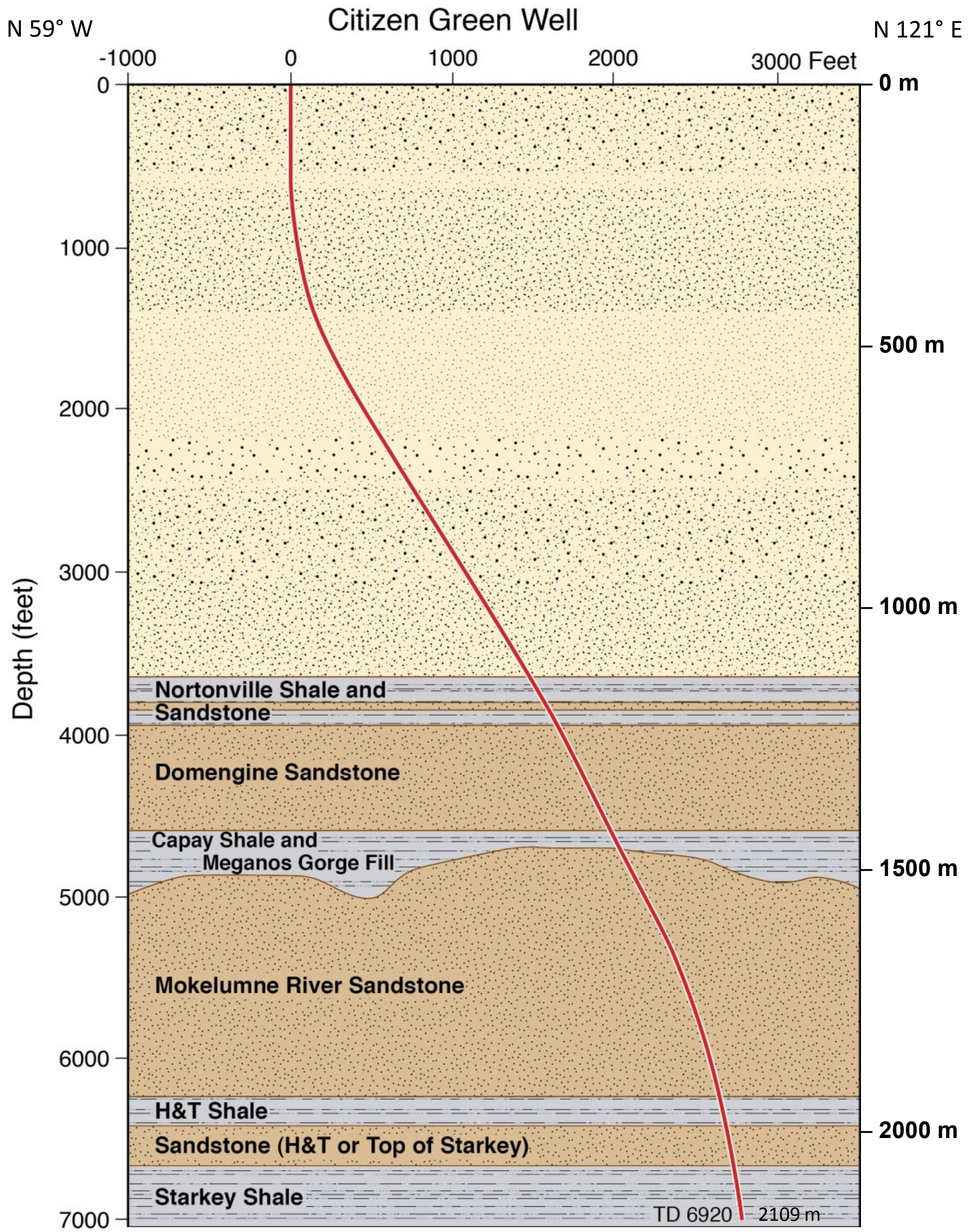
Citizen Green Well on King Island

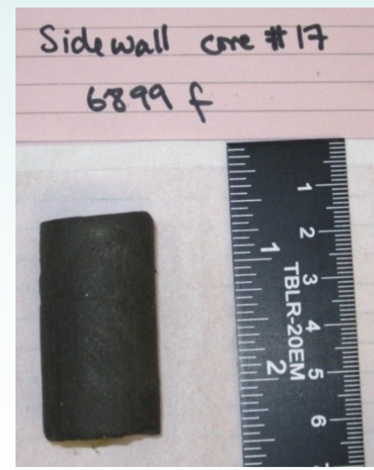
Geologic column for the deviated Citizen Green well on King Island, California



