



# WESTCARB Annual Business Meeting

## Arizona Utilities CO<sub>2</sub> Storage Pilot

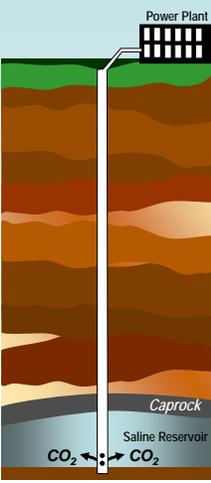
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John Boyer,<sup>3</sup> Daniel Collins,<sup>4</sup> Dennis Shirley,<sup>5</sup> Kirk Delaune<sup>4</sup>**

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Scottsdale, AZ  
September 15–17, 2009



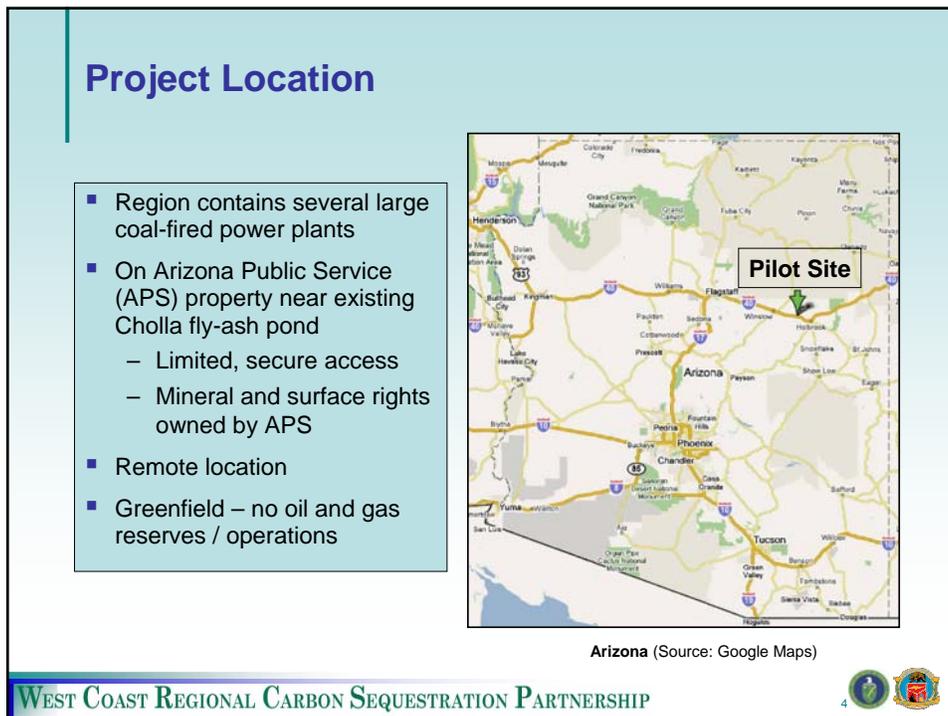
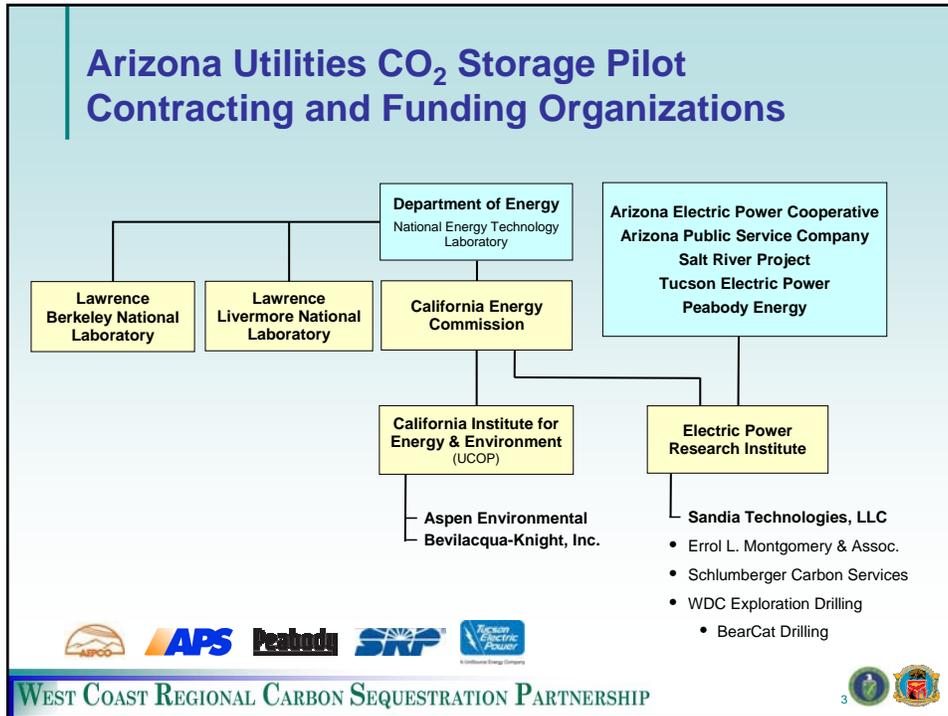
## Purpose and Objectives



