Characterization of Most Promising Sequestration Formations in the Rocky Mountain Region

(RMCCS)

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US DOE/NETL
Project Manager
Bill O'Dowd

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Co-PI: Vince Matthews
Colorado Geologic Surv.

Partners

TRI-STATE Generation and Transmission Association, Inc.

Colorado Geological Survey

Southwest Carbon Partnership

Shell

THE UNIVERSITY OF UTAH™

Utah Geological Survey

New Mexico Bureau of Geology

Schlumberger

Arizona Geological Survey

RMCCS

- Project Overview
  - Regional Geology
  - Site Specific Characterization
  - Basin-wide Characterization
- Well Construction

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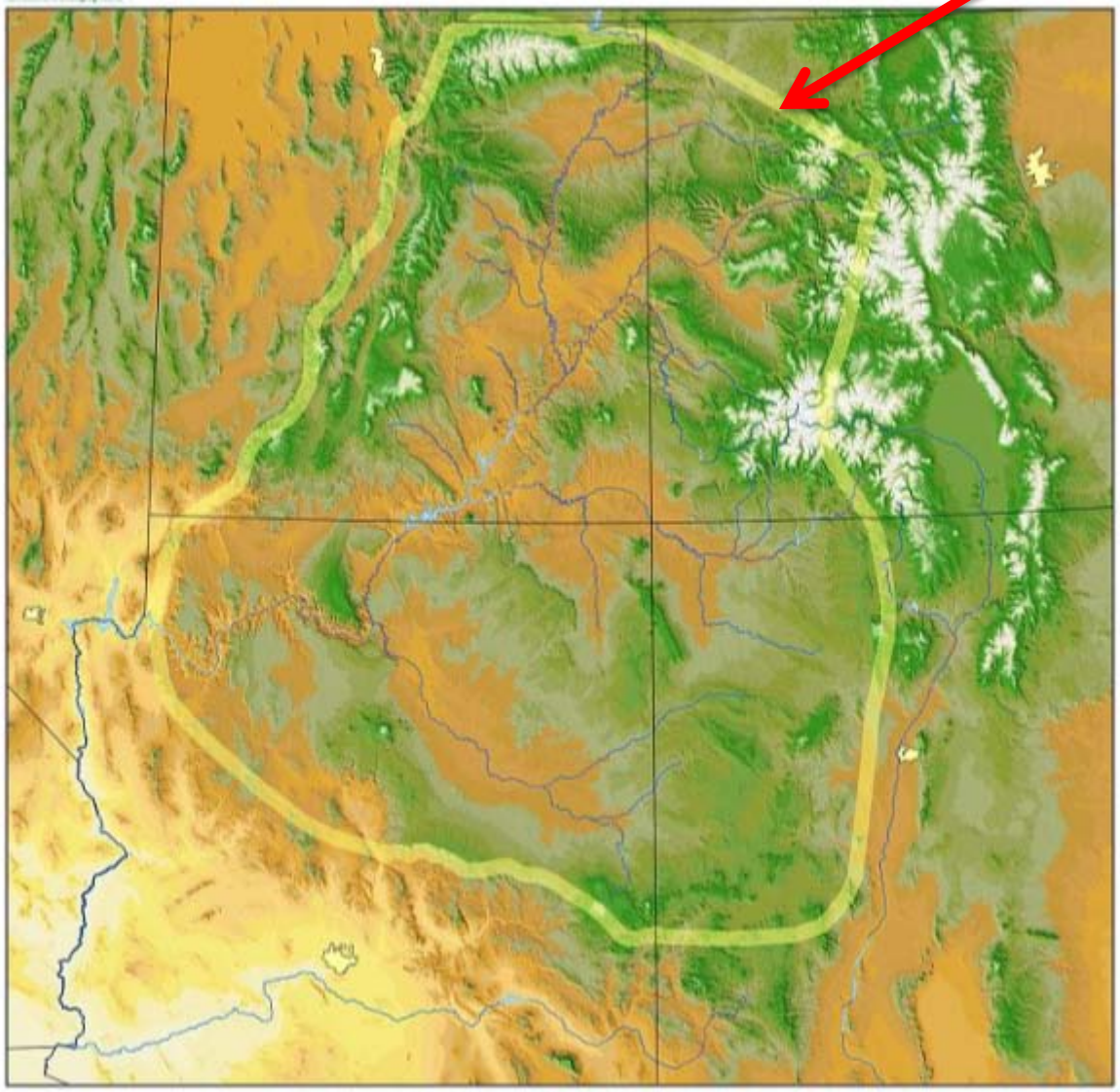
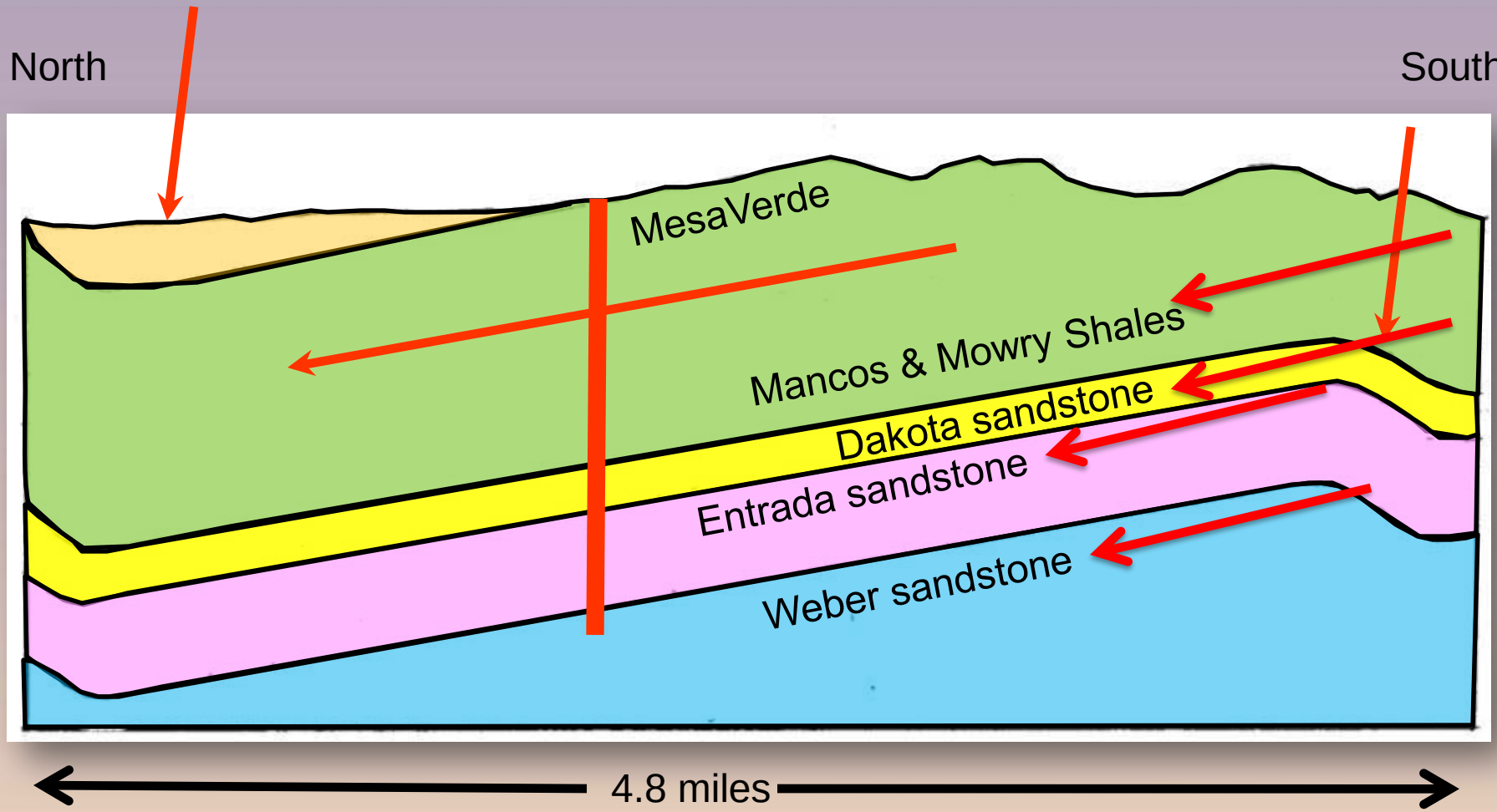
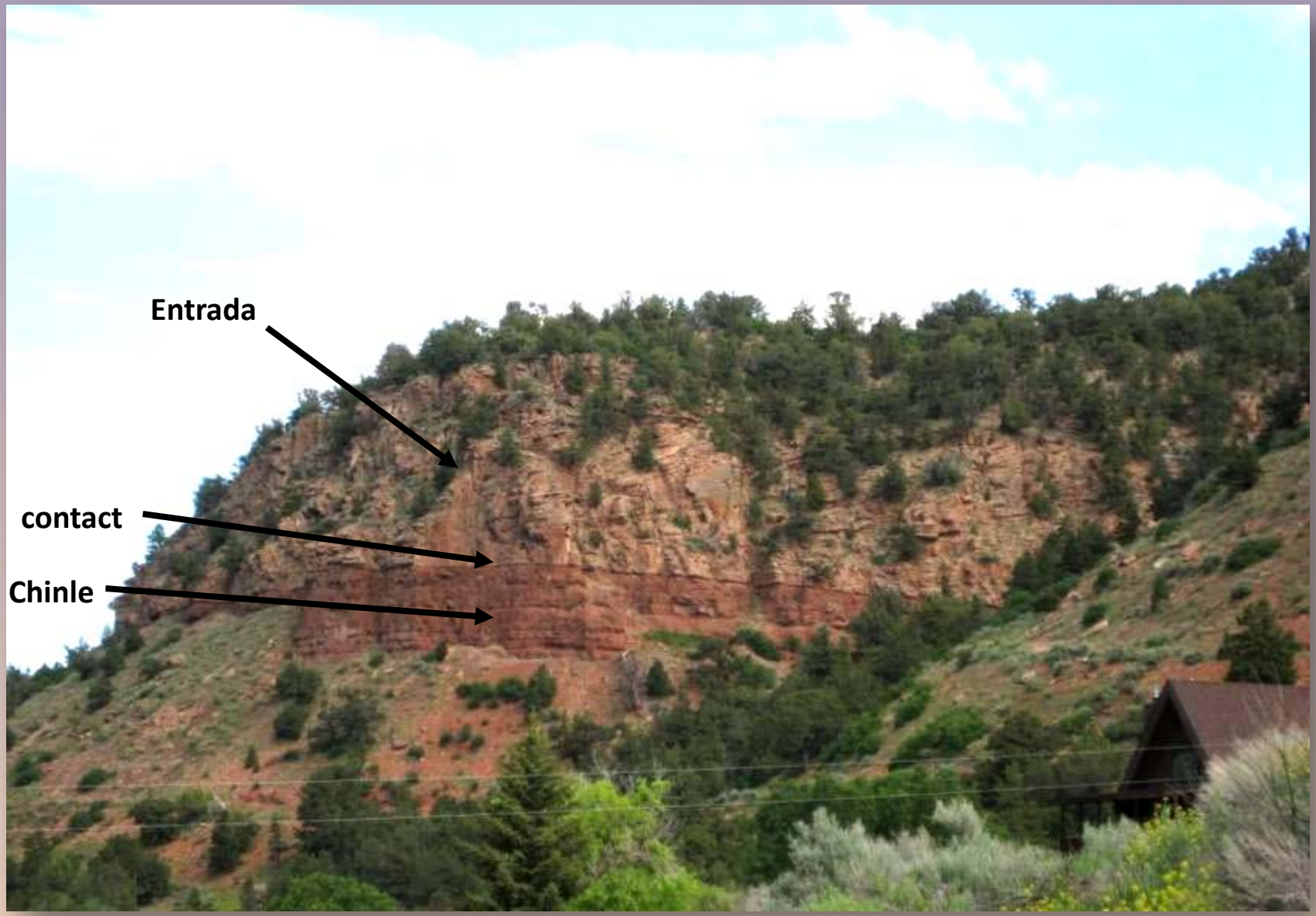
- Project Overview
  - Regional Geology
  - Site Specific Characterization
  - Basin-wide Characterization
- Well Construction

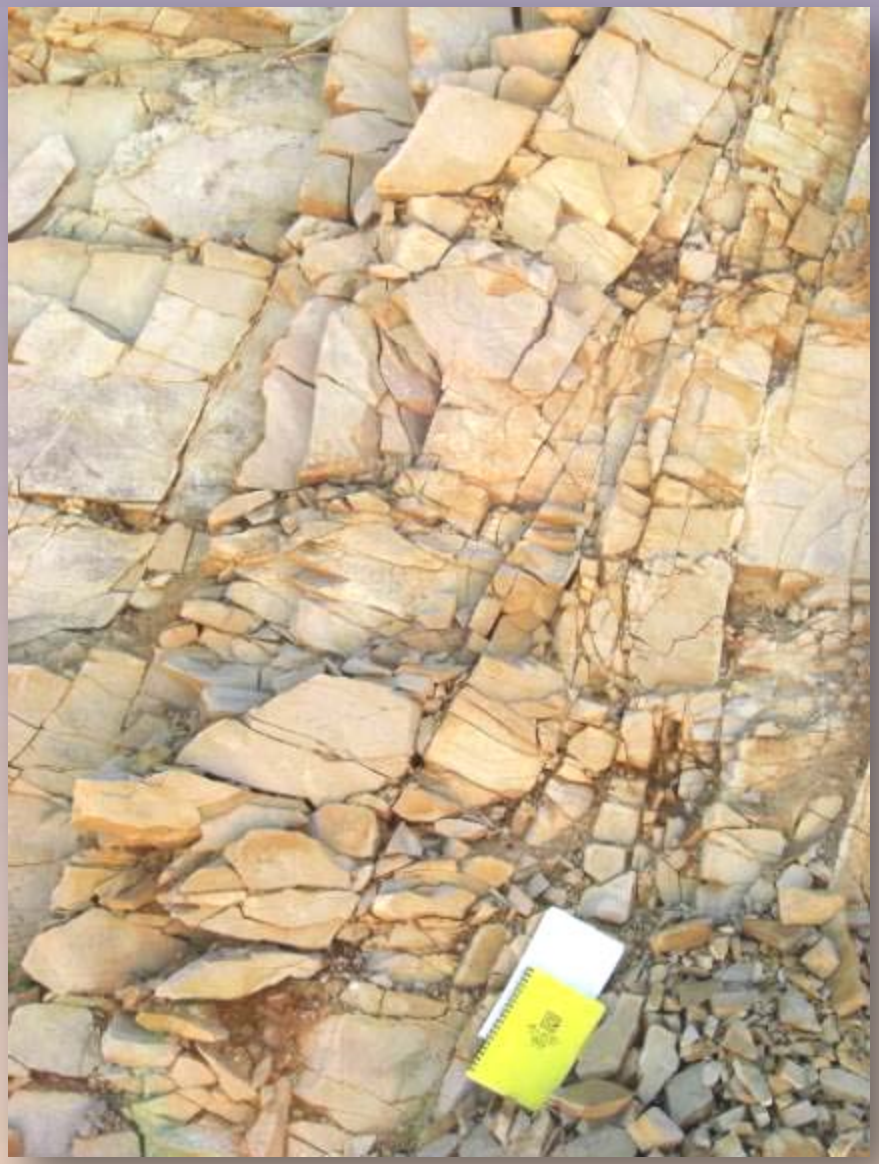


Colorado Plateau


North
South
MesaVerde
Mancos & Mowry Shales
Dakota sandstone
Entrada sandstone
Weber sandstone
4.8 miles