Topography of the top of the Mokelumne River Formation based on an interpretation of 3D seismic data by Tom Fassio

Equal horizontal and vertical scales

Whole core (3.5-inch diameter) recovered:
- 19 feet from the bottom of the Nortonville shale-top of the Nortonville sand
- 55 feet from the top of the Mokelumne River sandstone, mostly unconsolidated sand

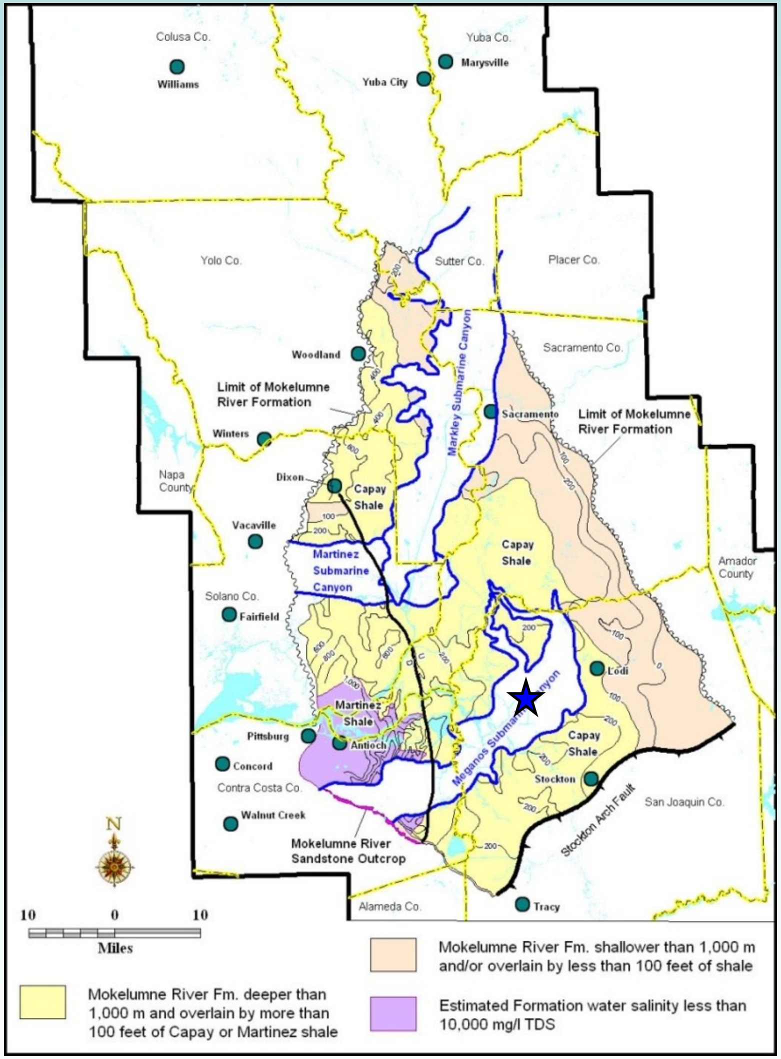


44 sidewall cores (1-inch diameter, ~2.5 inches long) recovered from all formations

