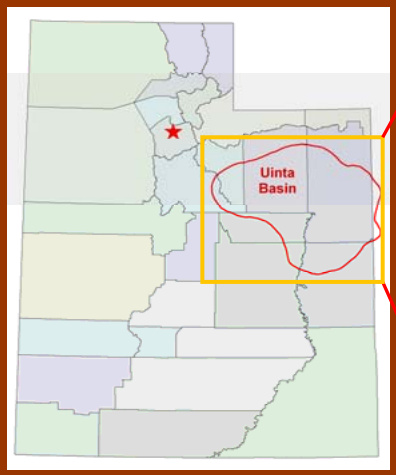
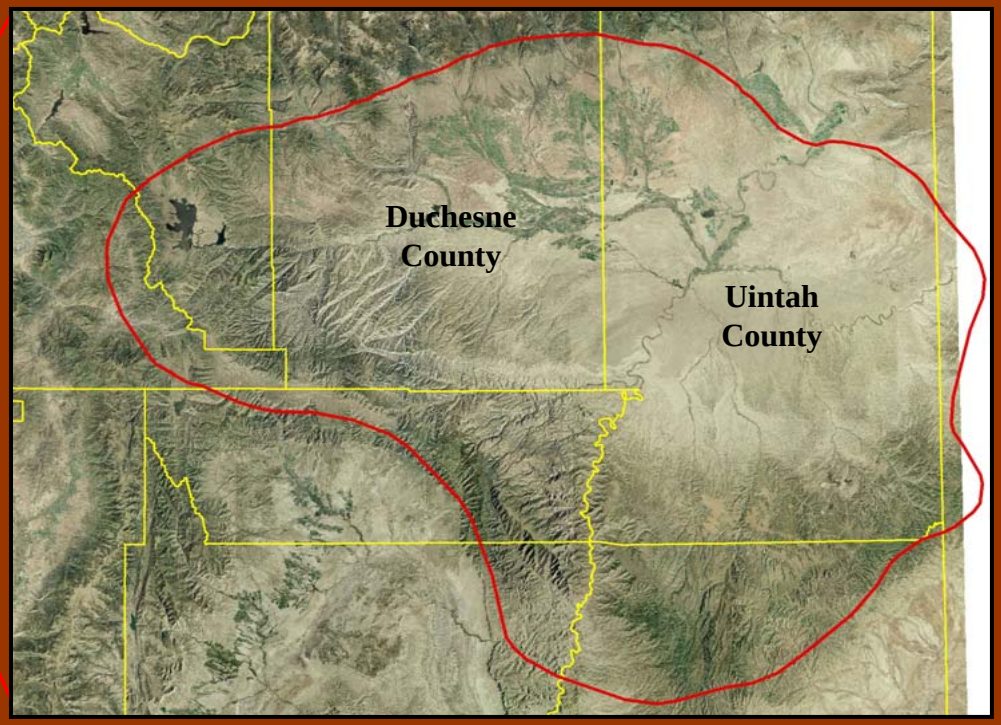
Water-related issues affecting conventional oil and gas recovery and potential oil shale development in the Uinta Basin, Utah