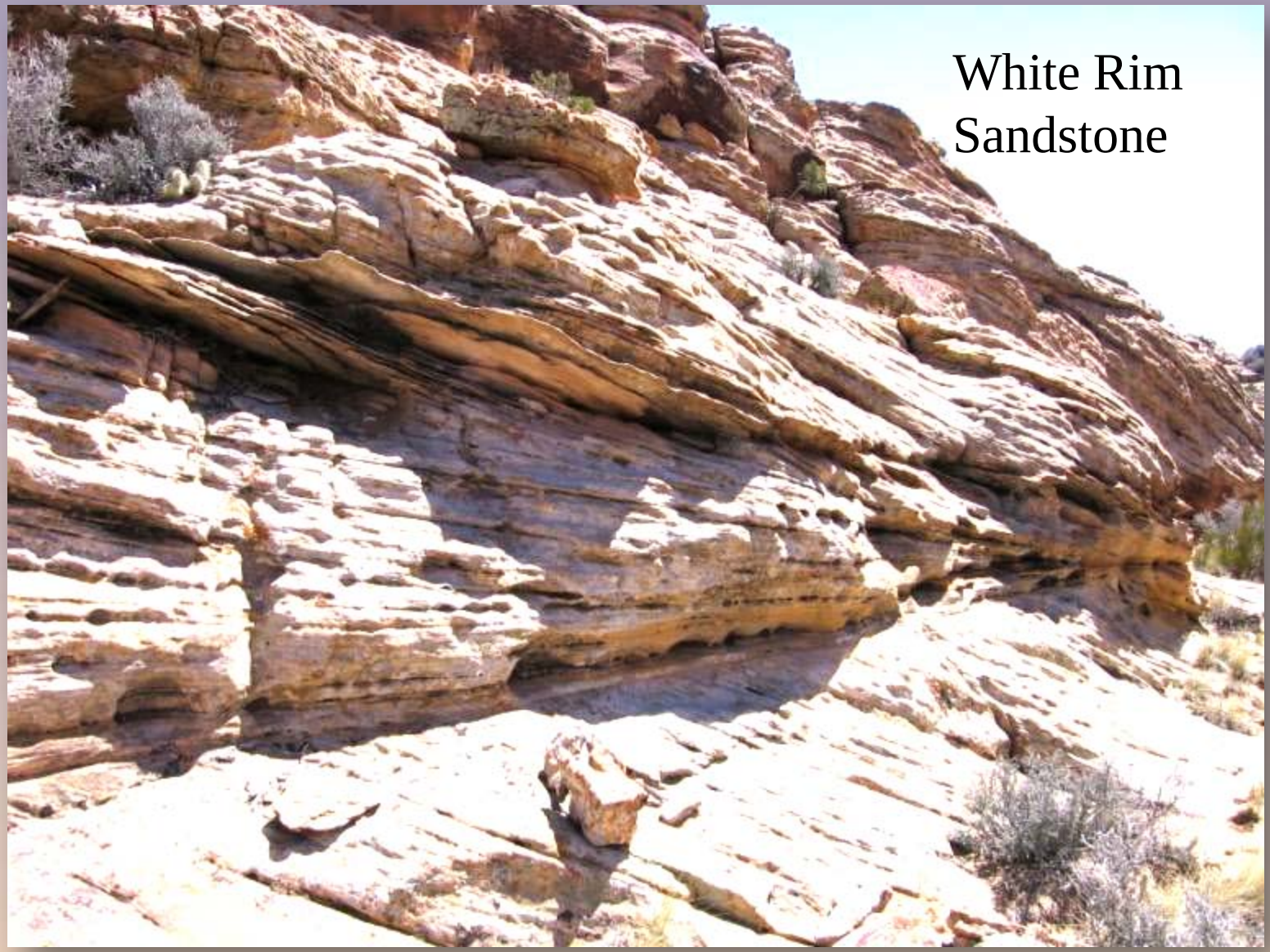
Dakota Sandstone


Entrada
contact
Chinle



Example of fracture behavior in steeply dipping Entrada sandstone

Weber sandstone outcrop


White Rim
Sandstone

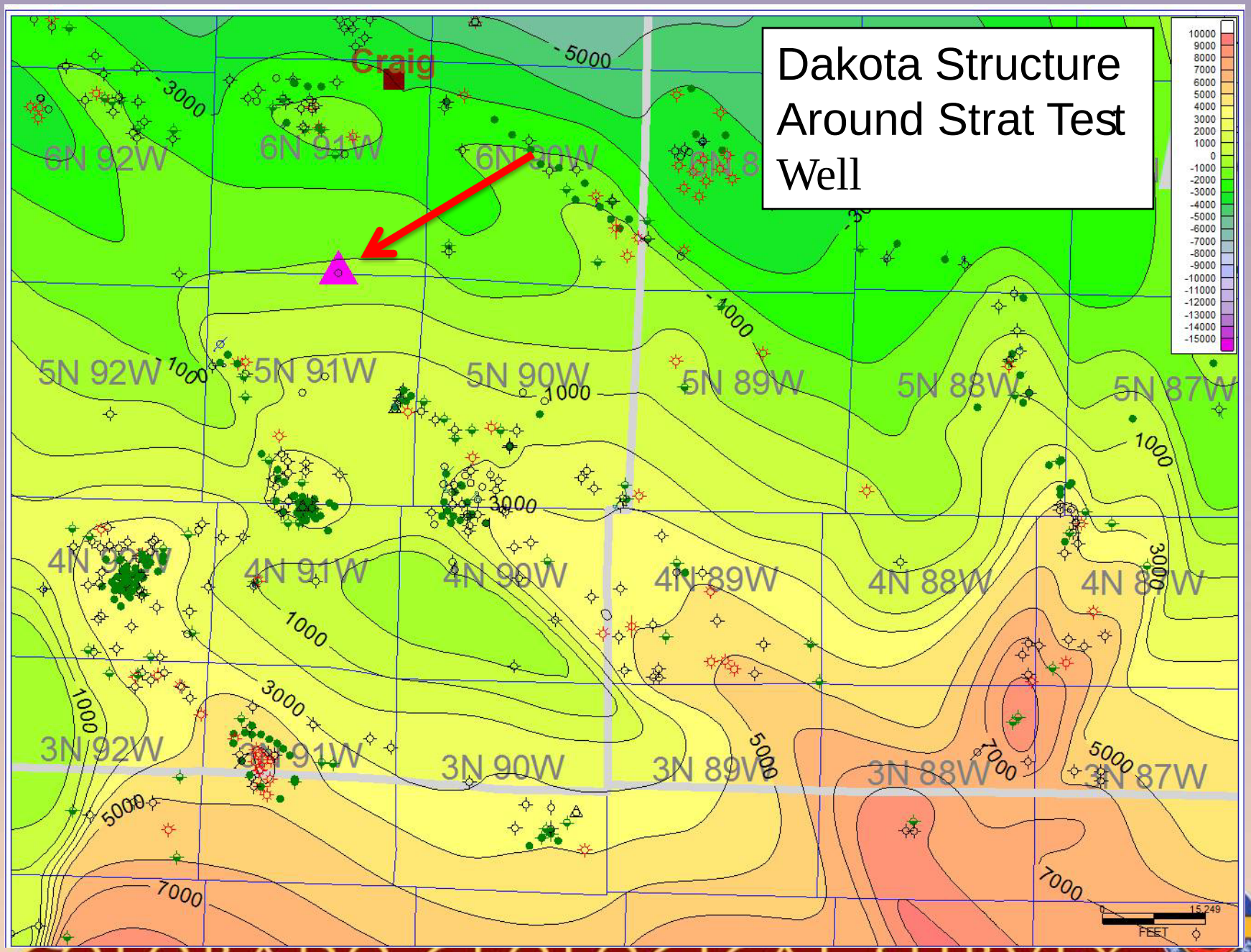
The Plan – Year 1

Characterize the Structure

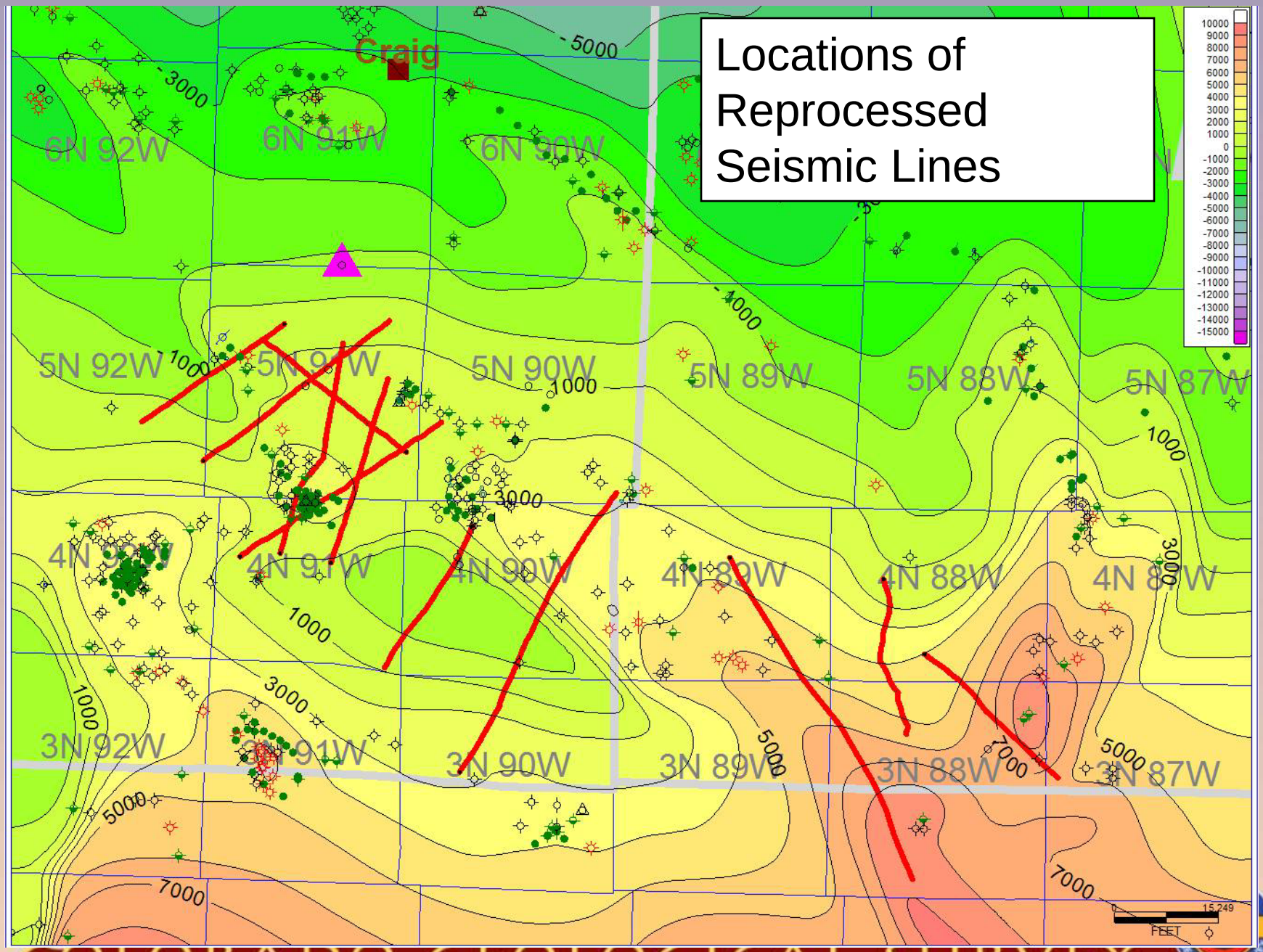
- Build database
- Purchase seismic
- Process & interpret seismic
- Map surface structure
- Shoot additional seismic lines

Pick location for drill hole

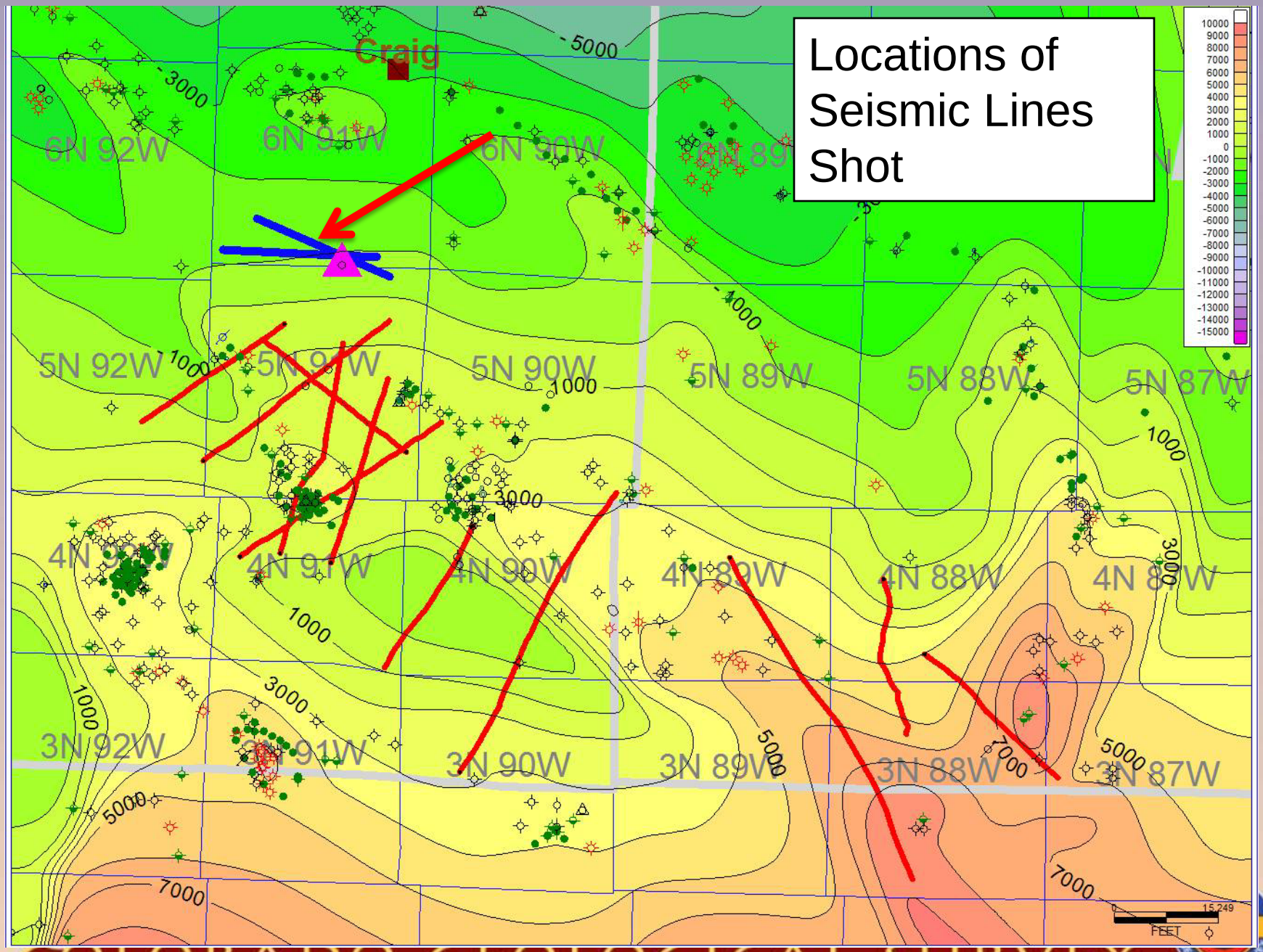
Permit well


Dakota Structure
Around Strat Test
Well
Craig
6N 92W
6N 91W
6N 90W
5N 92W
5N 91W
5N 90W
5N 89W
5N 88W
5N 87W
4N 91W
4N 90W
4N 89W
4N 88W
3N 92W
3N 91W
3N 90W
3N 89W
3N 88W
3N 87W
-3000
-5000
-4000
1000
3000
5000
7000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10000
-11000
-12000
-13000
-14000
-15000
0
15,249
FEET