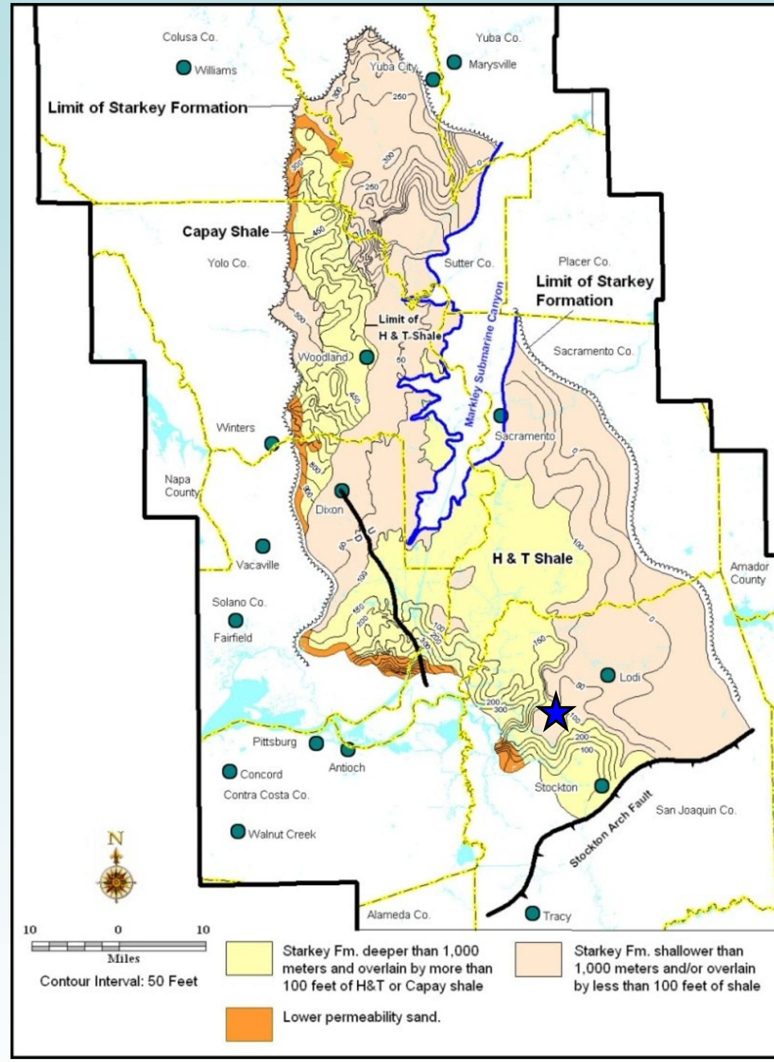
Many sandstone cores are unconsolidated

Side wall core #	Calculated Vertical depth (feet)	Calculated Vertical Depth (meters)	Formation	Sample Comments - Burton
50,49,48	3704	1129.0	Nortonville shale	core not recovered
47	3880	1182.6	Nortonville shale &	unconsolidated sand
46	4038	1230.8	Domengine sand	unconsolidated sand
45	4151	1265.2	Domengine ss	unconsolidated sand
44	4266	1300.3	Domengine ss	removed for entrained gas analysis
42	4490	1368.6	Domengine ss	unconsolidated sand
41	4572	1393.5	Domengine ss	unconsolidated sand
40	4605	1403.6	Capay shale	unconsolidated shale
39	4612	1405.7	Capay shale	a very small piece of shale
38	4632	1411.8	Sand in Capay	unconsolidated sand
37	4653	1418.2	Capay shale	unconsolidated shale
35	4685	1428.0	Capay shale	unconsolidated silty sand
34	4813	1467.0	Mokelumne ss	unconsolidated silty sand
33	5189	1581.6	Mokelumne ss	unconsolidated sand
32	5254	1601.4	Mokelumne ss	unconsolidated silty sand
31	5423	1652.9	Mokelumne ss	unconsolidated sand
30	5451	1661.5	Mokelumne ss	unconsolidated sand
29	5487	1672.4	Mokelumne (shaley)	clay-siltstone layer, removed for entrained gas analysis
28	5558	1694.1	Mokelumne ss	unconsolidated sand
27	5621	1713.3	Mokelumne ss	unconsolidated sand
26	5656	1723.9	Mokelumne ss	hard core, but not well consolidated
25	5718	1742.8	Mokelumne ss	unconsolidated sand
24	5782	1762.4	Mokelumne ss	hard core-silty sand
23	5843	1780.9	Mokelumne ss	hard core-silty sand
22	5907	1800.5	Mokelumne ss	hard core-silty sand
21	5972	1820.3	Mokelumne ss	hard core-silty sand

