




**WESTCARB Annual Business Meeting**  
October 25-26, 2011  
Sacramento, CA

**Geologic Evaluation for Potential CO<sub>2</sub> storage in Arizona's Cenozoic sedimentary basins: The Safford Basin, southeastern Arizona**


**Brian F. Gootee**  
Research Geologist  
**Arizona Geological Survey**  
brian.gootee@azgs.az.gov

WESTCARB Annual Business Meeting, 2011





## Outline

- AZGS project objectives
- Initial screening of 88 Cenozoic sedimentary basins in the Basin and Range province
- Preliminary evaluation of Arizona's largest basin, the Safford basin, with 2,300 km<sup>3</sup> below 800m depth
  - Methods and difficulties
  - Stratigraphy and structure
  - Storage and sealing conditions
  - Salinity
- Conclusions and recommendations



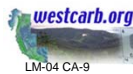
LM-04 CA-9

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



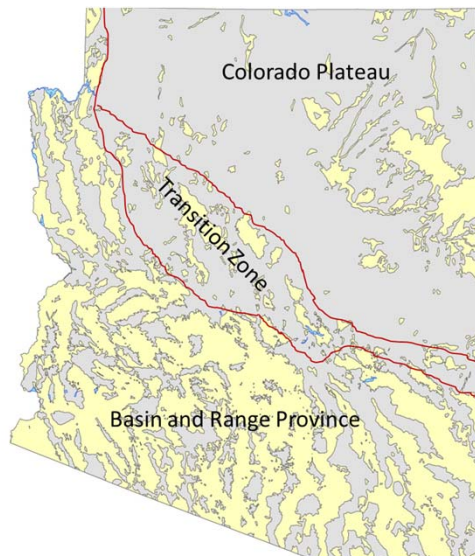
## AZGS WESTCARB Phase III Objectives

- Identify and assess subsurface geologic formations in the Colorado Plateau and Basin and Range Provinces of Arizona for CO<sub>2</sub> storage potential
- Determine where subsurface salinities approach 10,000 milligrams per liter (mg/l) of total dissolved solids (TDS) for areas identified as having potential for CO<sub>2</sub> storage