Locations of Reprocessed Seismic Lines

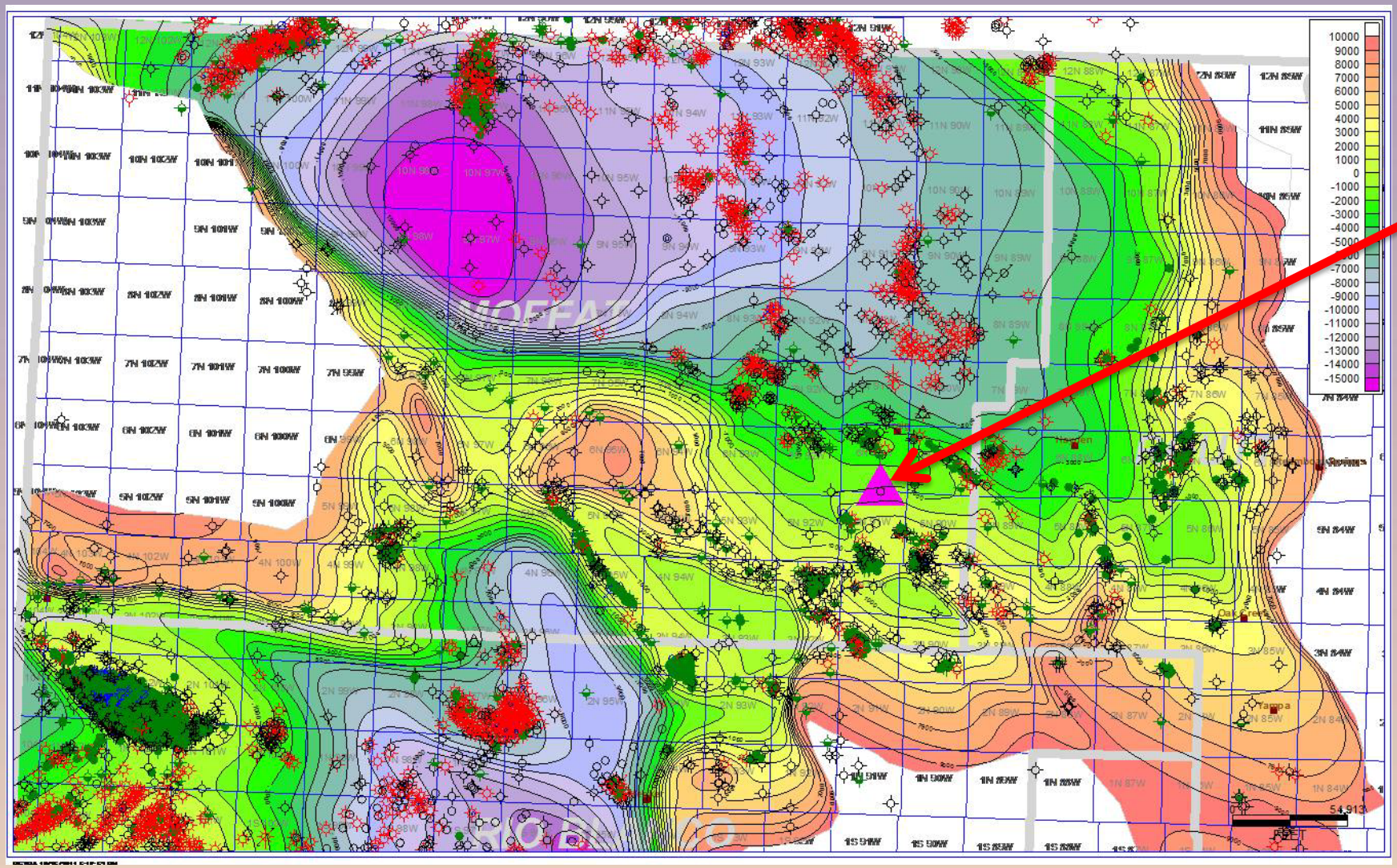


Locations of Seismic Lines Shot



Conduct a Seismic Survey

Structure Map: Top of Dakota Formation in Sand Wash Basin



The Plan – Year 2

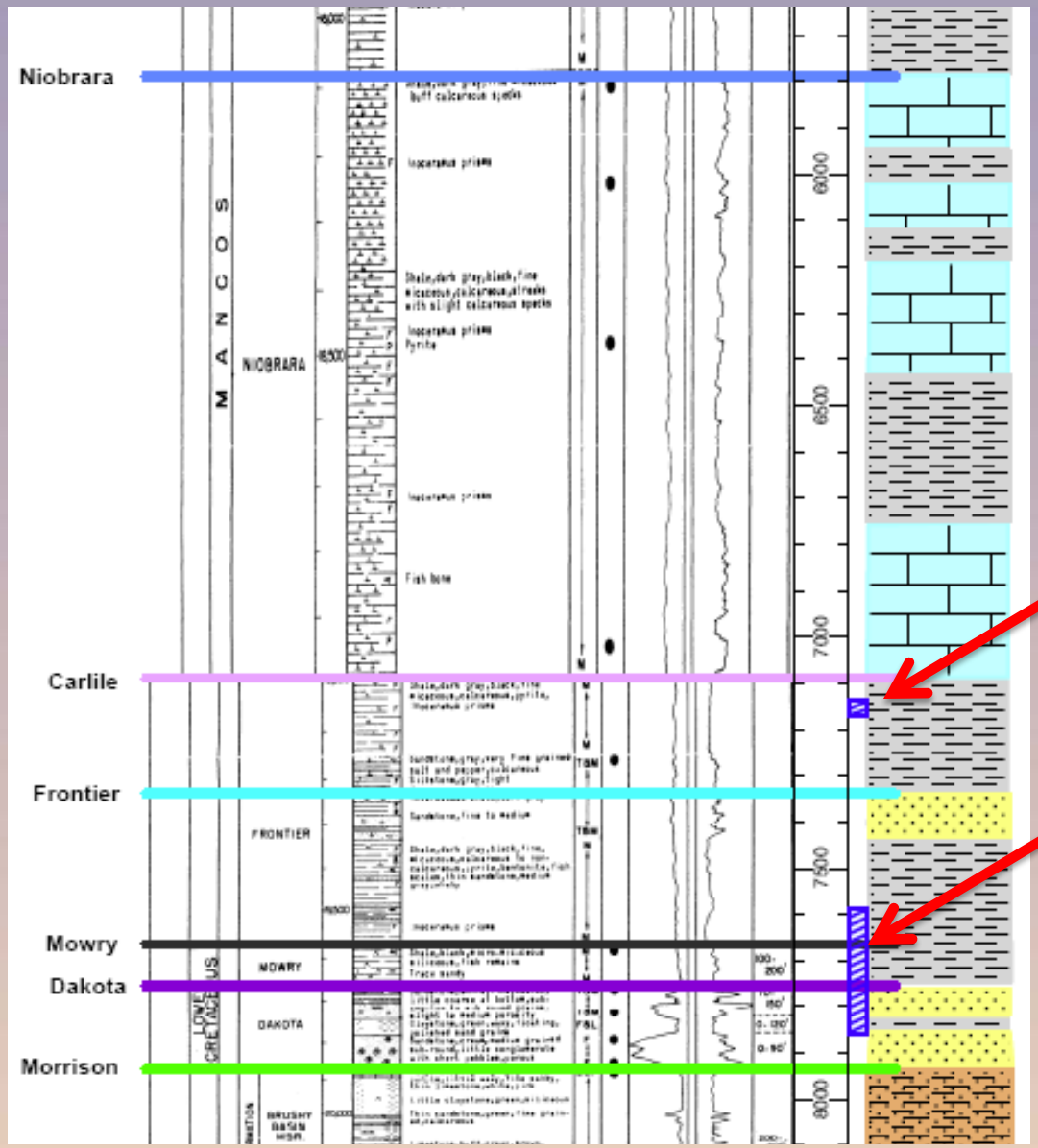
Drill Well

- Core Shale
- Core Sandstones
- Sample Waters
- Analyze Samples
- CO_2 Injectivity Experiments on cores

Begin Engineering Analysis & Reservoir Modeling

Extend results to Colorado Plateau

- UU-EGI Regional storage Model
- AZ, NM, UT, CO Geosurveys

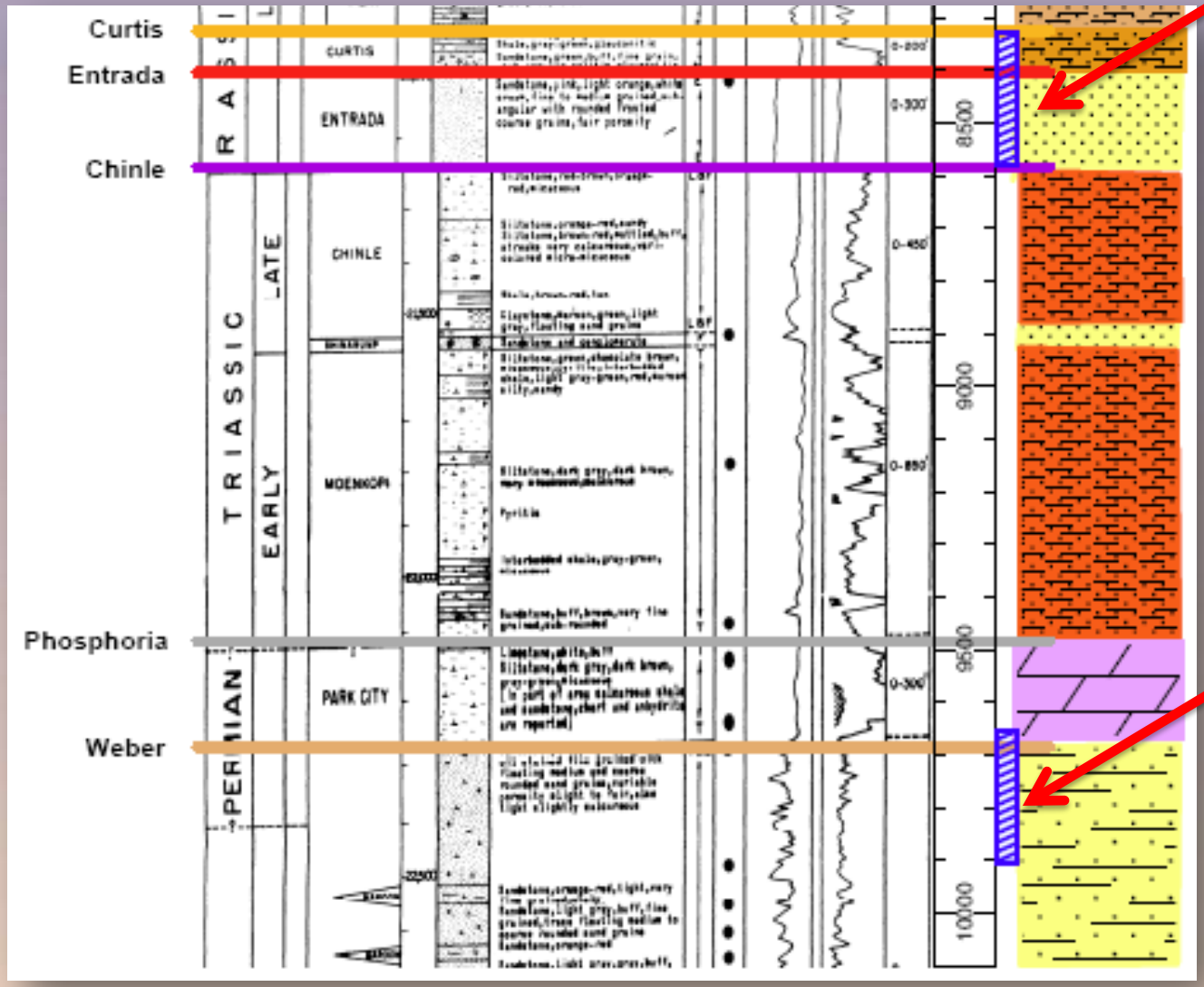


Coring Program: Carlile, Frontier and Mowry Seals and Dakota Saline Aquifer

Carlisle Shale Seal Core

Frontier and Mowry Seals and Dakota Sand Cores

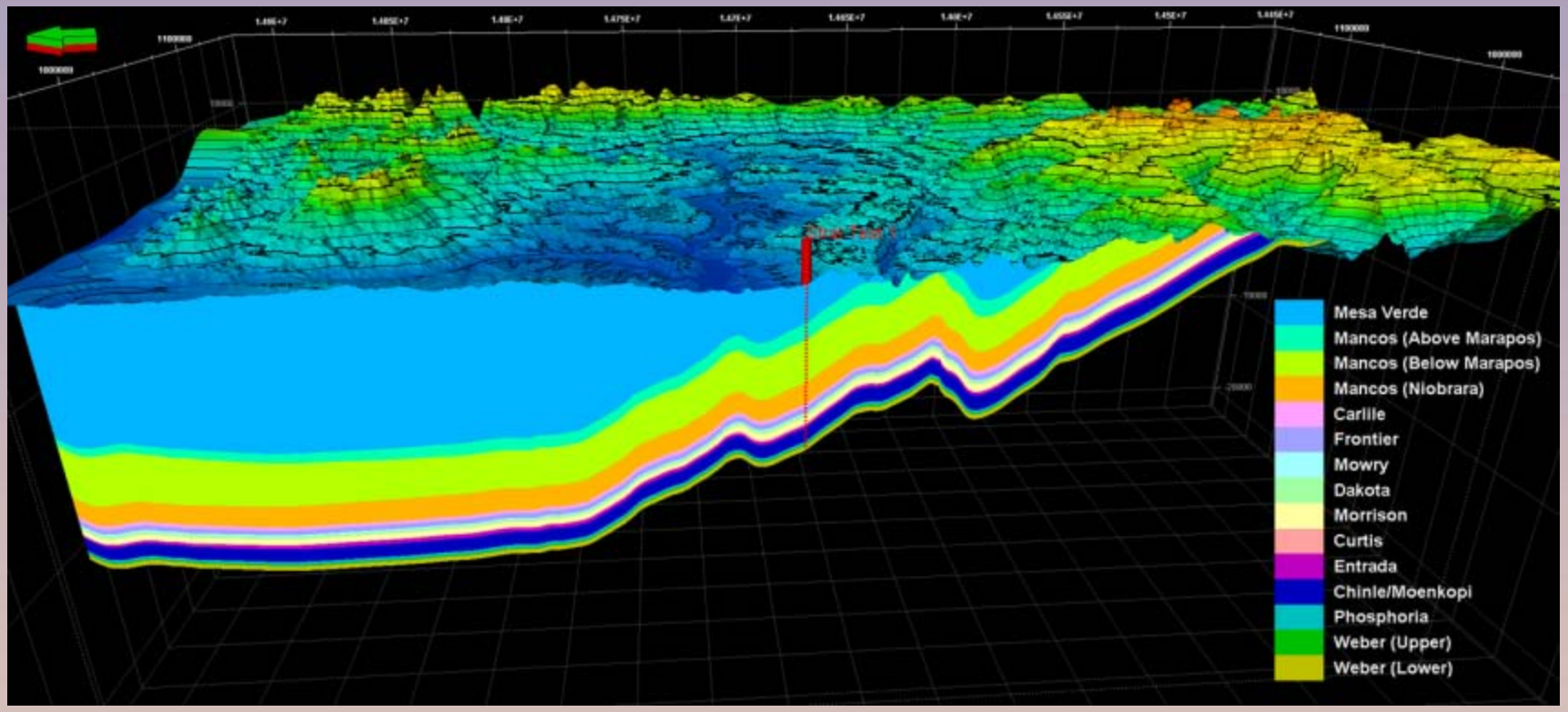
Coring Program: Entrada and Weber Saline Aquifers



Entrada Sand Core

Weber Sand Core

PETREL Model



North-South cross section through regional model.
Thirteen model surfaces are shown.
Vertical exaggeration = 5.

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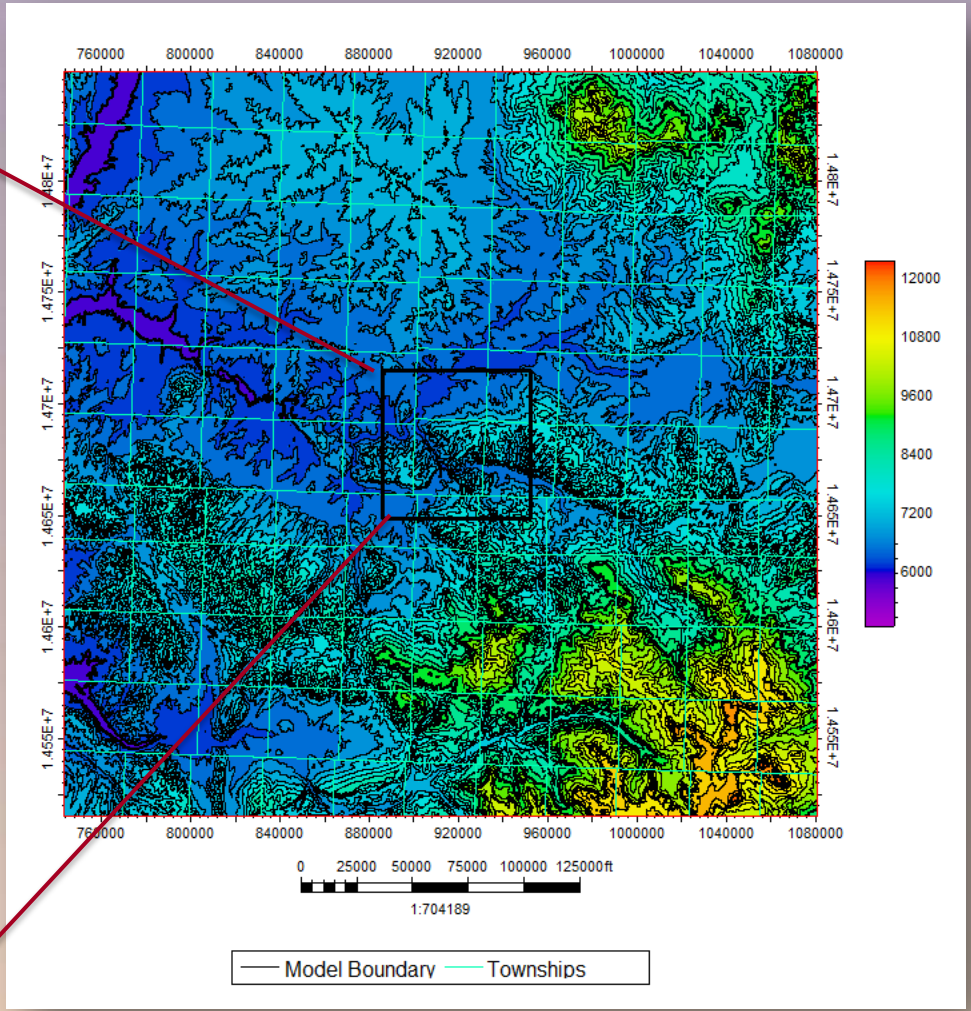
Craig Site, CO (construction and refinement of model)

- Model domain : 66,000 x 66,000 ft^2
- # of cells : 200x200x31 (x-, y-, and z-dir)
- Cell size : 330 ft (dx=dy) dz = 20 equally spaced vertically in Weber
- Two geo model cases :
  - 200 ft thick Weber
  - 800 ft thick Weber