Side wall core #	Calculated Vertical depth (feet)	Calculated Vertical Depth (meters)	Formation	Sample Comments - Burton
20	6036	1839.8	Mokelumne ss	hard core-silty sand
19	6165	1879.1	Mokelumne ss	hard core-silty sand; not convincingly shale; gradational contact from Moke to H&T
18	6203	1890.7	H&T shale	hard core-sandy shale
17	6262	1908.7	H&T shale	definitely shale; removed for entrained gas analysis
16	6283	1915.1	H&T shale	hard core-shaly, marly?
15	6300	1920.2	H&T shale	hard core-sand
14	6315	1924.8	H&T shale	1 piece partial-shale
13	6334	1930.6	H&T shale	sand stringer; core not recovered
12	6354	1936.7	H&T shale	hard core pieces-shale
11	6370	1941.6	H&T shale	hard core pieces-sand
10	6426	1958.6	H&T sand	hard core-sand
9	6464	1970.2	H&T sand or shale	hard core-sand; shale stringer or still in H&T shale?
8	6496	1980.0	H&T sand	hard core-sand
7	6530	1990.3	H&T sand or shale	hard core-sand with shale
6	6585	2007.1	H&T sand	sand; removed for entrained gas analysis
5	6614	2015.9	H&T sand	hard core-sand
4	6666	2031.8	Starkey shale	hard core-shale
3	6704	2043.4	Starkey shale	removed for entrained gas analysis
2	6738	2053.7	Starkey shale	2 large pieces and 1 small hard core-shale
1	6775	2065.0	Starkey shale	hard core-shale
TD	6920	2109.2	in Starkey shale	