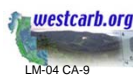
LM-04 CA-9

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



Arizona  
Physiographic  
Provinces

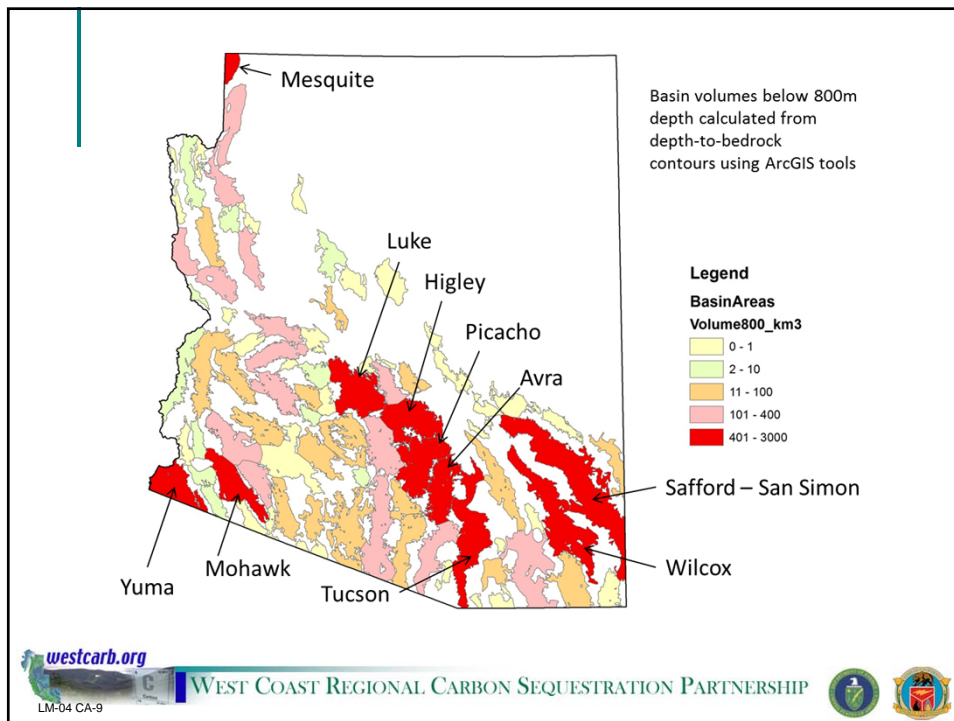
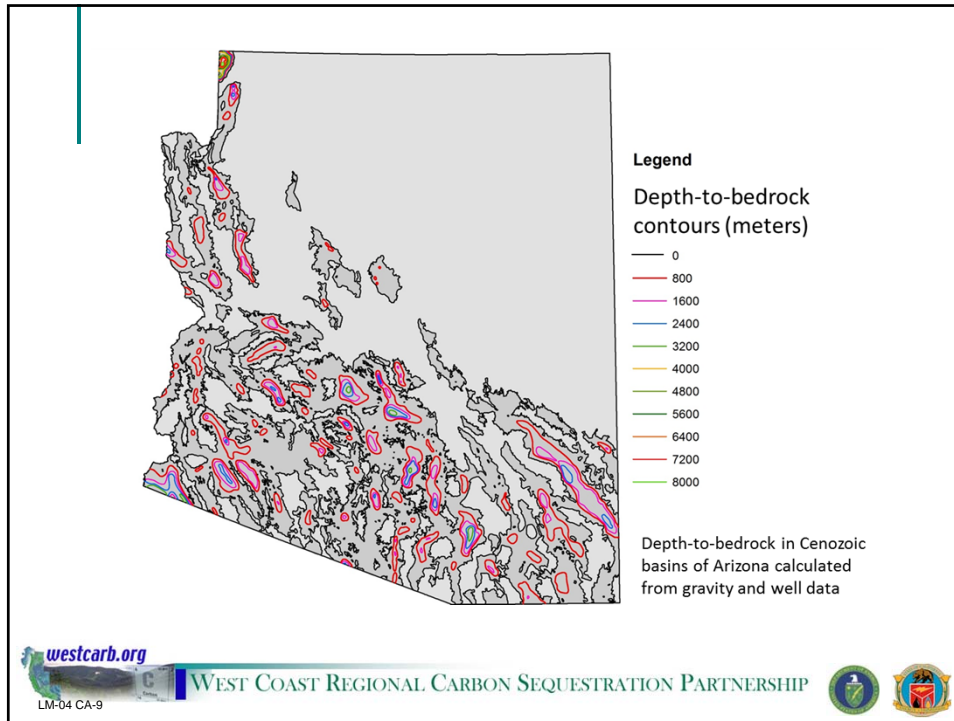
- Water
- Rock
- Surficial deposits  
and basin fill