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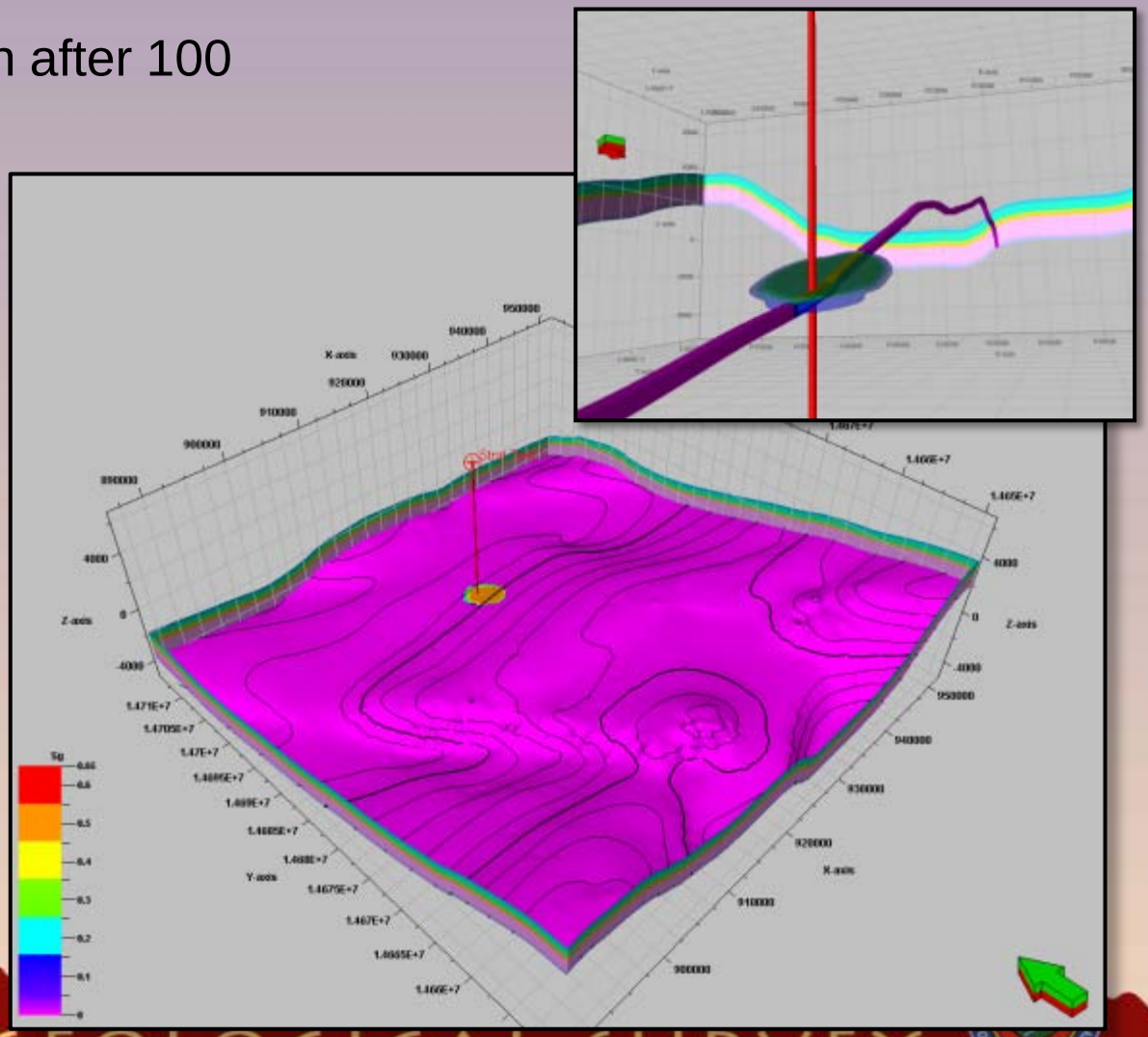
Craig Site, CO (preliminary simulations)

Simulated CO_2 Saturation after 100 years

- Weber : 200 feet thick
- CO_2 injection : 2 Mt for one year
- Simulated plume front is about 4,300 ft away from the injection well after 100 yrs.
- CO_2 migrated toward structural up-dip direction



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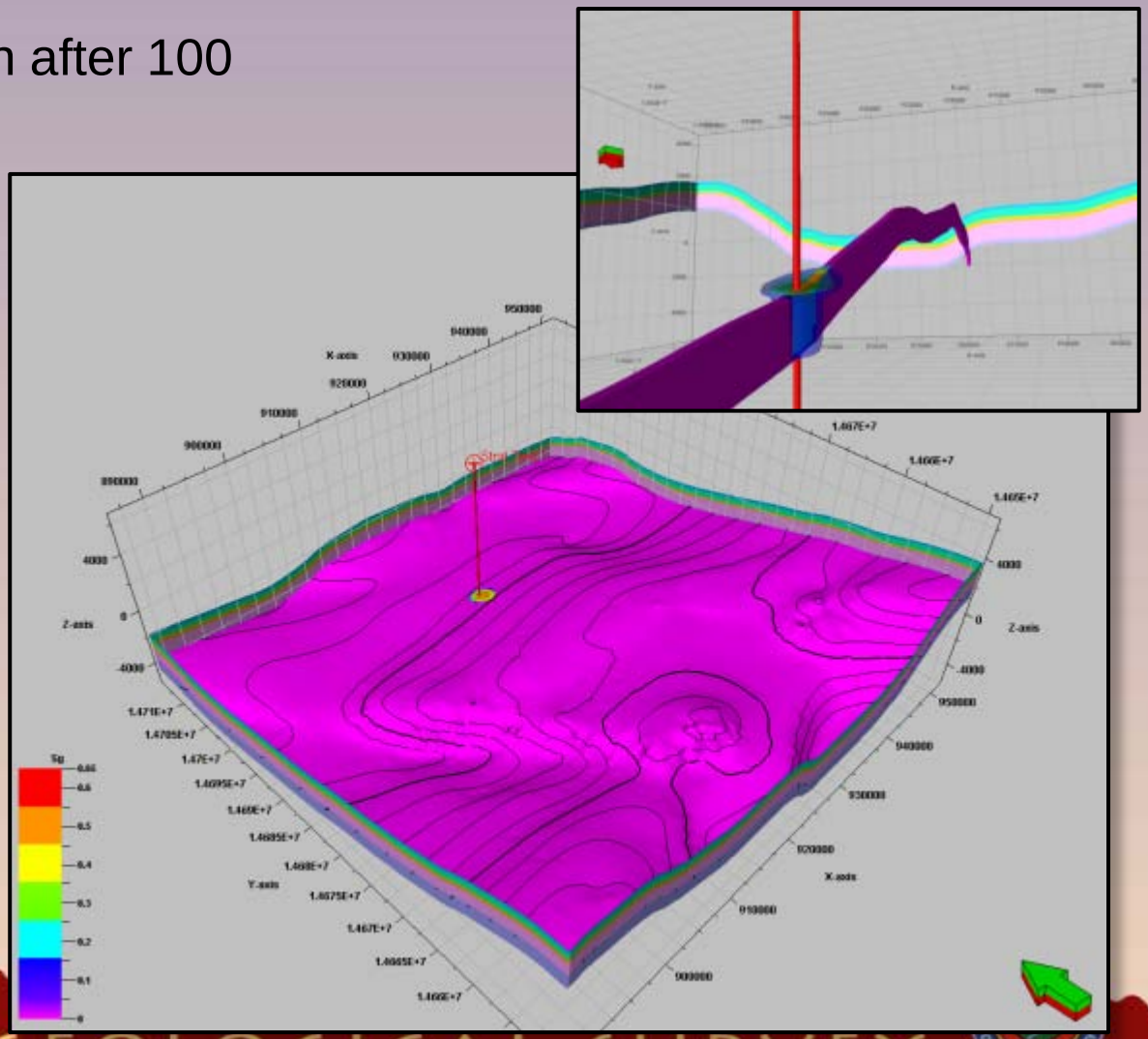
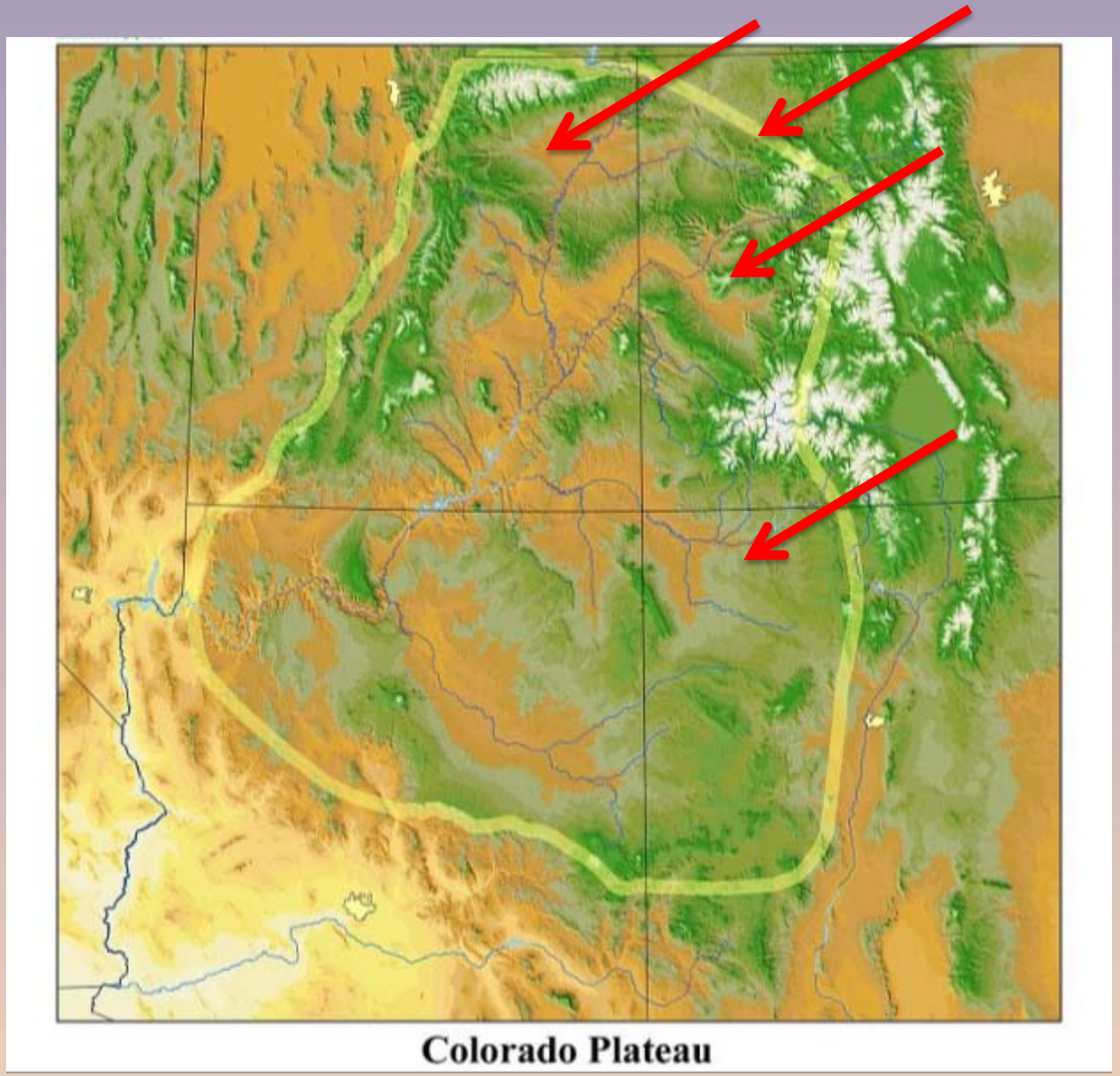
(Oct 2010 – Oct 2011)

Craig Site, CO (preliminary simulations)

Simulated CO_2 Saturation after 100 years

- Weber : 800 feet thick
- CO_2 injection : 2 Mt for one year
- Simulated plume front is about 2,500 ft away from the injection well after 100 yrs.
- CO_2 migrated toward structural up-dip direction