Capay shale and Mokelumne River sandstone

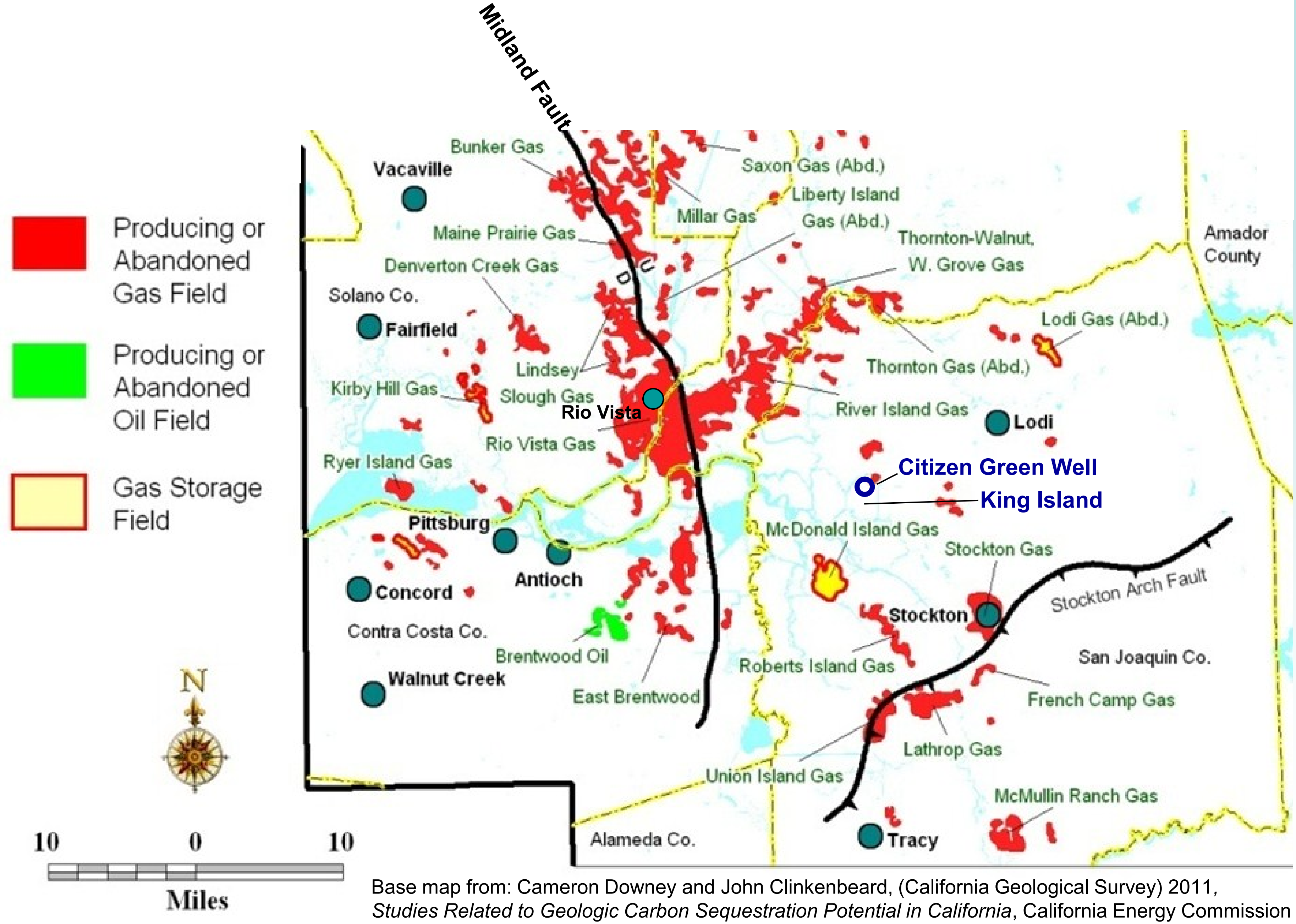


H&T shale and Starkey sandstone

At King Island, the Mokelumne River sandstone is gas-bearing in a pinnacle in the Meganos Gorge. The Capay shale overlies the pinnacle. The Domengine and Starkey sandstones are not intruded by the gorge. The well penetrated these potential reservoir formations and overlying shale seals.

★ Citizen Green well on King Island

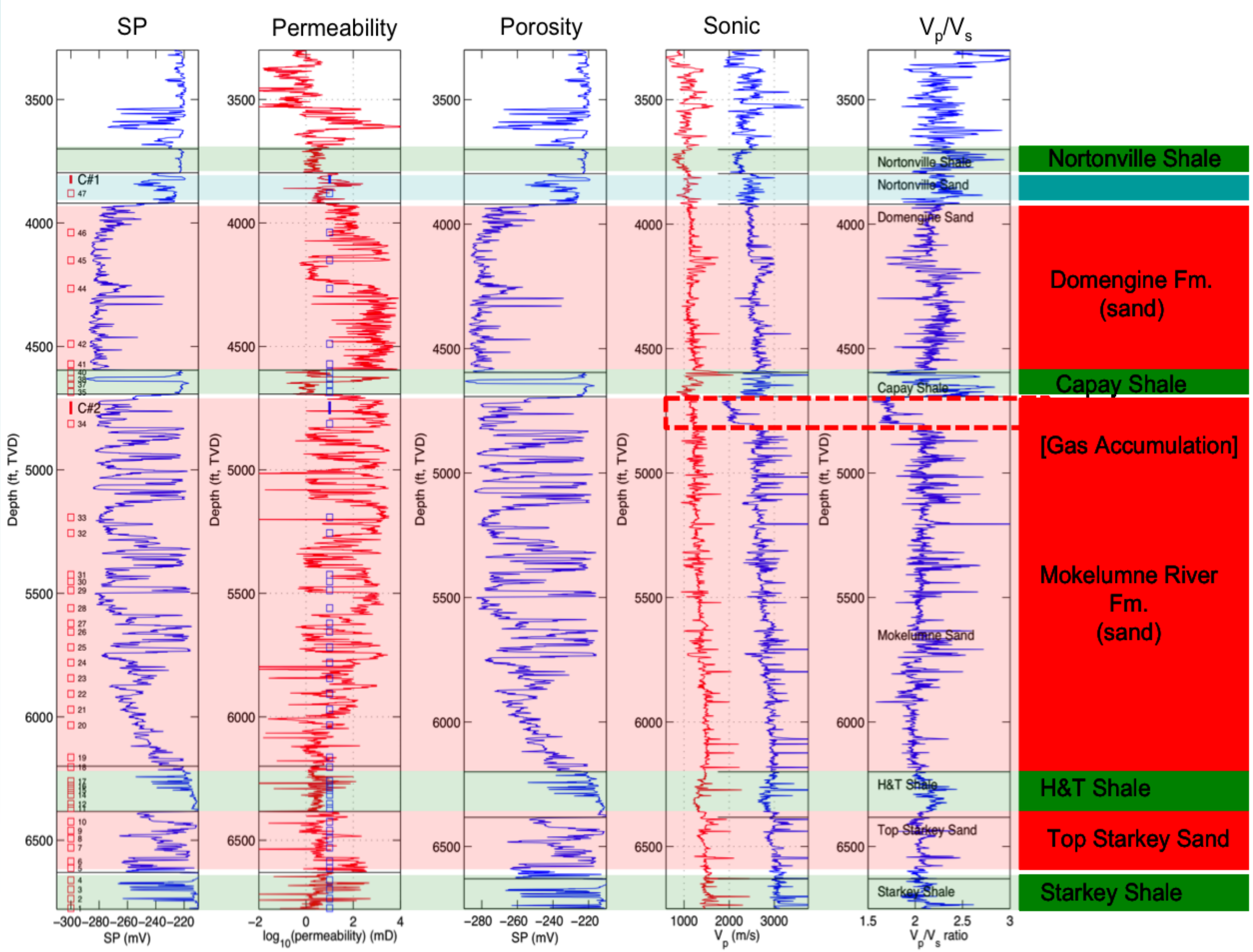
Reference: Downey, Cameron, John Clinkenbeard, (California Geological Survey) 2011, *Studies Related to Geologic Carbon Sequestration Potential in California*, California Energy Commission