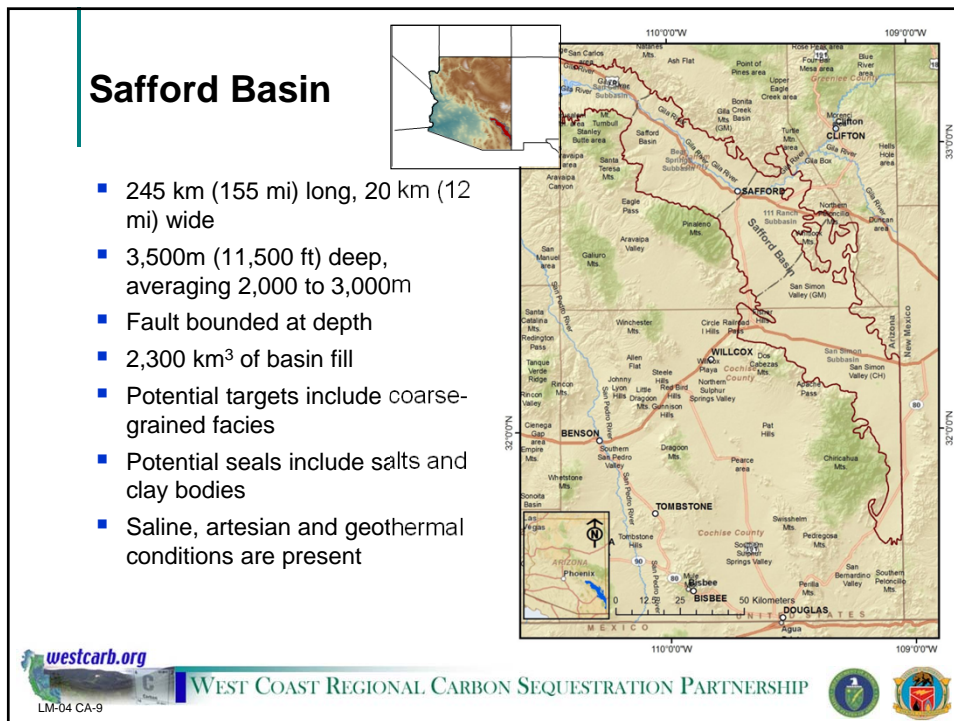
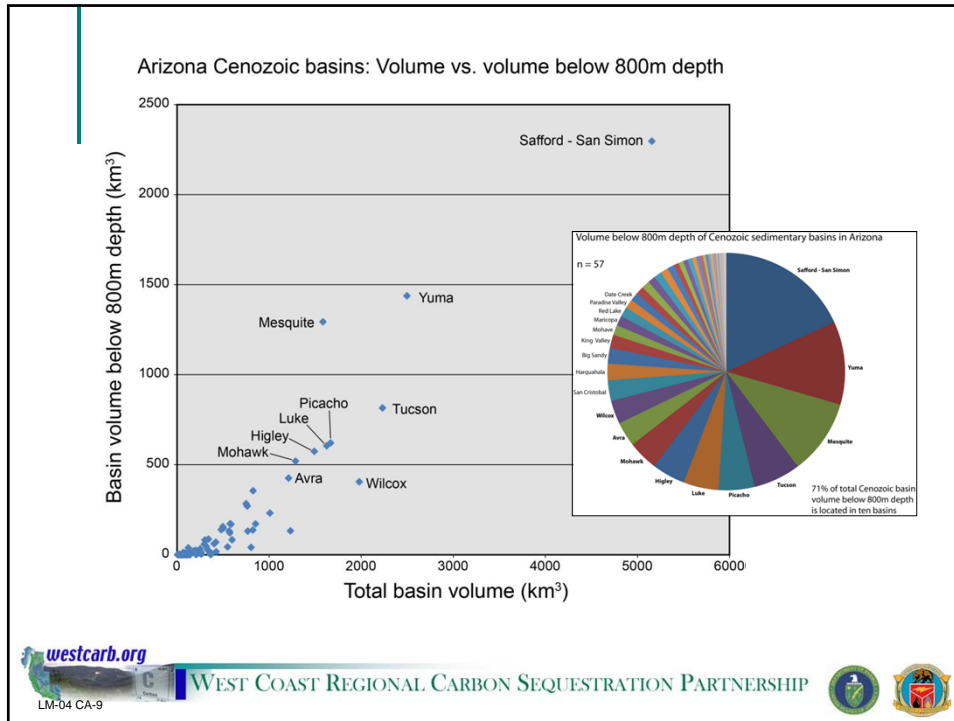