- **Purpose:** Locate and test suitable geological sequestration sites in proximity to large coal-fired power plants in northeast Arizona
- **Target:** Naco and Martin Formations - Deep saline formations in Colorado Plateau
- **Objectives:**
  - Investigate efficacy of geologic storage in northeast Arizona
  - Validate reservoir models used to estimate injectivity, storage capacity, and long-term fate of injected CO<sub>2</sub>
  - Work with state, local and federal agencies to develop permitting framework for GS
  - Foster public education and outreach
  - Inject 2,000 tons of CO<sub>2</sub>

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## Drill Site Location



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## Drilling and Well Completion Operations

### Site Preparation



### Pre-Site Construction

View to the North-Northeast  
(Photo source: R. Trautz, LBNL)



### Graded Drill Pad

View to the Northwest  
(Photo source: R. Trautz, EPRI)

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## Surface Hole/Casing Installation (959 ft) Dual-Wall Reverse Air Circulation



WDC Exploration setting up drilling equipment  
(Photo source: K. Delaune, Sandia Technologies)



Running surface Casing to 959 ft  
(Photo source: K. Delaune, Sandia Technologies)

**Purpose:** Surface casing isolates potable shallow groundwater from potential contamination from surface water or fluids from deeper zones



## 8½ inch Protection Hole (959 - 3,853 ft TD) Conventional Mud Rotary



**Clockwise from Top Left:**

- Well cellar installation (Photo source: K. Delaune, Sandia Tech.)
- Well cellar completion (Photo source: K. Delaune, Sandia Tech.)
- BearCat #2, 24/7 drilling operations (Photo source: R. Trautz, EPRI)



## Open-Hole Logs (Schlumberger) Formation Evaluation



Hoisting downhole geophysical logging tool into well  
(Photo source: R. Trautz, EPRI)



Schlumberger wireline processing truck on location  
(Photo source: R. Trautz, EPRI)

Purpose: Open-hole geophysical logs are used to evaluate formation & fluid properties.

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## Drill Stem Tests (DST) - Formation Evaluation



Bulldog Tester's DST assembly  
prior to installation



Upper pressure / temperature gauge assembly  
(Photo source: all R. Trautz, EPRI)

Supai Formation showing  
good "Blow" during DST



Purpose: Drill stem tests are used to measure formation productivity and collect fluid samples.

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## 5½ inch OD Protection Casing (TD 2,504 ft)



Pipe rack - 3,800 ft protection casing  
(Photo source: R. Trautz, EPRI)

Purpose: Long-string casing system isolates injection or producing zones from other formations or zones



## Well Completion Summary

### Casing Completion

Conductor Casing  
14 in. OD to 35 ft.

Surface Casing  
25 joints of casing  
9-5/8-inch OD, 36 lb/ft,  
Grade J-55, STC connection

Protection Casing  
63 joints of casing  
5-1/2 inch OD, 15.50  
lb/ft Grade J-55  
APISCT

### Cement Completion

12 ¼ in. surface hole

178 sacks (67 bbl) lead cement mixed at 12.5 lb/gal density  
69 sacks (14.4 bbl) tail cement mixed at 15.5 lb/gal density  
959 ft

8 ½ in. protection hole

342 sacks of 75/25 TXI/G lead cement + additives, mixed at  
11.7 lb/gal. Cement volume pumped was 35% excess over  
open-hole caliper.  
267 sacks of tail cement, Lite-Crete + additives, mixed at 12.5  
lb/gal. Cement volume pumped was 20% excess over open-  
hole caliper.