PI: Michael D. Vanden Berg

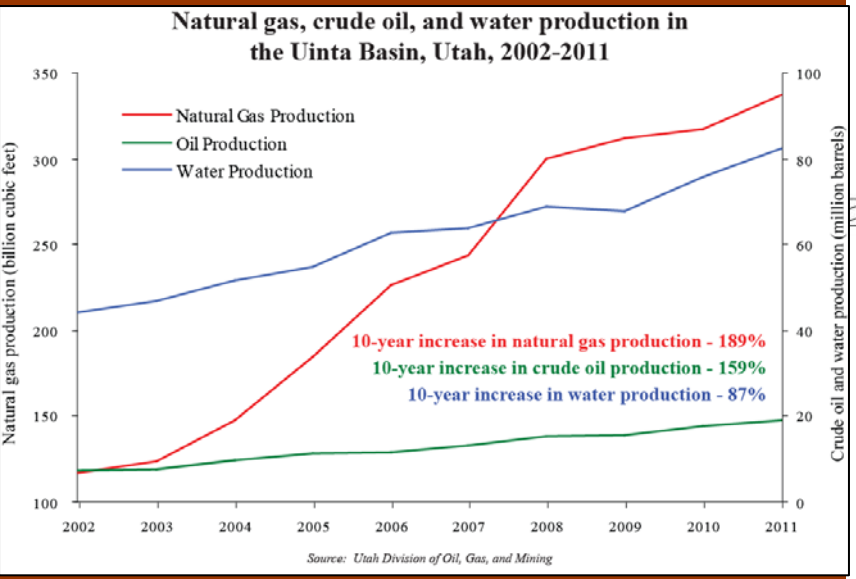
DOE number: NT0005671

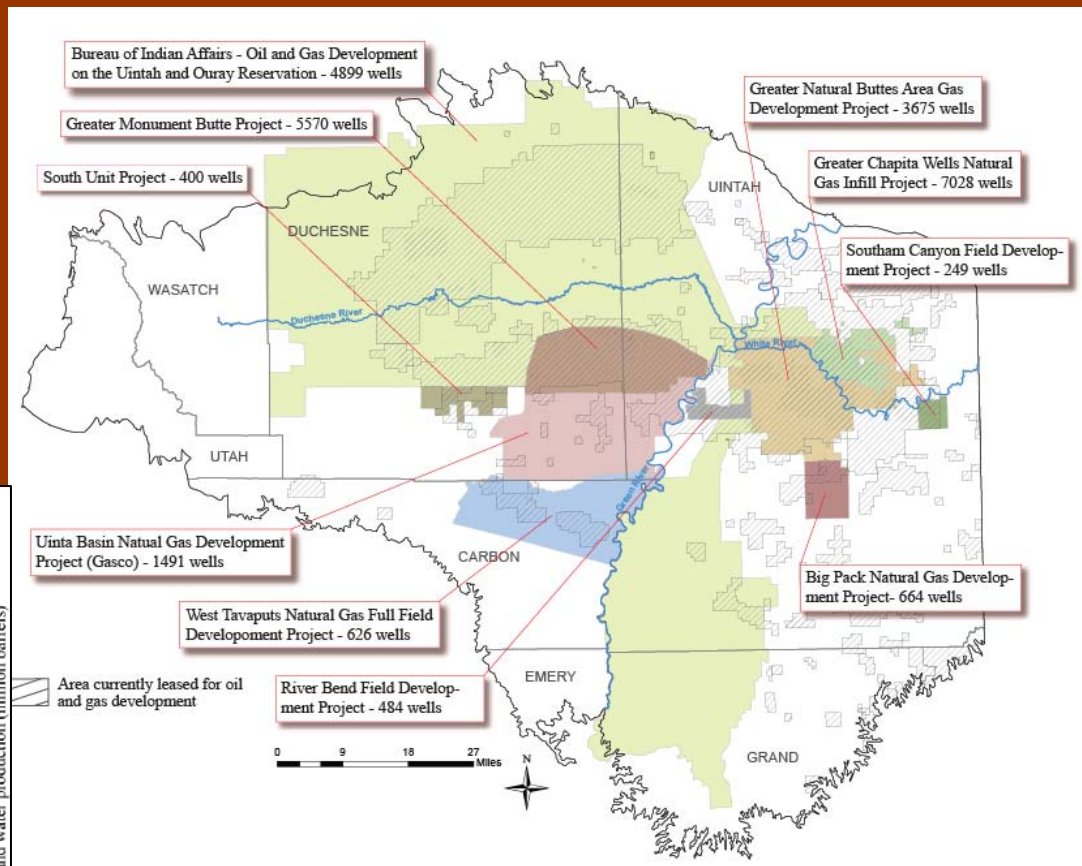
Project website: geology.utah.gov/emp/UBwater_study

Overall Goal #1

Assess groundwater aquifers in the Uinta Basin to help facilitate prudent saline water disposal

- Facilitate increased petroleum development
- Protect freshwater resources
- Reduce the need for evaporation ponds