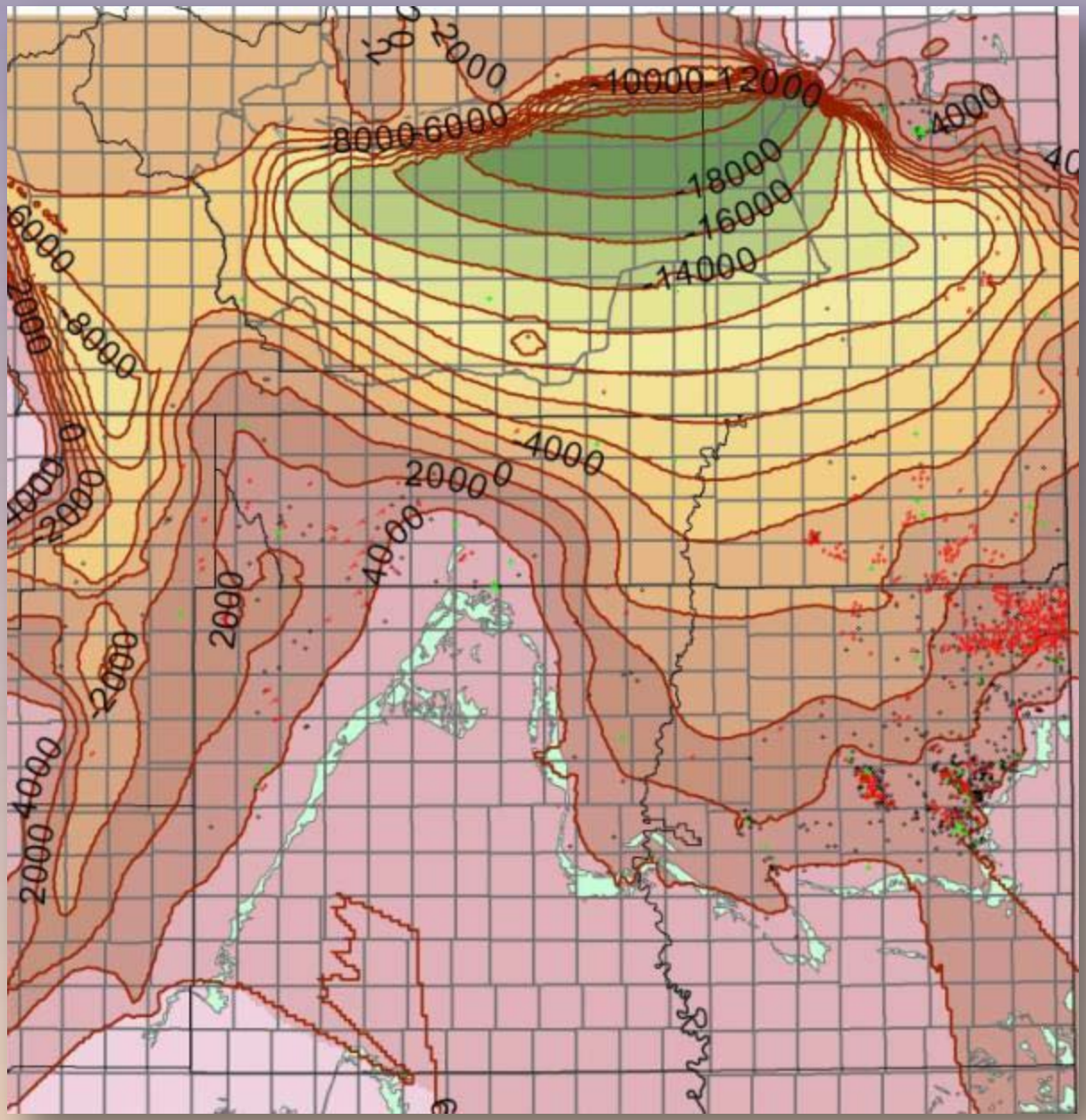




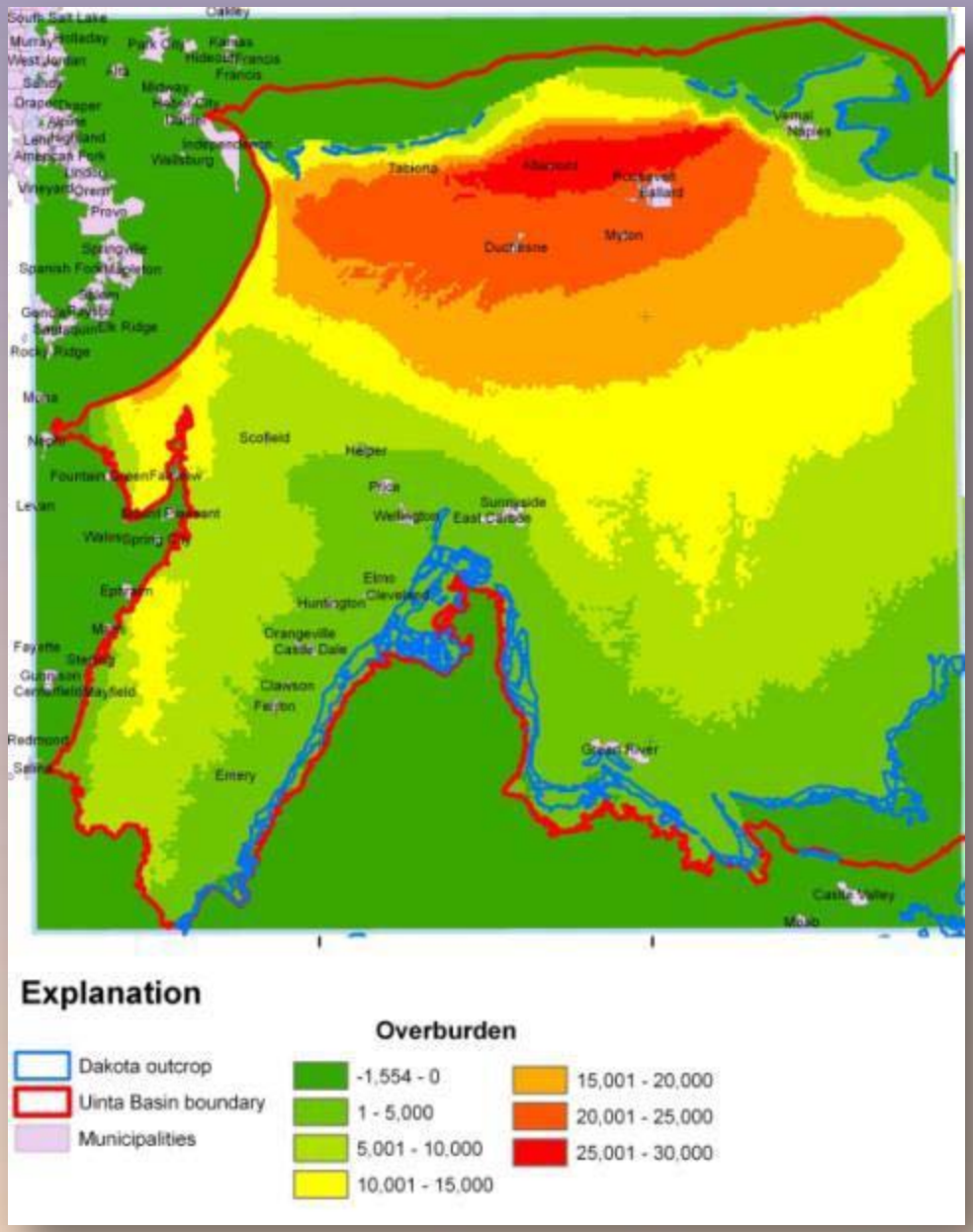
BASIN-WIDE STUDIES

BASIN-WIDE STUDIES

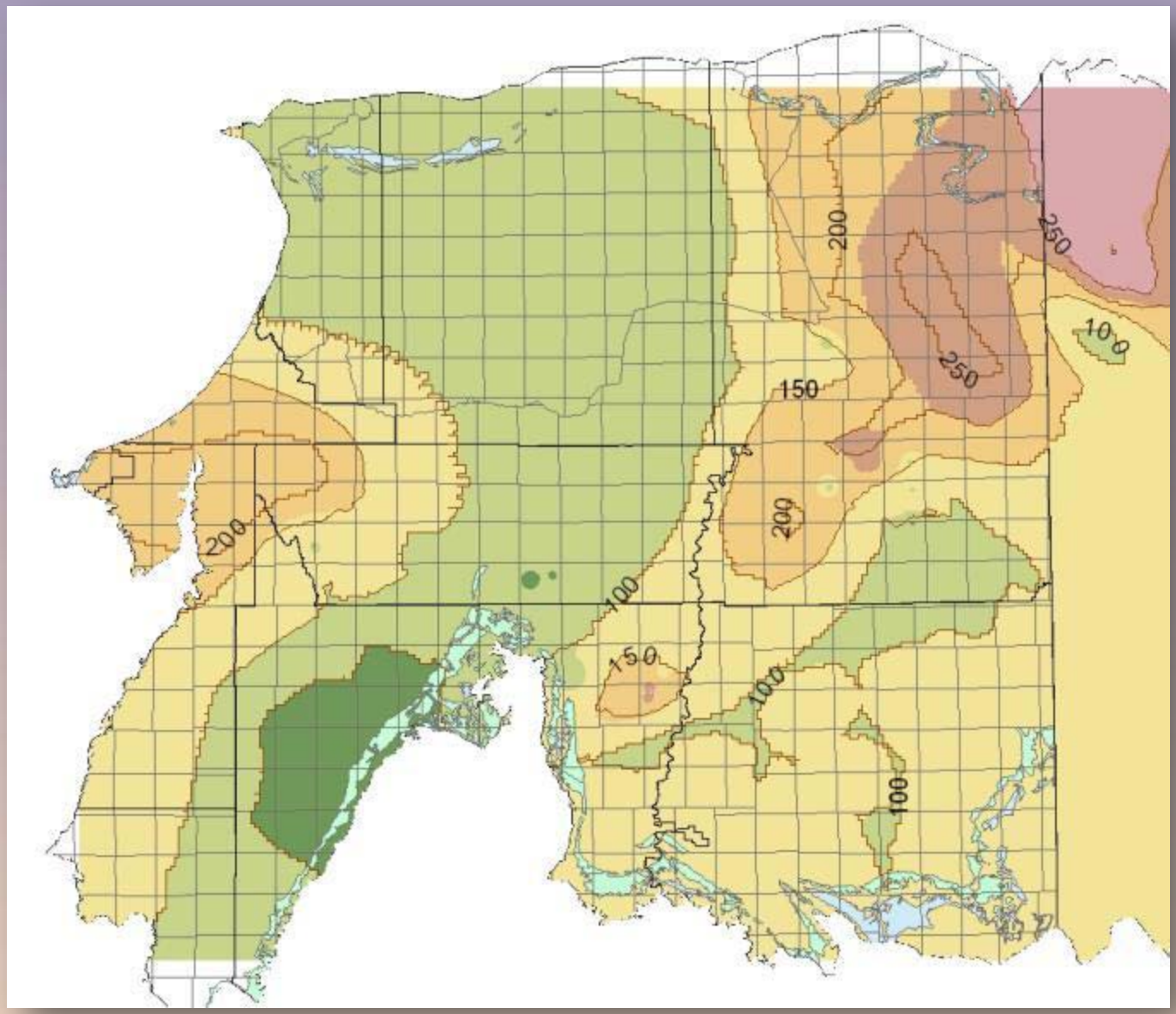
Uinta Basin, Utah



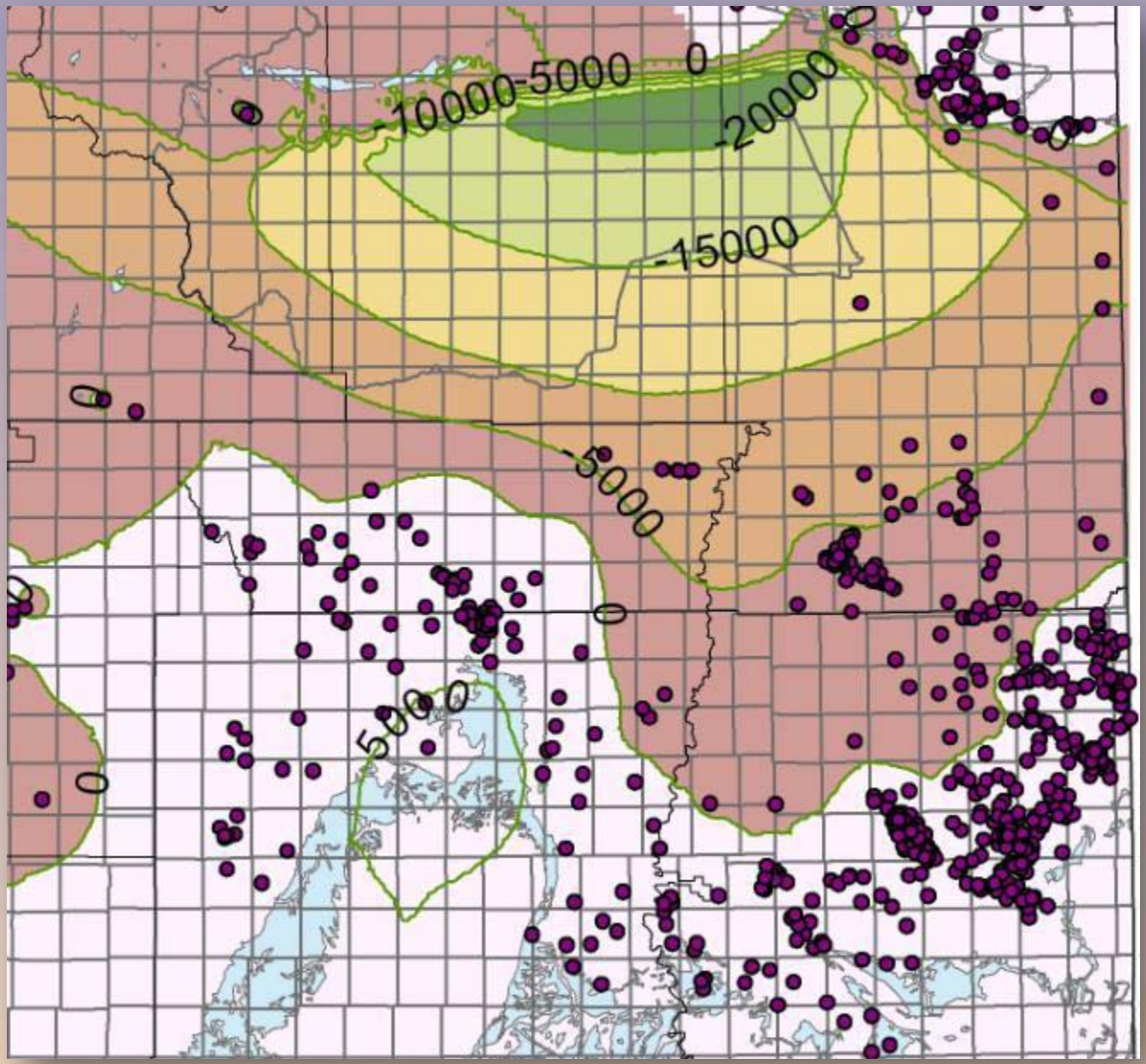
Structure contour of Dakota Sandstone



Overburden (drill depth) map of the Dakota Sandstone