2,504 ft

Balanced cement plug 2,505 – 2,683 ft.

Total Depth 3,853 feet



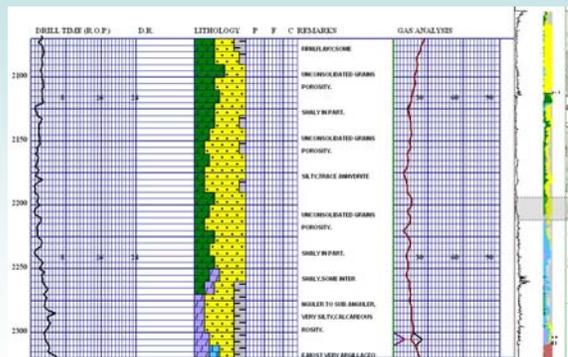
## Reservoir Characterization

- Mud logs (0 – 3,853 ft)
- Rotary side-wall cores (25)
- Open-hole logs (Schlumberger)
- Drill-stem tests
- Martin and Supai)
- Fluid samples
  - Base of Coconino Formation, > 3,000 EC
  - Supai Formation, 145,000 ppm total chlorides

## Mud Logs (0 – 3,853 ft)

### Primary drilling record

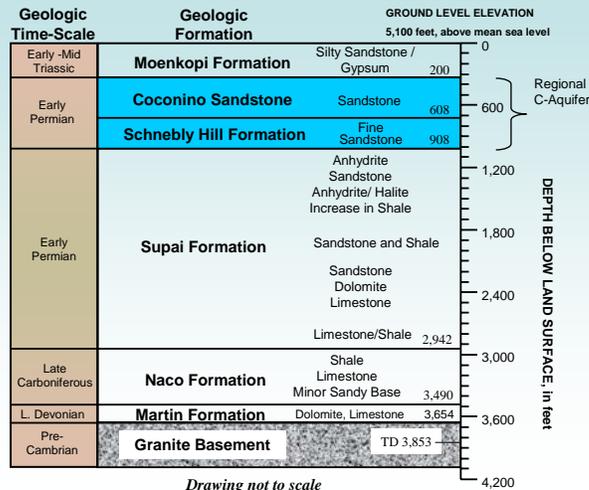
- Drilling parameters
  - Rate of penetration (ROP)
  - Mud properties
  - Mud use and lost circulation
- Geology
  - Formation tops
  - Lithology
  - Fractures, vugs
  - Qualitative properties (porosity description)
- Gas analysis
  - Hydrocarbons
- Measurement Uncertainty



Partial mud log for the Supai Formation (2,075-2,340 ft)  
(Source: Suttles Logging, Inc.)

## Geologic - Interpretation

- General coursing of sediments upward
  - Very little sand in deep section
- Supai Formation
  - Thick seal
  - Alternating layers of anhydrite and shale
- Naco and Martin Formations
  - Marine deposition
  - Limestone, dolomite and shale



Drawing not to scale  
(Source: modified after EM&A cross-section)



## Rotary Side-Wall Cores (Results Pending)



### INVENTORY OF ROTARY CORE ANALYSES SAMPLES

Sandia Technologies Navajo County, AZ  
Cholla CO2 Test 1 Fee Well File: H44837  
Cholla Plant Field Date: 09-03-09