LM-04 CA-9

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

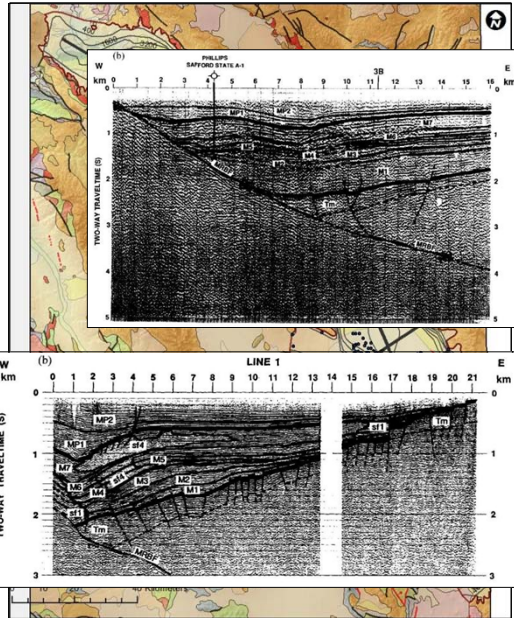






## Methods and Difficulties

- ArcGIS
- Borehole data
- Gravity
- Vintage seismic
- Surficial geologic maps
- Aquaveo for cross-sections

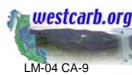
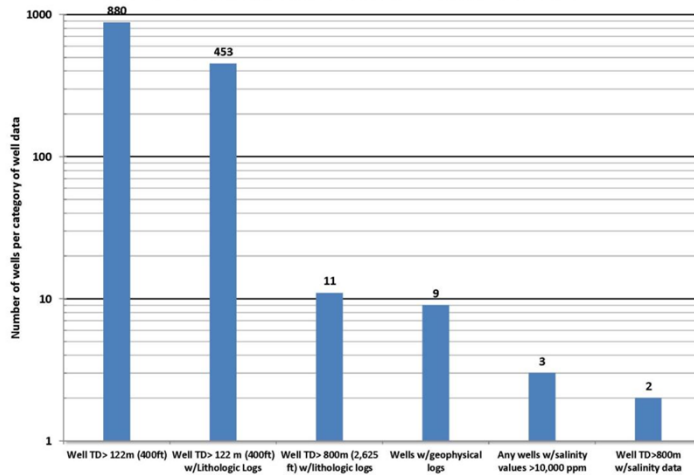


WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



## Well Data

Criteria and categories of well data for the Safford Basin

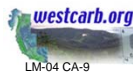


WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



## Stratigraphy

Geologic Unit	Description	Age (Ma)	Thickness (m)
Gila River alluvium	Alluvial and fluvial deposits derived from the modern Gila River drainage network.	0 to 2	0 to 25
Upper Basin Fill	<ul style="list-style-type: none"> <li>Unconsolidated</li> <li>Coarse and fine siliciclastics, evaporites and limestone</li> <li>Alluvial, fluvial and lacustrine environments</li> <li>Basalt flows interbedded with lower portion of this unit</li> <li>Generally undeformed</li> <li>Unconformable with underlying basin fill unit</li> </ul>	2.3 to 8	0 to 2,000
Lower Basin Fill	<ul style="list-style-type: none"> <li>Semi-consolidated to indurated</li> <li>Coarse and fine siliciclastics, evaporites and limestone</li> <li>Alluvial, fluvial and lacustrine environments</li> <li>Basalt flows interbedded in the lowermost portions</li> <li>More deformation apparent (folds, faults, fractures)</li> <li>Unconformable with underlying bedrock.</li> </ul>	8 to 12	0 to 2,300
Bedrock	<ul style="list-style-type: none"> <li>Consolidated</li> <li>Proterozoic igneous and metamorphic rocks</li> <li>Paleozoic sedimentary rocks</li> <li>Cenozoic igneous rocks including andesite and basalt flows</li> </ul>	17 to 1,400	n/a

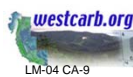
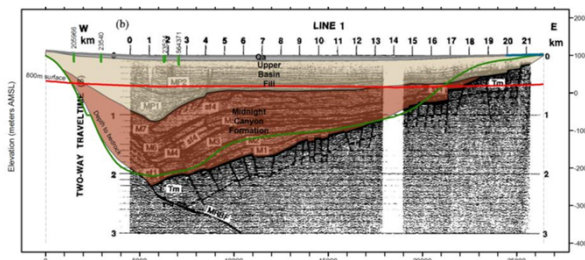
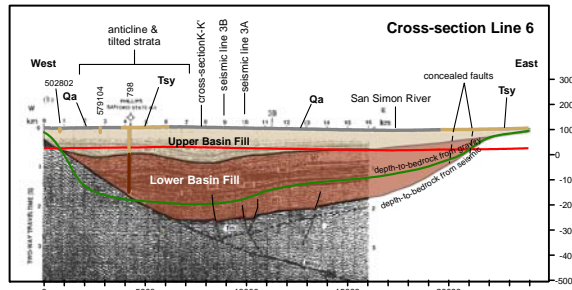


WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



## Structure

- Closed-basin in a half-graben, hinged-facies model
- Generally more deformation in the lower unit (folds, tilted bedding and faults)
- Fault activity present from late Miocene to late Pleistocene

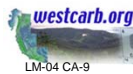
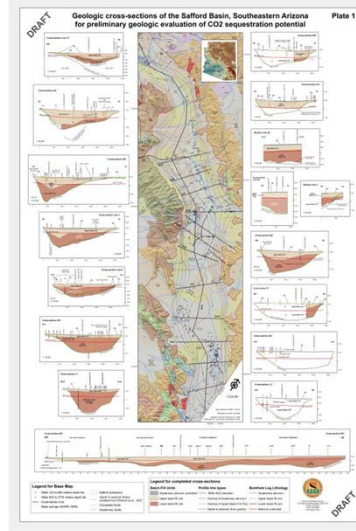


WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



## Stratigraphy and Structure in the Safford Basin

- Seventeen cross-sections (Plate 1)
- Only two basin-fill units discernable given subsurface data
- Facies changes are present vertically and laterally
- Evaporite and lacustrine basin centers with alluvial fan margins
- Lower Basin Fill is considered the primary target for CO<sub>2</sub> storage
- Sealing conditions present in both units, although vertical and lateral limits unknown (subsurface data absent in largest of basin centers)



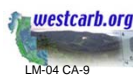
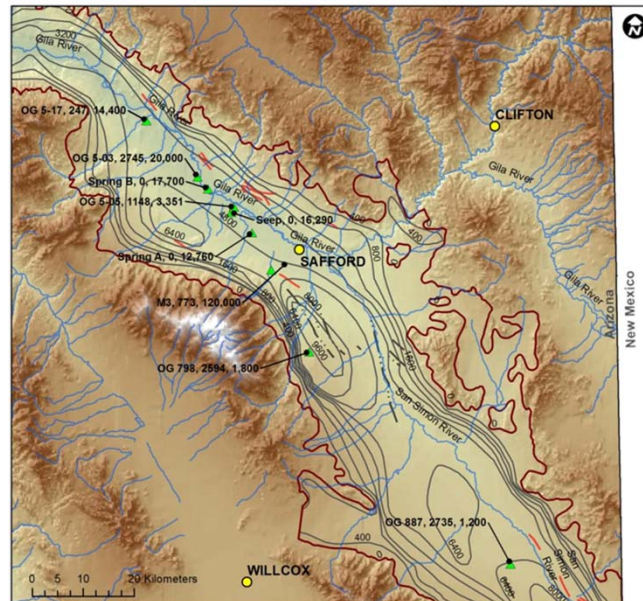
LM-04 CA-9

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



## Salinity

- Limited to six wells and 3 springs
- Ranges from 300 to 120,000 ppm
- Only one well >800m depth at 14,000 ppm
- Confining and geothermal conditions
- No iso-salinity contours



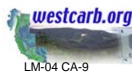
LM-04 CA-9

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



## Conclusions

- Depth, storage and sealing conditions favorable for CO<sub>2</sub> storage are present in Arizona's Cenozoic sedimentary basins.
- Results of the Safford Basin evaluation:
  - 2,296 km<sup>3</sup> of sediments below 800m depth
  - Siliciclastics, evaporites and limestone present
  - Lower Basin Fill unit considered the target formation
  - Both lower and upper basin-fill units have sealing conditions present
  - Elevated saline conditions present, although lack of data precludes iso-salinity contours for further volume estimates