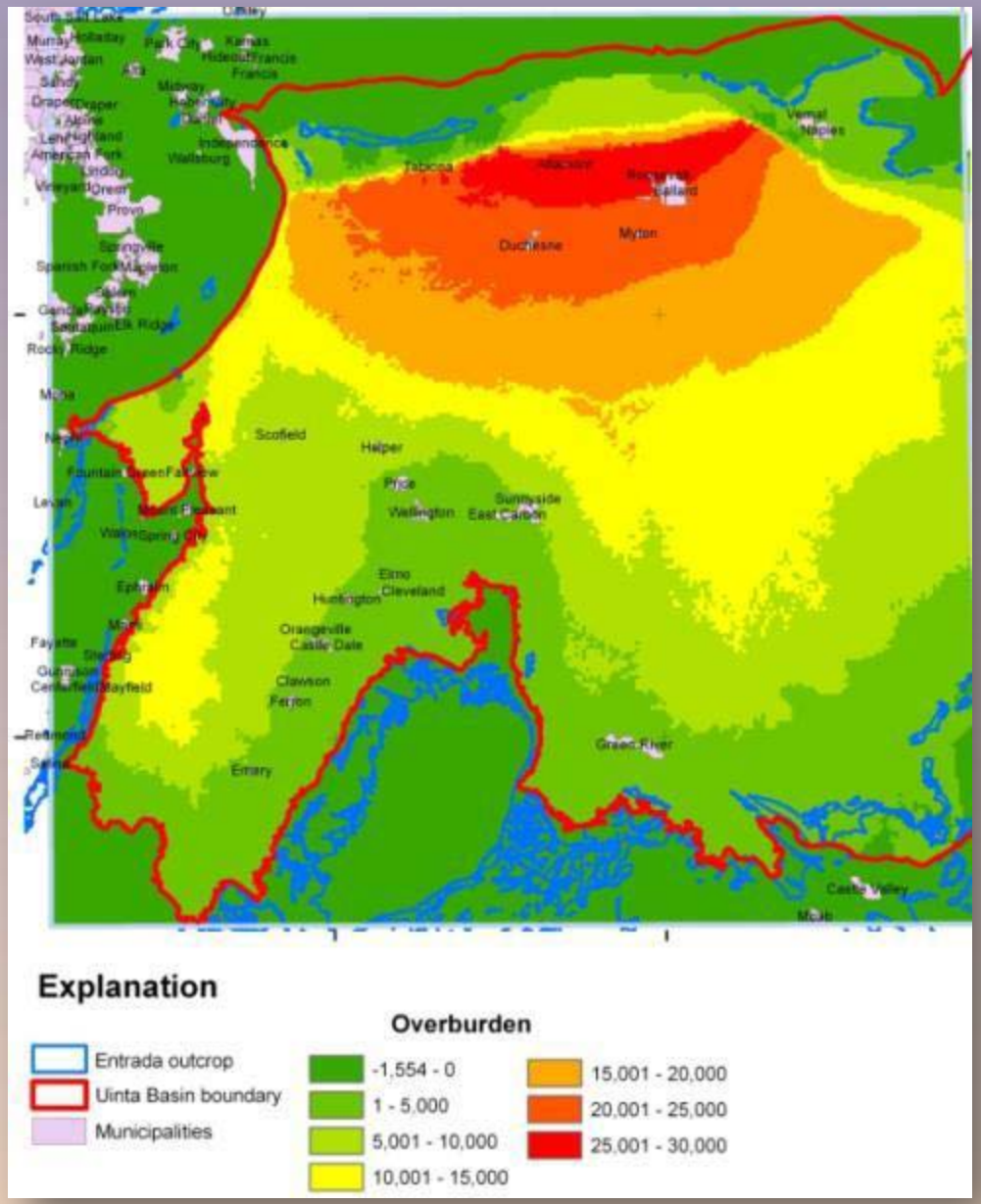


Dakota Sandstone - sandstone thickness map

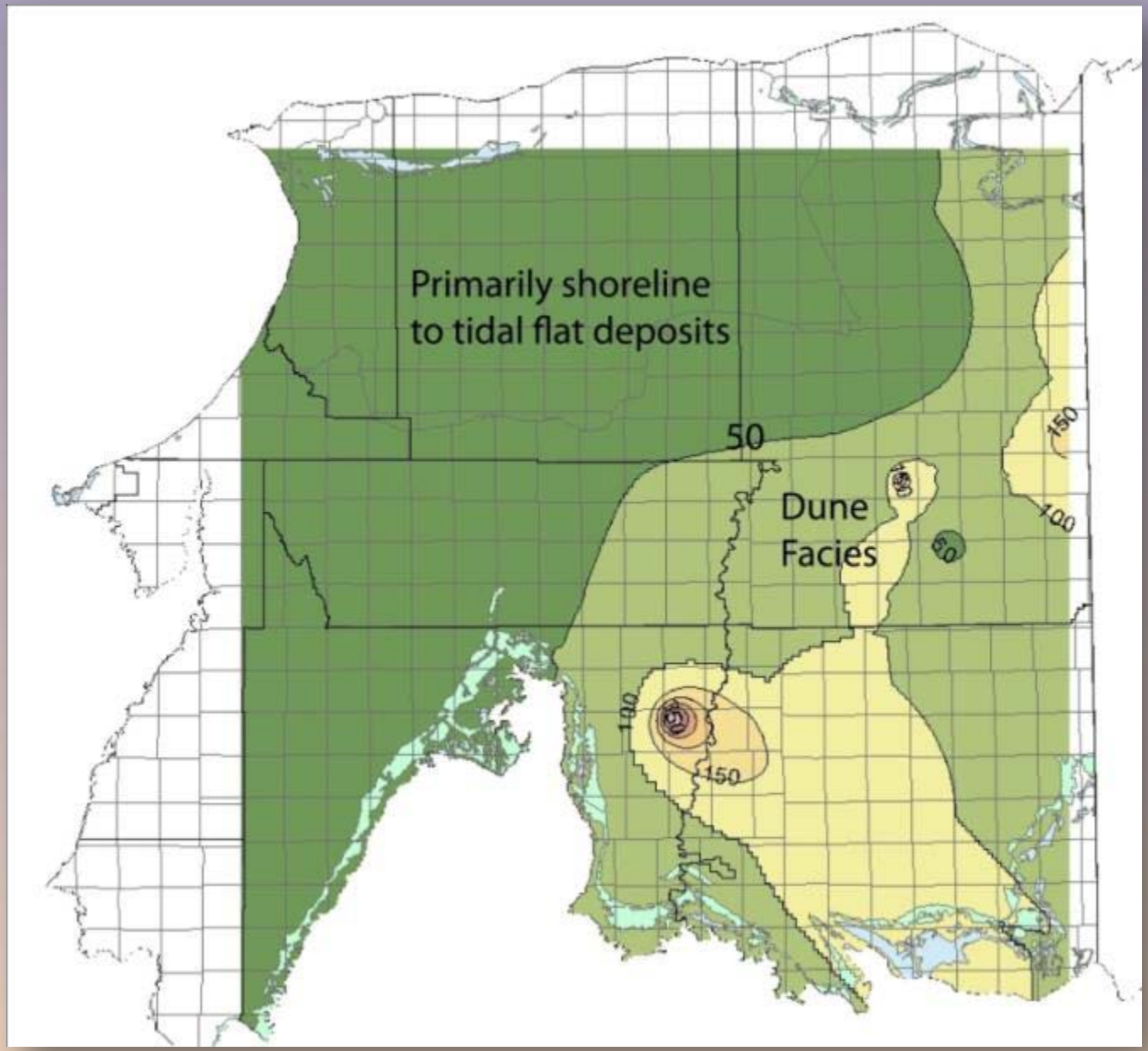


Structure contour map

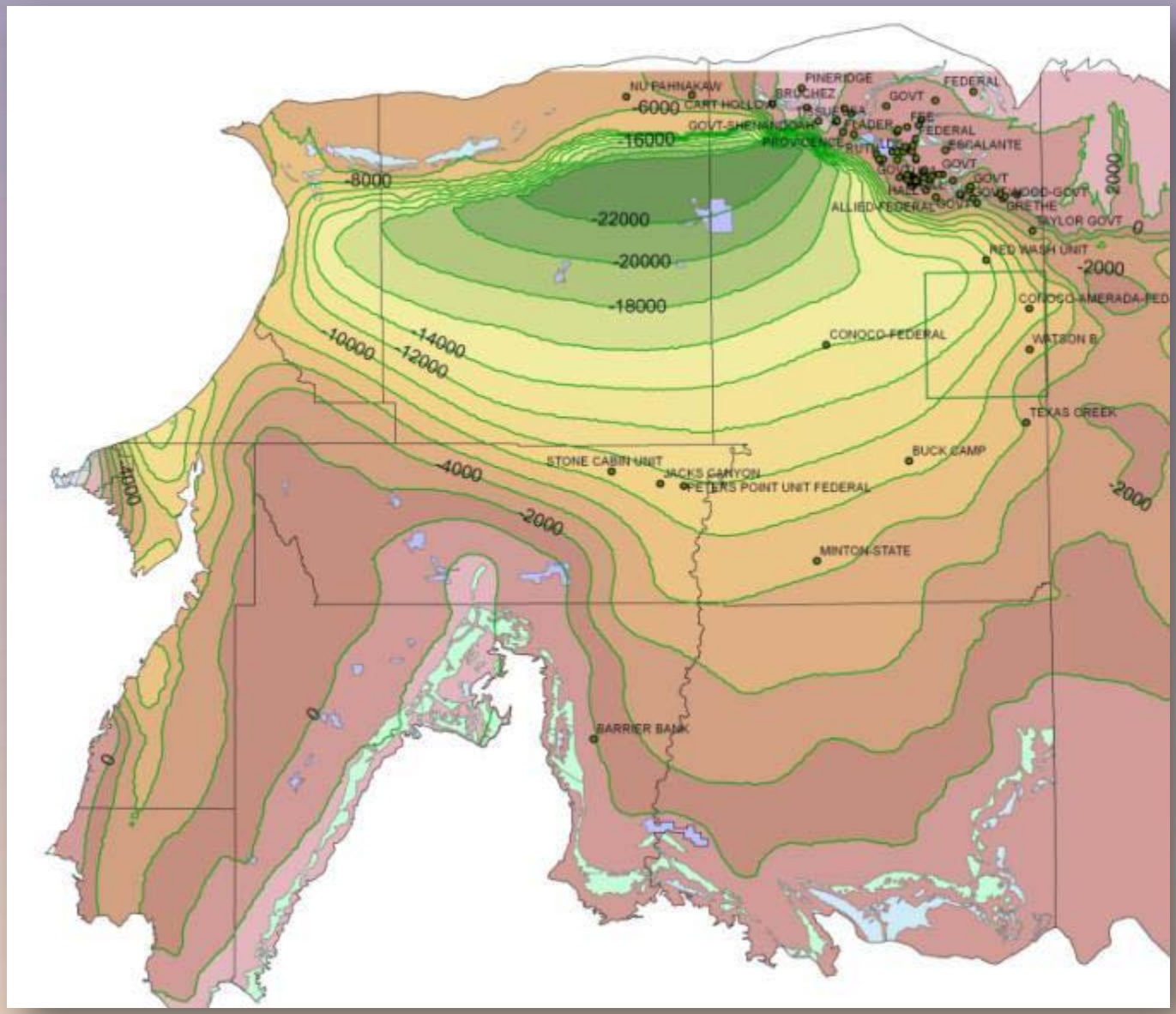
Entrada Sandstone



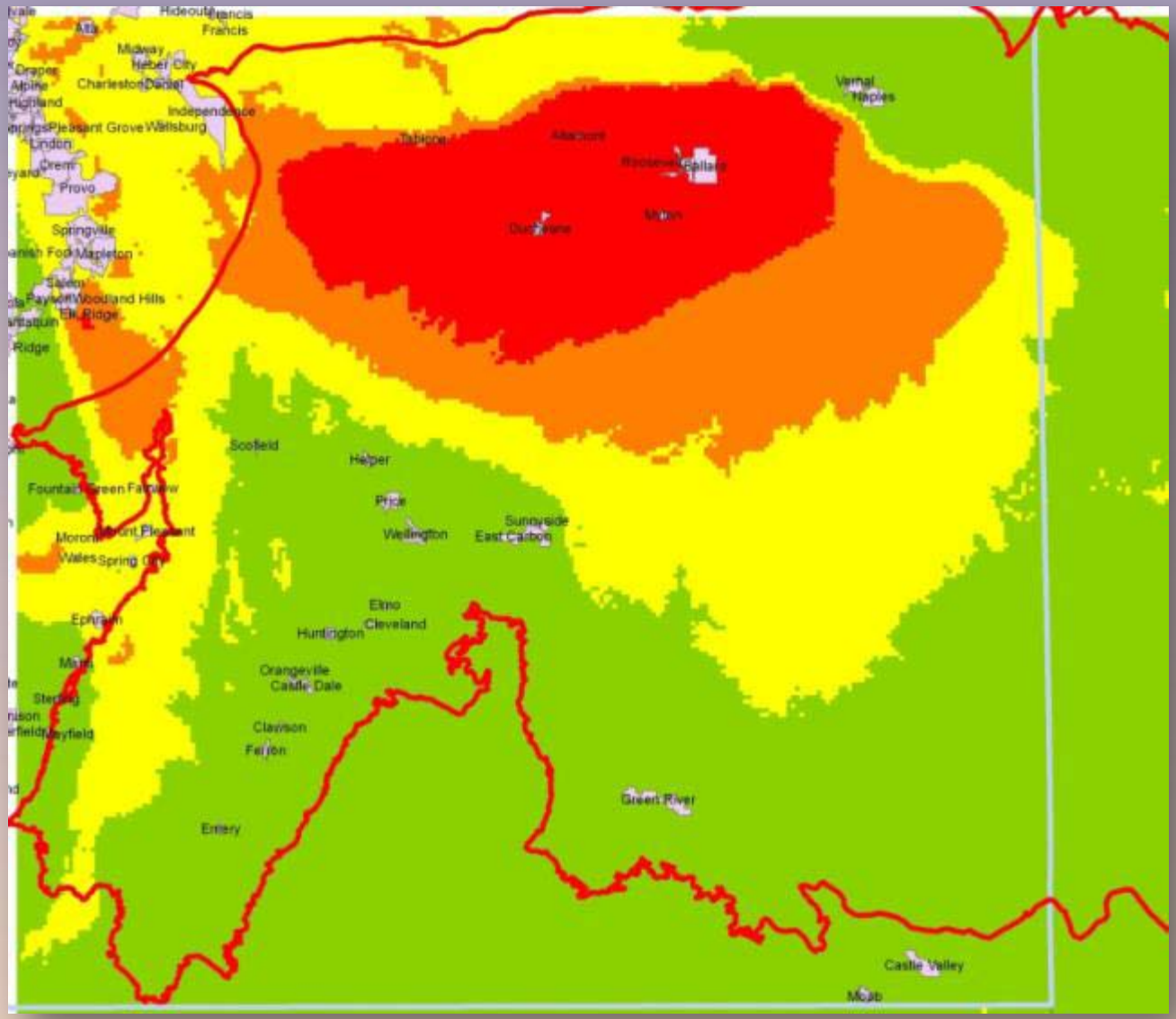
Overburden (drill depth) map of the Entrada Sandstone