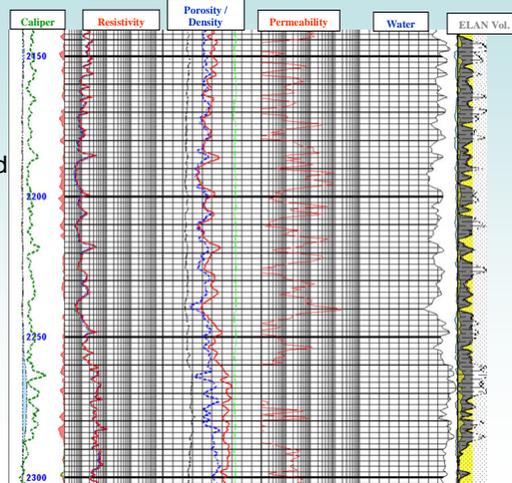
Sample Number	Sample Depth, feet	Approximate Sample Length, inches	Grain Density + Ambient Porosity	Permeability to Air and Porosity	Sample Condition	Conventional Analysis (k, phi, density)	Photograph White Light	Photograph White Light (add sets)	X Ray Diffraction	Thin Section Prep Only
1-1R	1340.00	1.5	+	+	cyf	1	1	4	1	
1-2R	2140.00	1.7	+	+	cyf	1	1	4		
1-3R	2191.00	1.6	+	+	cyf	1	1	4		1
1-4R	2240.00	1.7	+	+	cyf	1	1	4		1
1-5R	2682.00	1.7	+	+	cyf	1	1	4	1	
1-6R	3069.00	1.6	+	-	frac	1	1	4	1	
1-7R	3191.00	1.7	+	+	cyf	1	1	4	1	
1-8R	3259.00	1.6	+	+	cyf	1	1	4		
1-9R	3301.00	1.8	+	+	cyf	1	1	4		
1-10R	3322.00	1.7	+	+	cyf	1	1	4	1	
1-11R	3433.00	1.1	+	+	cyf	1	1	4	1	1
1-12R	3468.00	1.5	+	+	cyf	1	1	4		
1-13R	3492.00	1.3	+	+	cyf	1	1	4		
1-14R	3521.00	1.5	+	+	cyf	1	1	4		1
1-15R	3526.00	1.3	+	+	cyf	1	1	4		
1-16R	3538.00	1.4	+	+	cyf	1	1	4		
1-17R	3546.00	1.8	+	+	cyf	1	1	4	1	
1-18R	3585.00	1.6	+	+	cyf	1	1	4		
1-19R	3588.00	1.5	+	+	cyf	1	1	4		1
1-20R	3600.00	1.5	+	+	cyf	1	1	4		
1-21R	3613.00	1.5	+	+	cyf	1	1	4		
1-22R	3653.00	1.4	+	+	cyf	1	1	4		
1-23R	3654.00	1.7	+	+	cyf	1	1	4		
1-24R	3678.00	1.5	+	+	cyf	1	1	4	1	1
1-25R	3740.00	1.6	+	+	cyf	1	1	4	1	1

Source: Sandia Technologies LLC



## Open-Hole Logs

- Platform Express®
  - Spontaneous potential
  - Caliper
  - Gamma Ray
  - Resistivity (20, 30, 60 and 90 inches)
  - Neutron porosity
  - Density
- Combinable Magnetic Resonance (CMR)
- Formation Microimager (FMI)
- Dipole sonic scanner
- Elemental Capture Spectroscopy (EPS)