Base map from: Cameron Downey and John Clinkenbeard, (California Geological Survey) 2011, *Studies Related to Geologic Carbon Sequestration Potential in California*, California Energy Commission

Schlumberger Logs Run

- Platform Express
- Elemental Capture Sonde
- Sonic Scanner
- Combinable Magnetic Resonance (CMR)
- Formation Microimager (FMI) (We can select up to 1000 feet of images)



- Could not run MDT tool to collect water samples.
- Gas column observed in the upper Mokelumne River Fm.
- Several high quality reservoirs and seals identified.

Citizen Green Well Data Analysis To-Date

Jonathan Ajo-Franklin

- Core sample porosity/permeability measurements correlated with well log NMR pore/perm data and thin section analysis
- Virtual petrophysical analysis and permeability modeling based on 3D micro CT imaging

Tim Kneafsey & Seiji Nakagawa

- CT scans of CO_2 and brine injections into a Domengine Formation core
- Seismic velocity and electrical resistivity measurements during CO2 injection

Mark Conrad

- Mineralogical analysis of thin sections

Curt Oldenburg & Christine Doughty

- Multi-phase flow of simulations of CO_2 injection into the Mokelumne River Sandstone

Citizen Green Well Data Analyses Not Yet Started

WESTCARB is seeking water samples from deep wells in the King Island area for geochemical experiments.

Kevin Knauss

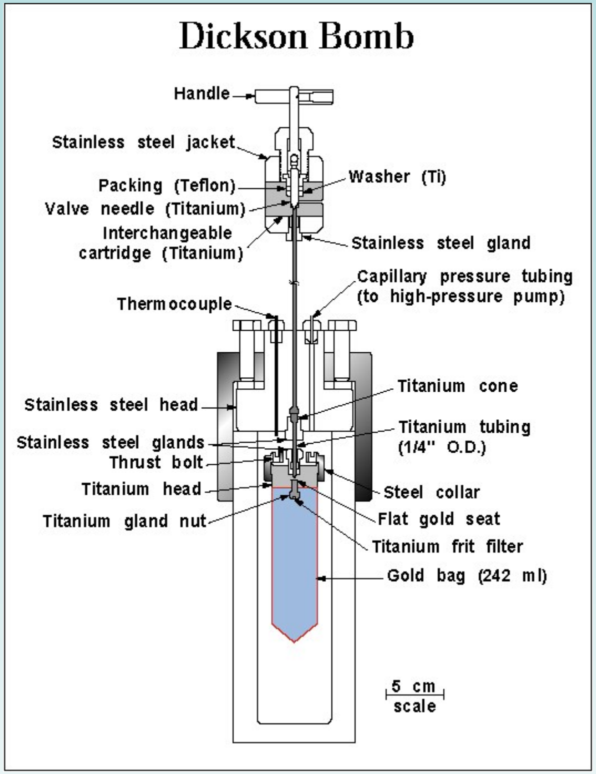
- High temperature/high pressure laboratory experiments to determine long-term geochemical interactions among the reservoir rock, CO_2, and brine

Nic Spycher

- Reactive transport simulation of injected CO_2 flow and trapping, considering geochemical reactions among the reservoir rock, CO_2, and brine