Entrada sandstone thickness map



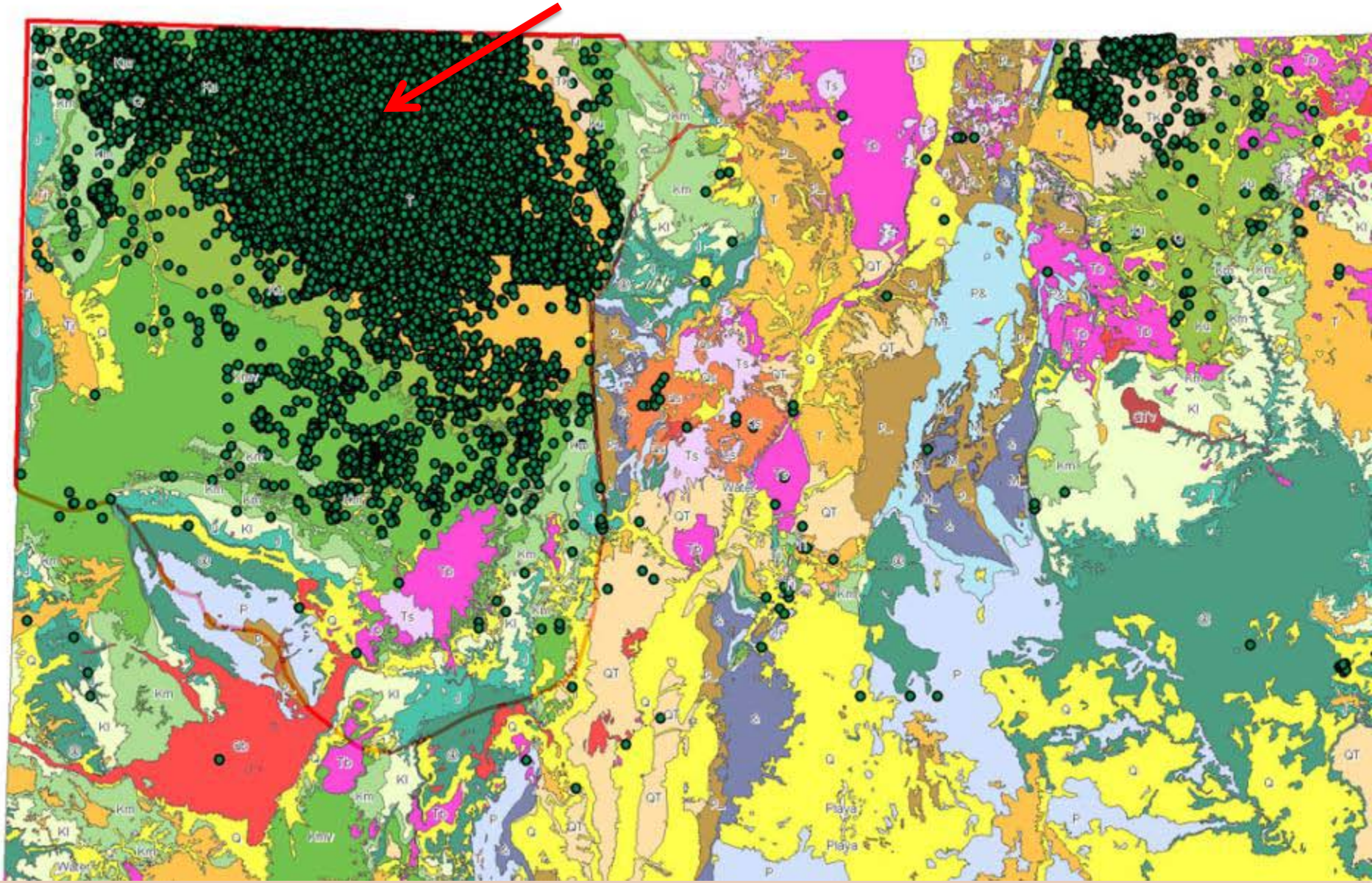
Weber Sandstone structure contour map

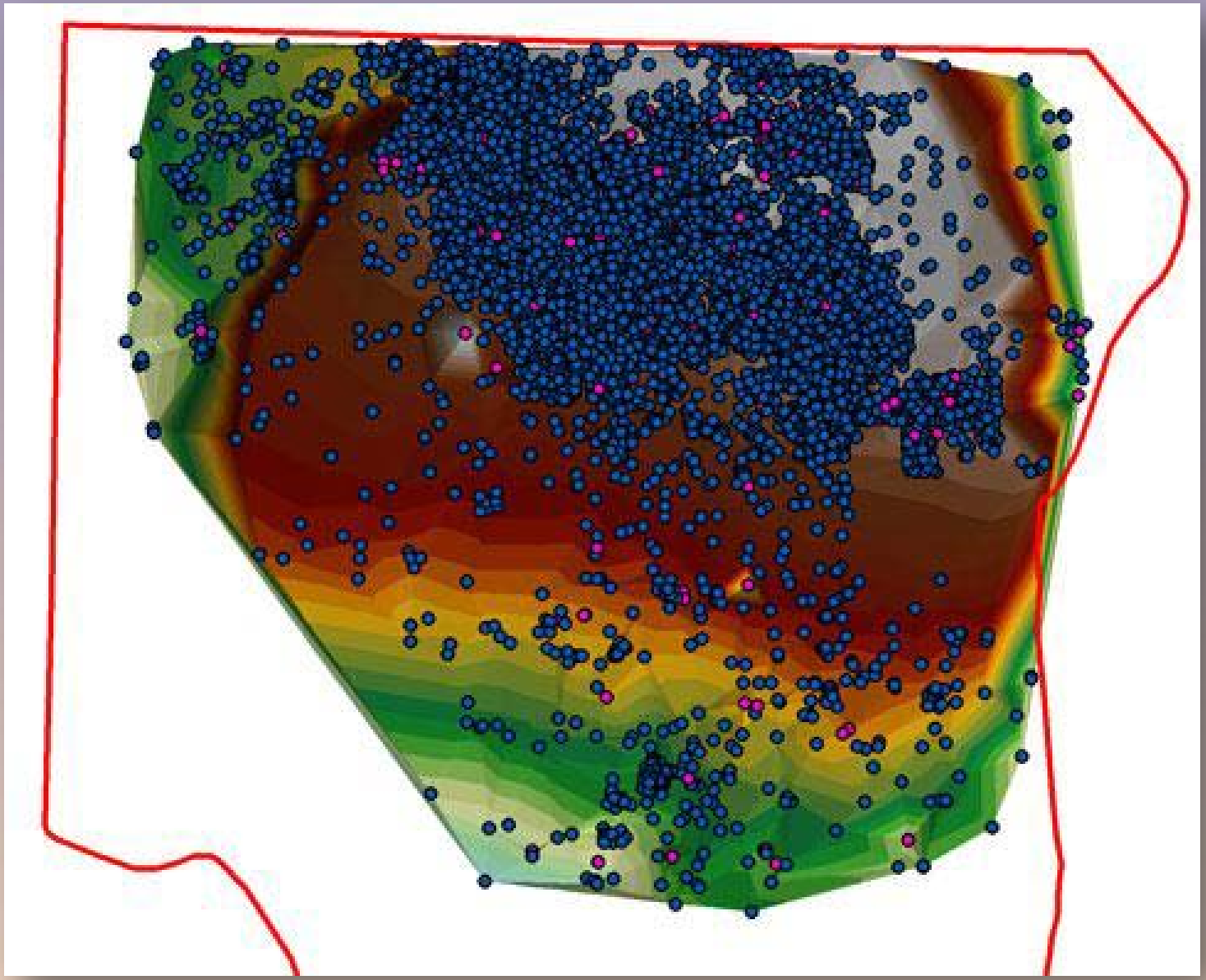


Overburden (drill depth) map of the Weber Sandstone

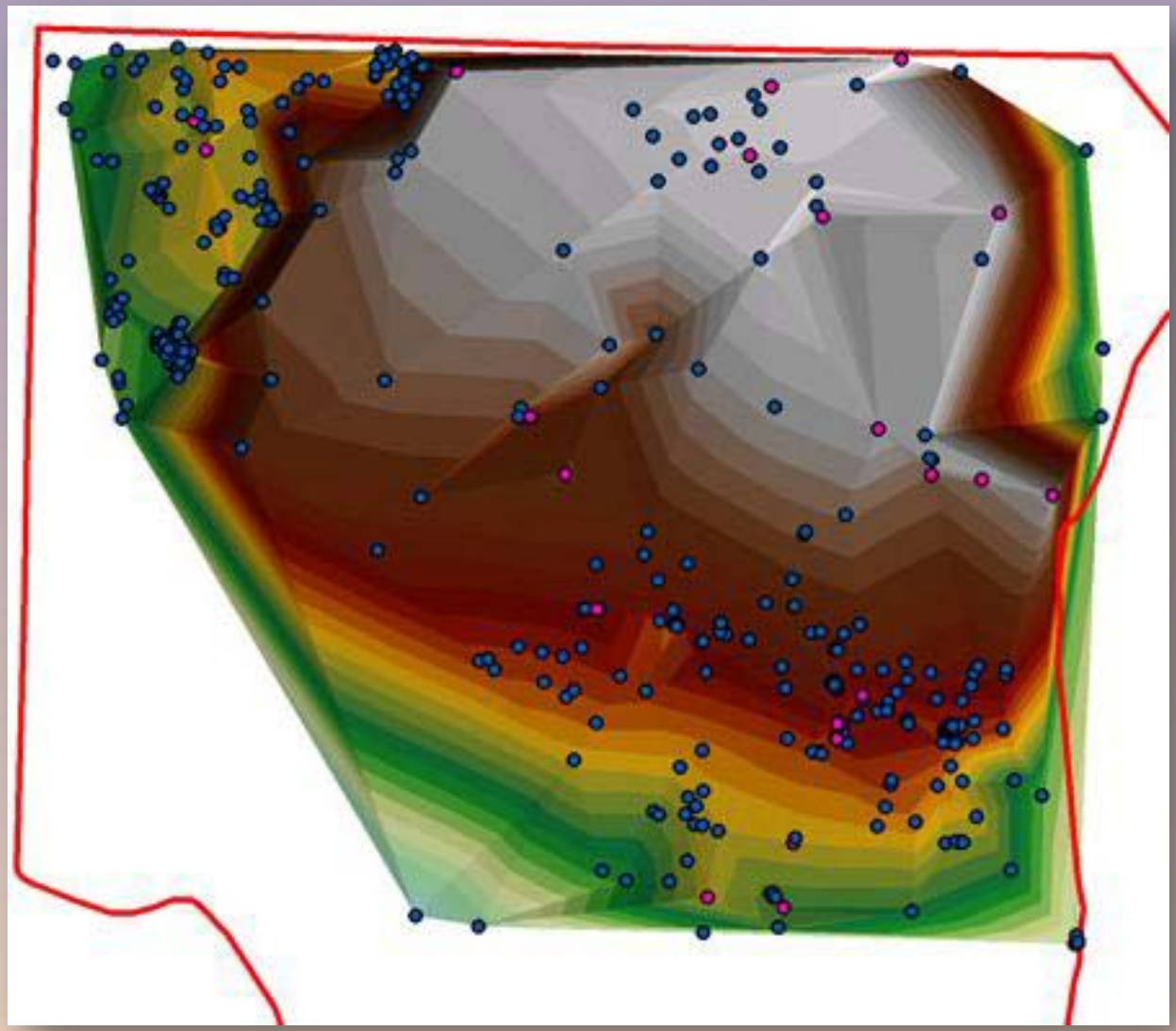
BASIN-WIDE STUDIES

San Juan Basin, New Mexico


Ts
Km
Kl
QT
Q
P
Tb
Playa



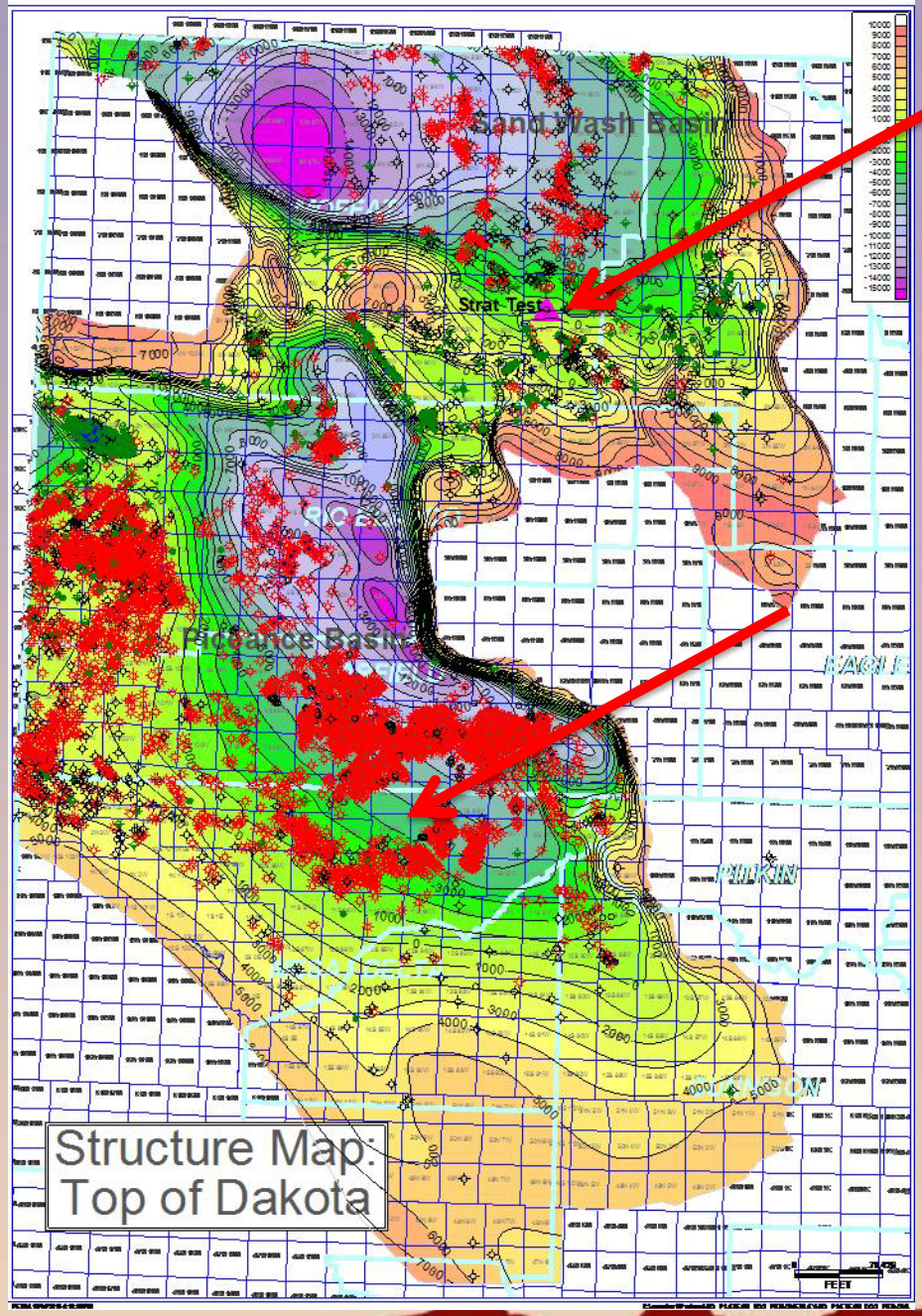
Dakota



Entrada

BASIN-WIDE STUDIES

Piceance Basin, Colorado



Dakota Structure Sand Wash and Piceance Basins

23,000 total wells in Piceance and Sand Wash Basins

14,000 wells with geophysical logs

9,700 wells used in construction of Dakota Structure map

- 2000 wells with Dakota tops
- 7700 additional wells with estimated Dakota tops

The Plan – Year 3

Model Reservoir

- Storage Volume
- CO2 Migration
- Potential Leakage Pathways

Develop Optimal Injection Program

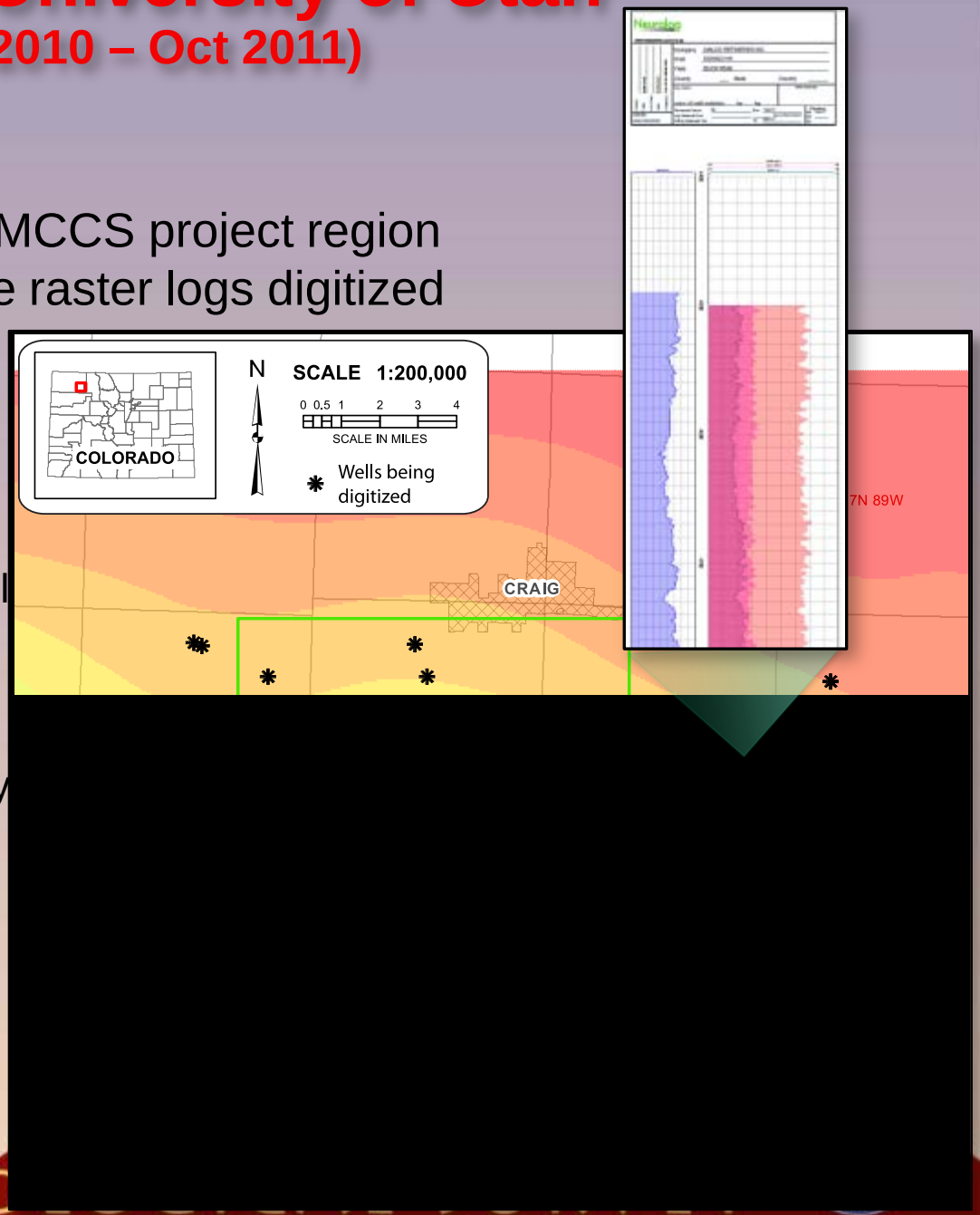
Final Report

AZ, NM, UT, CO Geosurveys

RMCCS – University of Utah
(Oct 2010 – Oct 2011)

Well Digitization

- Forty-Five wells in/around RMCCS project region
  - ~180 out of 230 separate raster logs digitized
    - Sonic, Gamma Ray, Caliper, Induction, Neutron Density, LateroLog
  - Ultimately, digitized data will be incorporated into 3D model of RMCCS project region (PETREL) to assess heterogeneity of porosity, permeability and CO_2 capacity and injectivity.

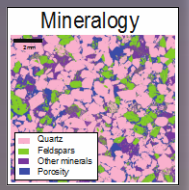


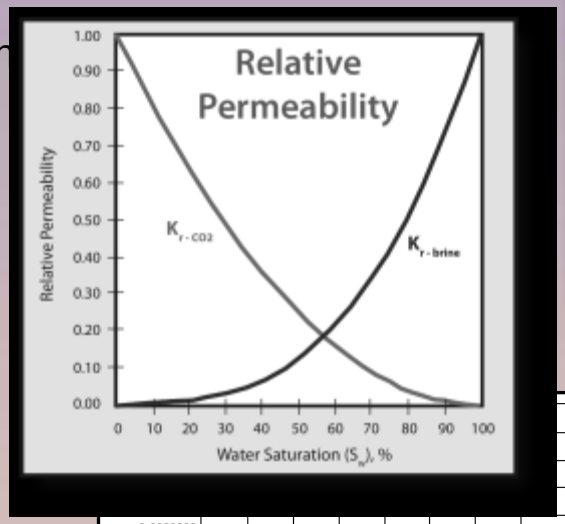
Map of RMCCS project area, showing wells being digitized

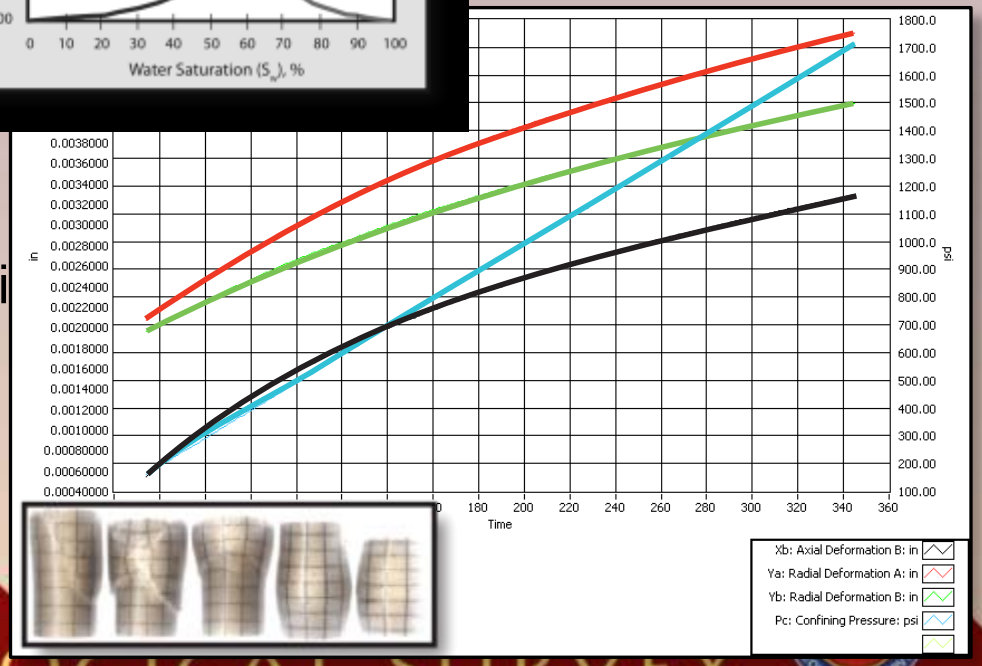
RMCCS – University of Utah
(Oct 2010 – Oct 2011)

Core Testing (Initiated and on-going)

- Geomechanical
  - Unconfined compressive strength
  - Triaxial (drained/undrained)
  - Hydrostatic compressive
  - Fracture toughness
  - Differential strain curve analysis
  - Thick wall cylinder
- Hydraulic
  - Porosity
  - Permeability
  - Relative Permeability
- Geochemical evolution
  - Long-term CO_2 flooding
- Pre- and Post-test Characterizati
  - Mineralogy
  - Morphology
  - Chemistry
  - Fluids



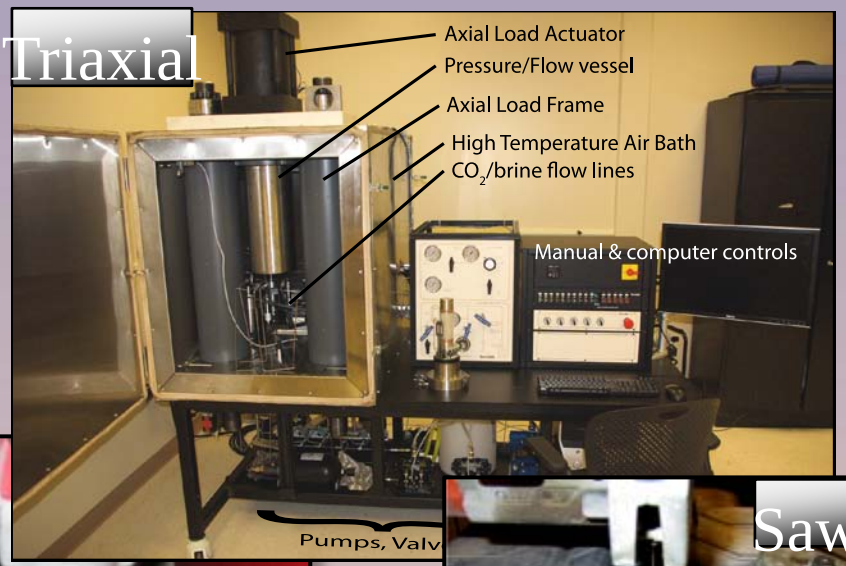


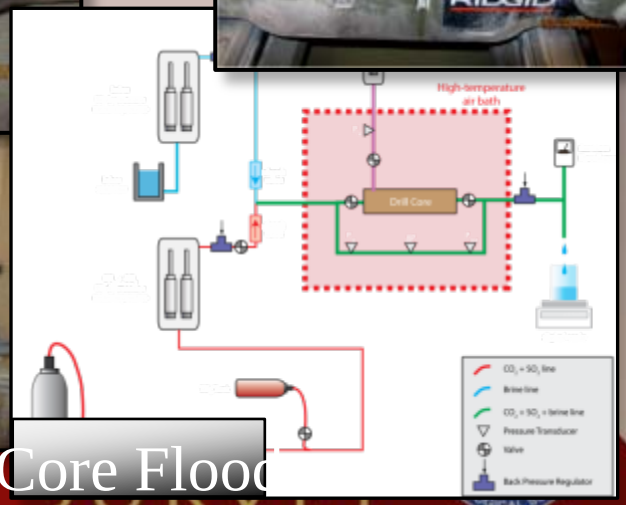


RMCCS – University of Utah
(Oct 2010 – Oct 2011)