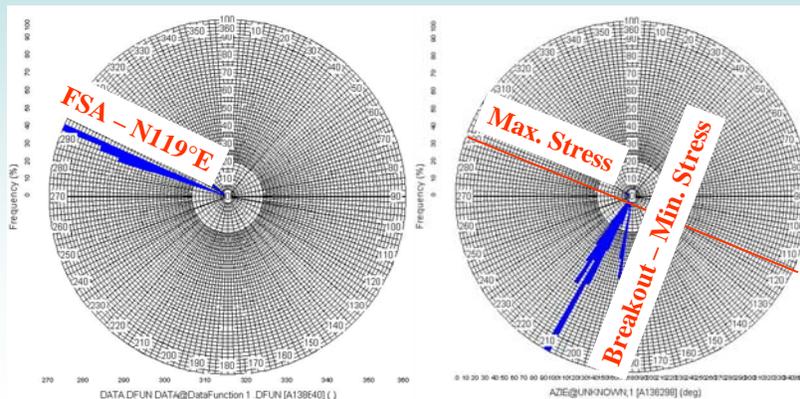


Source: Schlumberger ELAN analysis of formation/fluid properties

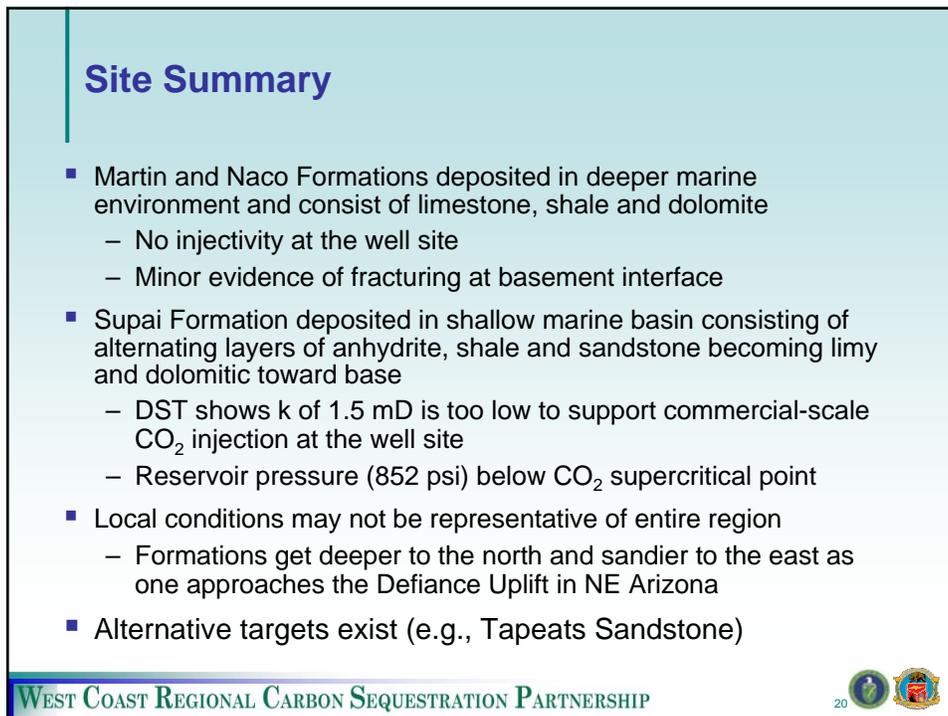
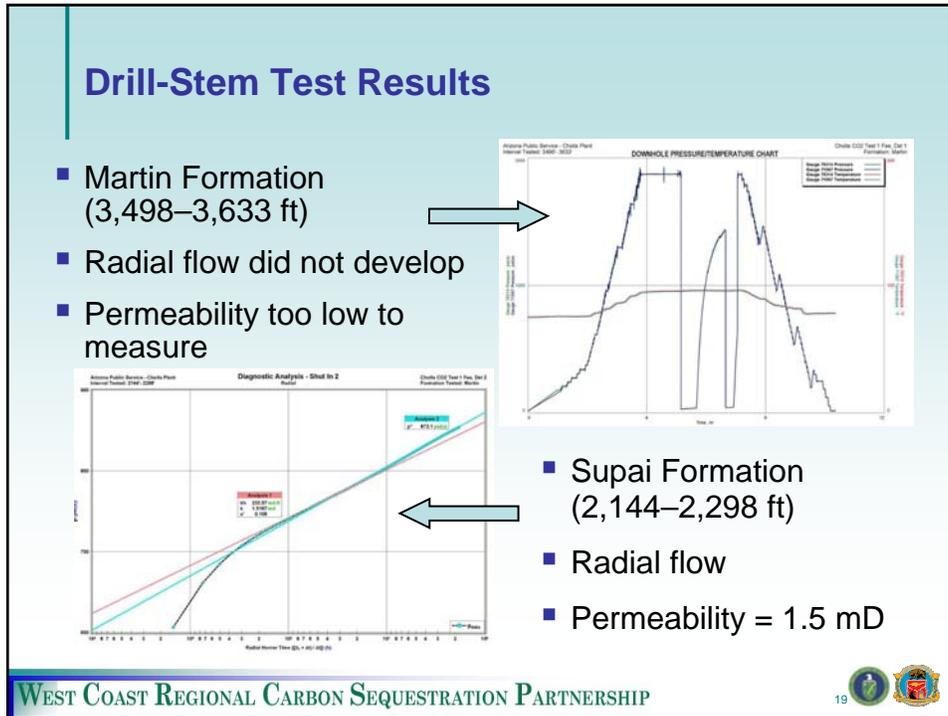
## Stress Analysis Comparison of Dipole Sonic, Caliper & FMI

Rose diagram fast shear azimuth

Rose diagram borehole enlargement



Perpendicular relation suggests borehole enlargement is in the direction of minimum horizontal stress.



## Acknowledgments

- Funders
  - Department of Energy
  - California Energy Commission
  - Industry Partners (AEP, APS, Peabody, SRP, TEP)
- Technical project team
  - LBNL, EPRI, Sandia Tech., EM&A,
  - and Schlumberger
- Regulatory agencies
  - USEPA, ADEQ and AZ O&GCC

Photo source: R. Trautz, EPRI