High Temperature/High Pressure Geochemical Laboratory Experiments

Kevin Knauss



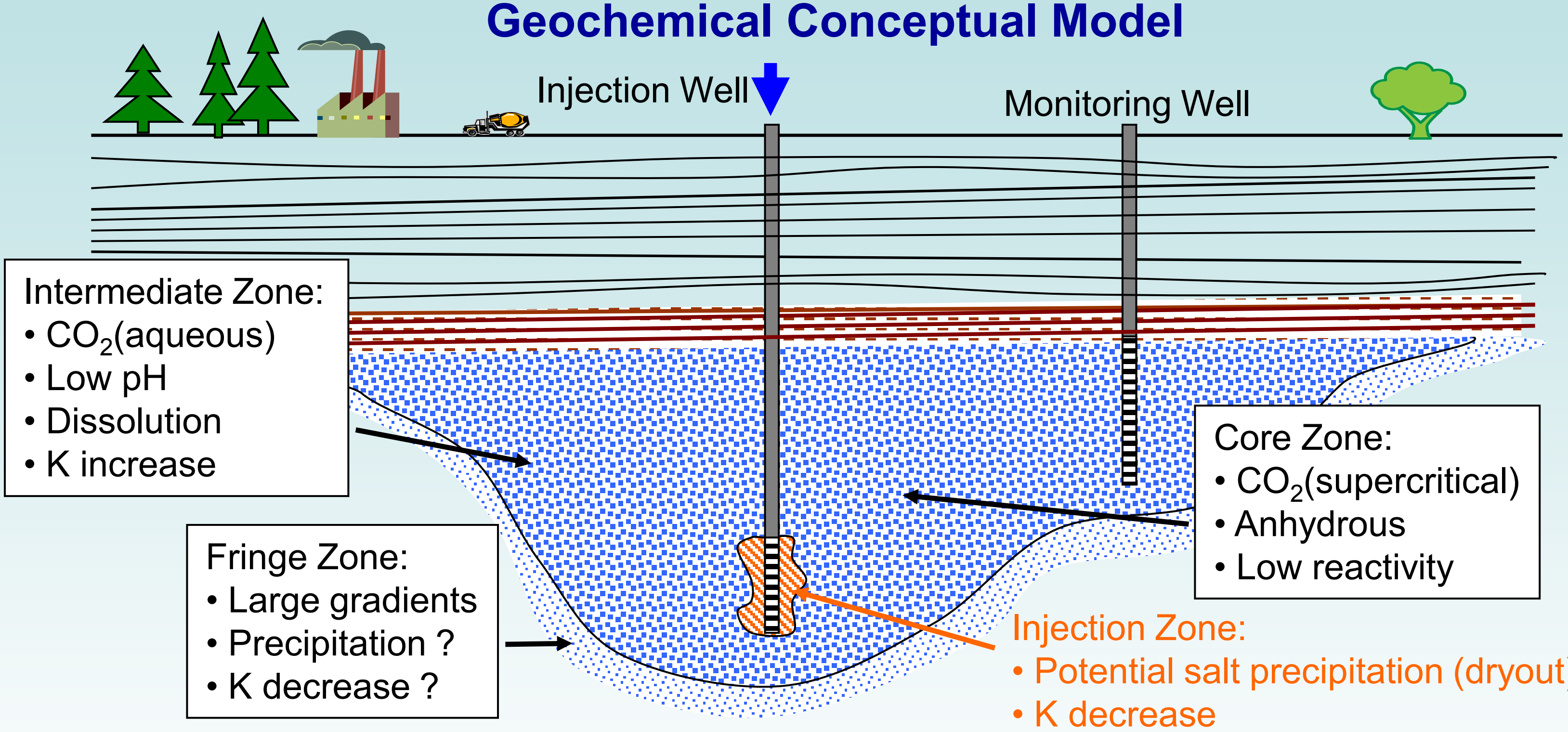
Laboratory experiments on long term geochemical interactions among core, synthetic formation fluid, and CO_2. These interactions determine the transport and fate of CO_2 in the deep subsurface.

Experiments are run at reservoir T and P, or higher T in the case of "accelerated" tests designed to maximize possible interactions. Geochemical reaction simulators are used to both design and interpret experiments. All work is closely coupled to the modeling effort at LBNL.

Reactive transport simulation of CO_2 Injection

Nic Spycher

Geochemical Conceptual Model



Geochemical Processes to Consider

- Multiphase fluid flow (CO_2/H_2O)
- Mutual CO_2/H_2O solubility
- Aqueous- and gas-phase transport
- Porosity-permeability coupling
- Multicomponent reactions
  - Mineral precipitation/dissolution
  - Aqueous complexation
  - Surface complexation (as needed)
  - Gas dissolution/exsolution