Core Testing (Initiated and on-going)

- General
  - Coring, slabbing, grinding equipment
- Geomechanical, Hydraulic & Geochemical
  - Purchase, fabrication and construction of calibration equipment to bring systems to NIST Traceable standards
  - Fabricate and construct end caps for different size core anticipated from RMCCS well
  - Calibrate and test pumps, heaters, actuators, g auges, load cells…
  - Benchmarked material standards (aluminum, Berea SS, Indiana LS)





RMCCS – University of Utah
(Oct 2010 – Oct 2011)

Core Testing (TerraTek Triaxial System with Supercritical CO_2)

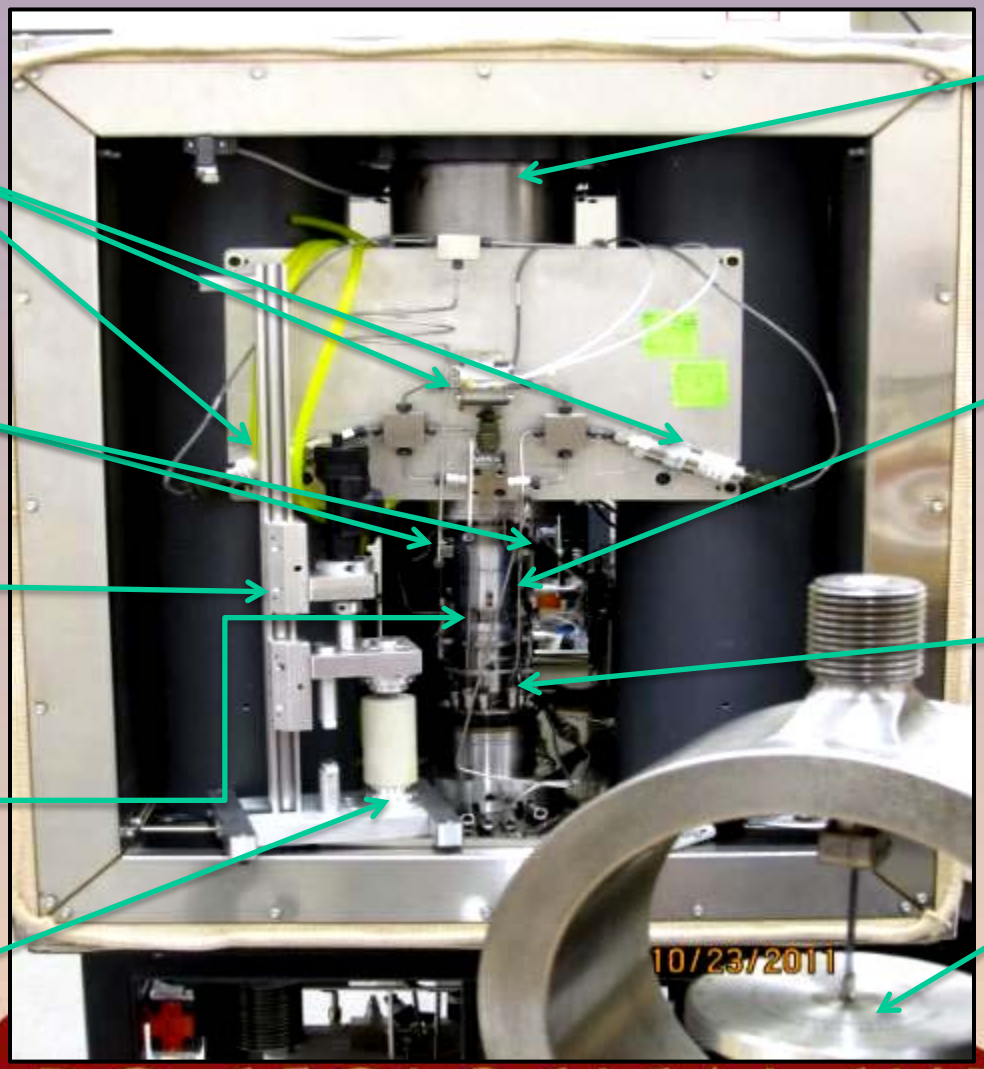
Pressure transducers (permeability measurements)

LVDT's for axial measurement

Linear measurement transducer calibration rack

Cantilever arms(strain gauged) for two axis radial measurement

2"X4"core (maximum)



Pressure vessel 10,000 psi

Billet sample for calibration

Load Cell 100,000 lb

Proving ring (for calibration of load cell) 100,000 lb

RMCCS

- Project Overview
  - Regional Geology
  - Site Specific Characterization
  - Basin-wide Characterization
- Well Construction
  - Schlumberger Carbon Services well operator
  - University of Utah well owner

Areal view of Project Site

• Technical Objectives

Well Specifications

- Sufficient Depth Capacity
- 1050 Ft Full Diameter Core
- Robust Logging Program
- Fluid Sampling
- Borehole Seismic
- Flexible Future Use

Prognosis for SCS RMCCS Strat Test

Formation	MD	SS Elev.	Est.Thick.	Thk. Range	Comments
Ground elev	0	6832			
			320		
Twentymile SS	320	6512			Est. from Tristate core holes
			1000	900-1000	
Trout Creek	1320	5512			Est. from Tristate core holes
			190	160-230	and USGS OFR str map on Tr Ck
Iles	1510	5322			
			1240	1200-1280	
Mancos	2750	4082			
			910	890-990	
Morapos Marker	3660	3172			
			1200	1100-1300	
Base Mancos B	4860	1972			
			1350	1300-1400	
Niobrara	6210	622			240'
			1400	1300-1500	
Carlile	7610	-778			30'
			240	230-260	
Frontier	7850	-1018			
			320	320-380	
Mowry	8170	-1338			
			90	80-100	90'
Dakota	8260	-1428			180'
			180	160-200	
Morrison	8440	-1608			
			390	370-440	
Curtis	8830	-1998			
			80	50-100	80'
Entrada	8910	-2078			180'
			180	100-250	
Chinle	9090	-2258			
			325	280-350	
Shinarump Marker	9415	-2583			Base of Chinle sand/silt--top of shale
Shinarump Main Sd	9575	-2743			Bottom 60' has most sand.
			220	200-250	
Moenkopi	9635	-2803			
			360	350-450	
Phosphoria	9995	-3163			
			190	170-220	25'
Weber	10185	-3353			225'

• Mine Operations

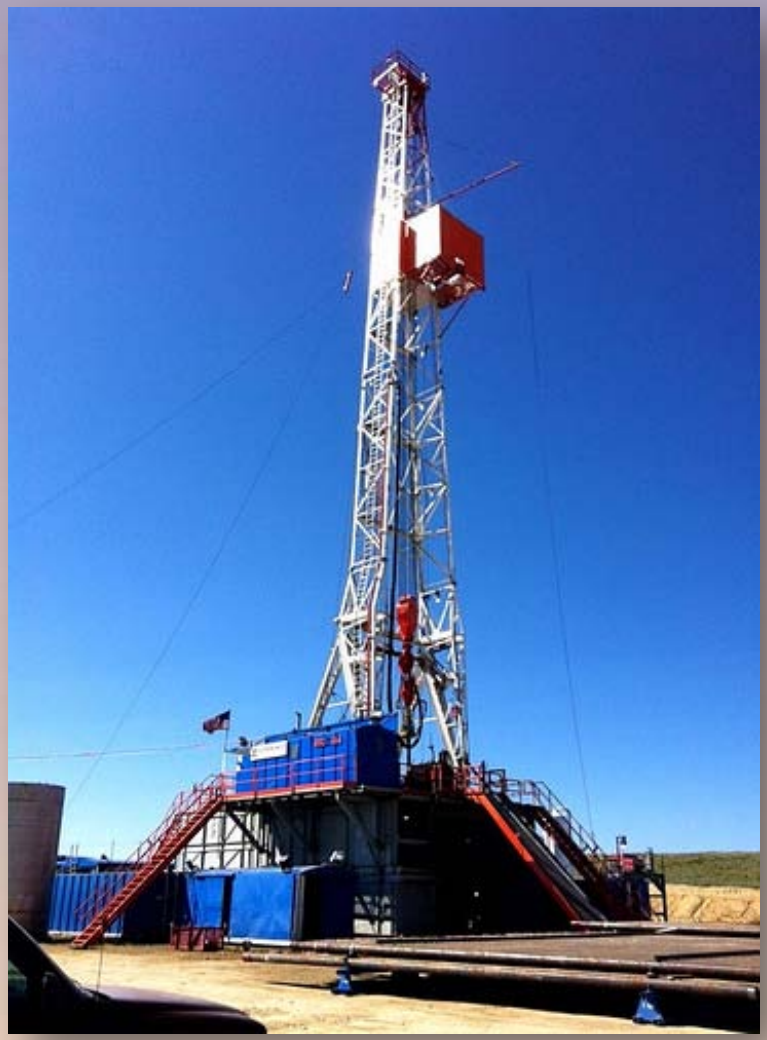
Critical Factors

- MSHA Jurisdiction
- Site Access
- Wildlife Stipulations
- Mine Activity

• Drilling Unit Requirements

Patterson-UTI Rig 166

- Regional Availability
- Depth Capacity
- Large Sub-structure
- Top flight, experienced crew
- Top Management



Q.H.S.E.

- Technical Peer Review
  - (Feb 2011)
- Project Assessment Review
  - (Mar 2011)
- Drill Well on Paper
  - (Nov 2011)
- Pre-Spud Meeting
- 24 Hr Site Supervision
  - Wellsite Supervisor
  - Safety Engineer/Paramedic
  - Wellsite Geologist
  - Mud Logging Engineer

- Quality, Health, Safety & Environment

Risk Matrix

-20 ≥ R > -25	BLACK	EXTREME:
-10 ≥ R > -20	RED	HIGH:
-5 ≥ R > -10	YELLOW	MEDIUM:
-2 ≥ R > -5	GREEN	LOW:
-1 ≥ R > -2	BLUE	INSIGNIFICANT:

MITIGATION / Control Measures / PREVENTION	SEVERITY	Very Low 1	Low 2	Medium 3	High 4	Very High 5
		LIKELIHOOD				
Light	-1	-1 1L	-2 2L	-3 3L	-4 4L	-5 5L
Serious	-2	-2 1S	-4 2S	-6 3S	-8 4S	-10 5S
Major	-3	-3 1M	-6 2M	-9 3M	-12 4M	-15 5M
Catastrophic	-4	-4 1C	-8 2C	-12 3C	-16 4C	-20 5C
Multi-Catastrophic	-5	-5 1MC	-10 2MC	-15 3MC	-20 4MC	-25 5MC

White arrow indicates decreasing risk

Severity scale numbers (-1 to –5) are negative because the result of an undesired incident is negative. When multiplied by the Likelihood numbers (1 to 5), the resulting Risk numbers are negative (-1 to –25).

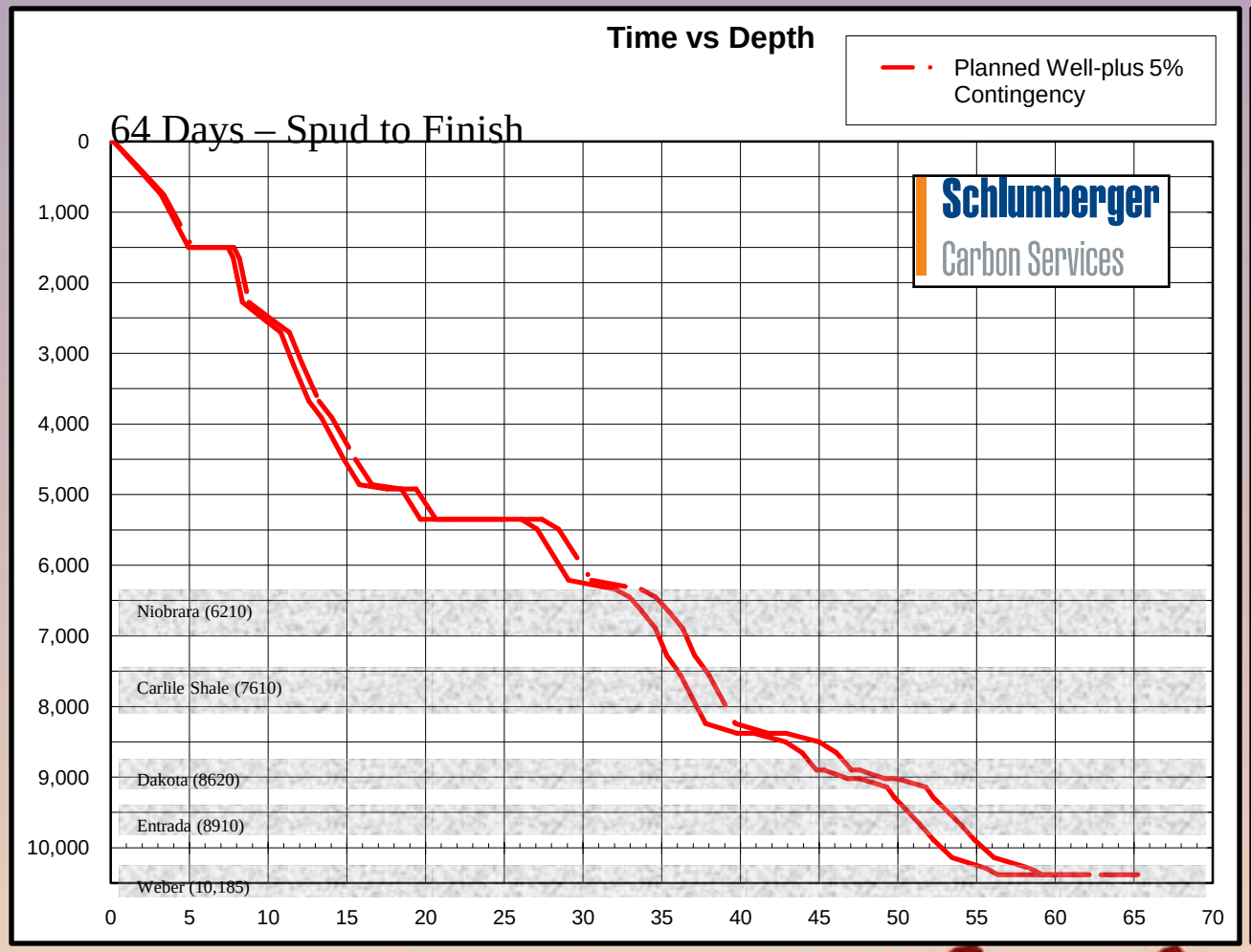
Prevention Measures reduce the Likelihood of occurrence of an undesired incident.

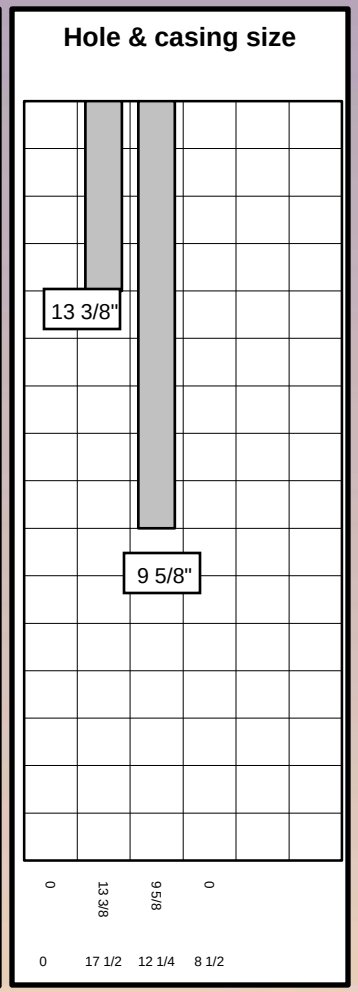
Mitigation Measures reduce the Severity of an undesired incident.

Drilling Program

- 20 ” conductor pipe set to 20 ft
- 13 $^{3}/_{8}$” to be set at 1,500 ft (17 ½” hole) cement to surface
- 9 $^{5}/_{8}$” protection pipe to 5,500 ft (12 ¼” hole) cement to surface
- Total Depth is expected to be 10,400 ft
- 1,050 ft of 4 in core to be cut in five formations
- Water based drilling fluid
- No casing string to bottom
- Well plugged after conclusion of project
- Abandonment designed for easy re-entry

Operating Company	Schlumberger Carbon Services	**Spud Date**	1-Dec-11
Well Name	RMCCS State No. 1	**To Date**	15-Nov-11
Rig	Patterson Rig 166	**Planned End Date Drilling**	3-Feb-12
Field (if applicable)	Trapper Mine site (S of Craig, Co)	**Planned End Date RD/MO**	4-Feb-12





Questions?

Thank You!