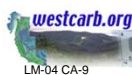
LM-04 CA-9

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



## Recommendations

- Cost-effective measures:
  - Acquire vintage seismic reflection data
  - Conduct salinity/conductivity profiles in existing deep wells
  - Conduct porosity/permeability tests on existing core
  - Showcase a GIS-interactive viewer of AZGS-WESTCARB data to facilitate awareness
- Conduct new seismic reflection work
- Drill additional deep wells in the gravity-low areas where wells are absent



LM-04 CA-9

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP





## Acknowledgments

- AZGS WESTCARB Team Jon Spencer, Steve Rauzi, Diane Love and Michael Mahan
- Elizabeth Keller (CEC)
- Arizona Department of Water Resources Terry Davis
- Arizona Department of Environmental Quality

[westcarb.org](http://westcarb.org)

LM-04 CA-9

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



## Additional Slides

[westcarb.org](http://westcarb.org)

LM-04 CA-9

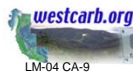
WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



Salinity Point ID	UTMX	UTMY	Sample Date	Land Elevation (ft)	Well Depth (m)	Well Depth (ft)	Total Dissolved Solids (ppm)	Basin Fill Unit at Total Depth	Remarks
M3: Safford Golf Course well; Water Well #8 (Witcher, 1982, AZ-259)	614372	3629509	n/a	3,068	773 (5)	2,536	115,000 (3) to 120,000 (4)	UBF	Considerable salt encrustation from 1,465 to 1,780 feet depth bls. Chloride of 168,200 ppm recorded (4).
OG 5-05: Mary Mack Well	608061	3642477	11/30/1933	2,780	1,148	3,767	3,351 (1)	LBF (?)	
			10/30/1940				3,530 (2)	LBF (?)	
			10/27/1943				3,400 (2)	LBF (?)	
			5/8/1952				3,440 (3)	LBF (?)	
OG 5-17: R.S. Knowles well	590899	3659453	11/22/1933	2,769	247	810	14,035 (1)	UBF	
			4/24/1941				14,290 (2)	UBF	
			1/6/1944				14,400 (2)	UBF	
OG 5-03: Gila Oil Syndicate #1	600906	3648398	12/15/2000	2730	806	2,645	20,000 (6)	UBF	From depth interval between 630 to 1025 ft (6)
			12/15/2000				5,500 (6)	UBF	From depth of well, reported to be 2,400 feet depth (6)
OG 798: Phillips Petroleum A1 Safford State	622815	3614079	4/11/1982	3,562	2,594	8,509	600 to 1,800* (6)	UBF and (?) LBF	Chloride data not reliable of formation salinity
OG 887: Arzon Corporation No. 1 State	662242	3572465	7/28/1995	3,600	2,735	8,974	300 to 1,200* (6)	UBF and (?) LBF	Chloride data not reliable of formation salinity
Spring at Terrace Scarp	611564	3637447	12/1/1940	2,907	0	0	12,760 (2)	UBF and (?) LBF	From Hem (1950; sample no. 1592)
Unnamed spring (ADWR, 2009, Map Key 19)	603000	3646098	8/7/1943	2,740	0	0	17,700 (2)	UBF and (?) LBF	From Hem (1950; sample no. 1730). Location from ADWR (2009)
Seep from Terrace Gravel	607553	3641434	11/29/1940	2,845	0	0	16,290 (2)	UBF and (?) LBF	Location from Hem (1950; sample 2597) to the nearest 1/4, 1/4 of section 13, T6S, R24E

Table 2. Salinity data for wells and springs with depths greater than 800m-bl or salinity above 10,000 ppm for the Safford basin.

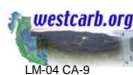
Notes: n/a = not available; UBF = Upper Basin Fill; LBF = Lower Basin Fill; \* = value represents chloride concentration; 1=Knechtel (1938); 2=Hem (1950); 3=Witcher (1982); 4=Rauzi (2002); 5=Conley et al. (2005); 6=Harris (2004).



WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP



### Core from 8,506 feet depth in OG well 798 (Tertiary conglomerate below the lower basin fill unit)



WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