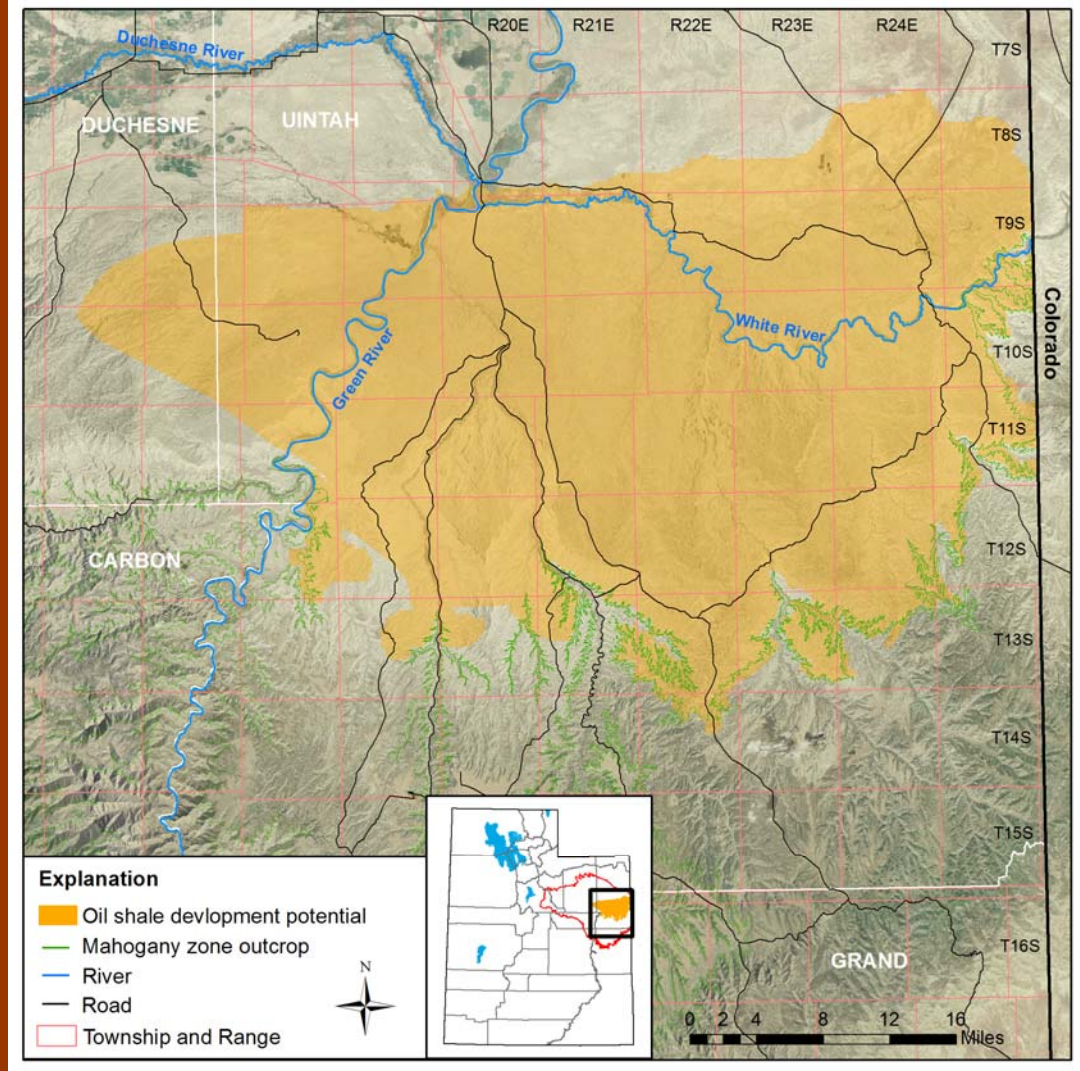
More than 25,000 oil and gas wells are currently proposed for drilling in the Uinta Basin

This future drilling will greatly increase the amount of produced water needing proper disposal

Overall Goal #2

Establish baseline surface and shallow groundwater chemistry data for lands with oil shale development potential

- Lands designated by BLM in PEIS
- Pre-development data
- Bi-annual sampling



3 Main Tasks

Task 1: Project Management – PI: Michael Vanden Berg, UGS

Task 2: Re-map the base of the moderately saline water

Task Leader: Paul Anderson, Consulting Geologist

Scale: Basin-wide

Task 3: Geologic characterization of the Birds Nest aquifer

Task Leader: Michael Vanden Berg, UGS, Energy and Minerals Program

Scale: Regional (central Uintah County)

Task 4: Baseline water chemistry database for lands with oil shale development potential

Task Leader: Janae Wallace, UGS, Groundwater Program

Scale: Regional (central Uintah County)

Task 5: Analysis of produced water from simulated in-situ oil shale extraction technologies - Collaboration with University of Utah

Task 6: Technology Transfer

Project Funding and Deadlines

Total Funding = $860,279

- 20% UGS cost share
- $243,966 subcontract to Paul Anderson (Task 2) (billed out)
- ~$32,000 remaining (to be spent January-April 2012)

Timeline:

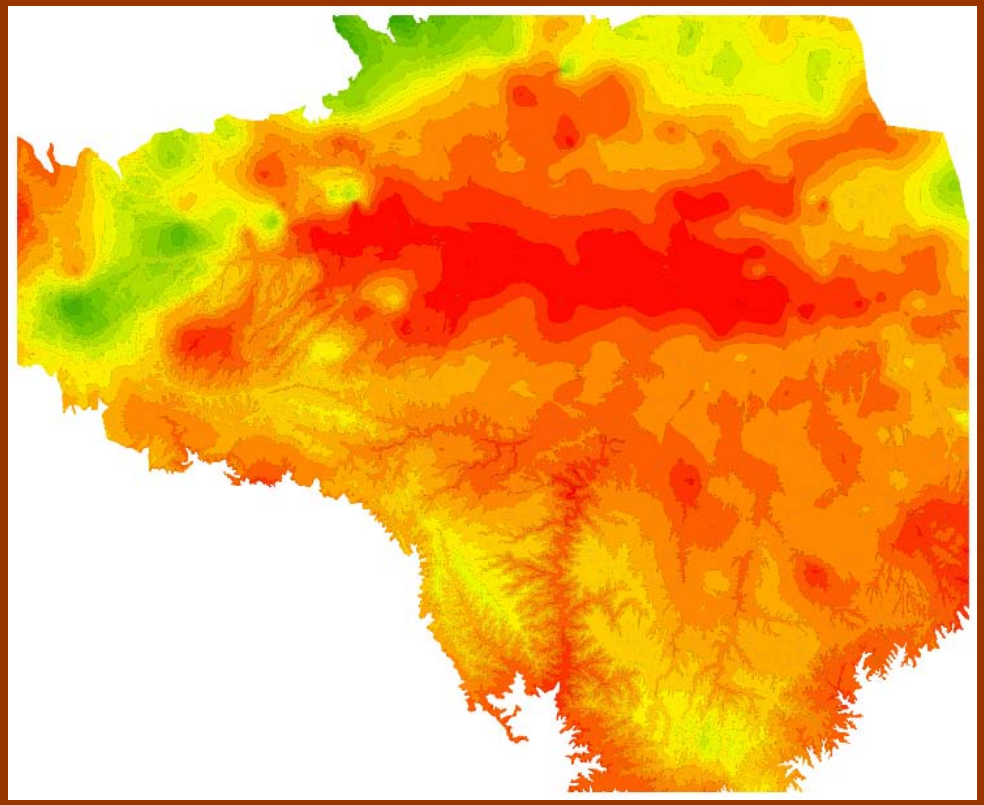
- Original time frame: October 1, 2008 to September 30, 2011
- First no-cost extension: Extended project to December 31, 2011
- Second no-cost extension: Extended project to April 30, 2012

Task updates:

- Task 2 – draft final report finished, in review
- Task 3 – draft final report 25% finished
- Task 4 – draft final report finished, in review
- Task 5 – experiments completed, report in prep.

Task 2:

Mapping the base of the moderately saline water in the Uinta Basin, Utah



Problem:

A lack of saline water disposal options is a significant limiting factor with regard to increases in oil and gas production in the Uinta Basin, Utah

- Saline water from oil and gas wells can only be injected into aquifers containing water that is >10,000 TDS salinity
  - Protection of "freshwater" (0-10,000 TDS) is a priority
- Current disposal wells are at or near capacity
- Evaporation ponds can not handle the increase in saline water and pose several environmental challenges
  - Brine concentration
  - Potential for contaminating shallow groundwater
  - Wildlife hazard
  - Potential for increased ozone and VOC emissions

- Re-using water is an option, but treatment is expensive
- Quality groundwater data is lacking, delaying approval of disposal permits
  - Original reference map is 25 years old - >8000 wells have been drilled since

Solution:

Provide reliable and accurate groundwater data to operators and regulators to facilitate prudent saline water disposal plans

Research / Deliverables:

- New GIS-based map showing the base of the moderately saline water within the Uinta Basin, Utah (10,000 TDS surface)
  - Below which, saline water can be injected without compromising “freshwater” resources
- Database of water quality information (ground truth)
  - ~2800 water analyses from ~1500 individual wells throughout the basin
- Five geologic cross sections showing the saline water transition and its relationship to the subsurface geology

Collaboration – The key to our success!!!

Operator / Service Company:

- Alta-Blue
- Anadarko Petroleum Corp.
- Anschutz
- Berry Petroleum Co.
- Bill Barrett Corp.
- Blue Tip Castlegate Inc.
- Devon Energy Production Co.
- El Paso E&P Co.
- Elk Resources
- Enduring Resources
- EOG Resources
- FMIL Natural Resources
- Flying J
- Forest Oil Corp.
- GASCO Inc.
- Halliburton
- JW Operating
- McElvin Oil & Gas
- Mustang Fuel Corp.
- Newfield Production Corp.
- Pendragon Energy Partners
- Questar Energy Co.
- Robert L. Bayless Production
- Rosewood Resources
- Royale Energy Inc.
- Summit Operating
- TCC Royalty Corp.
- Whiting Oil & Gas Corp.
- Wind River Resources Corp.
- XTO Energy Inc.

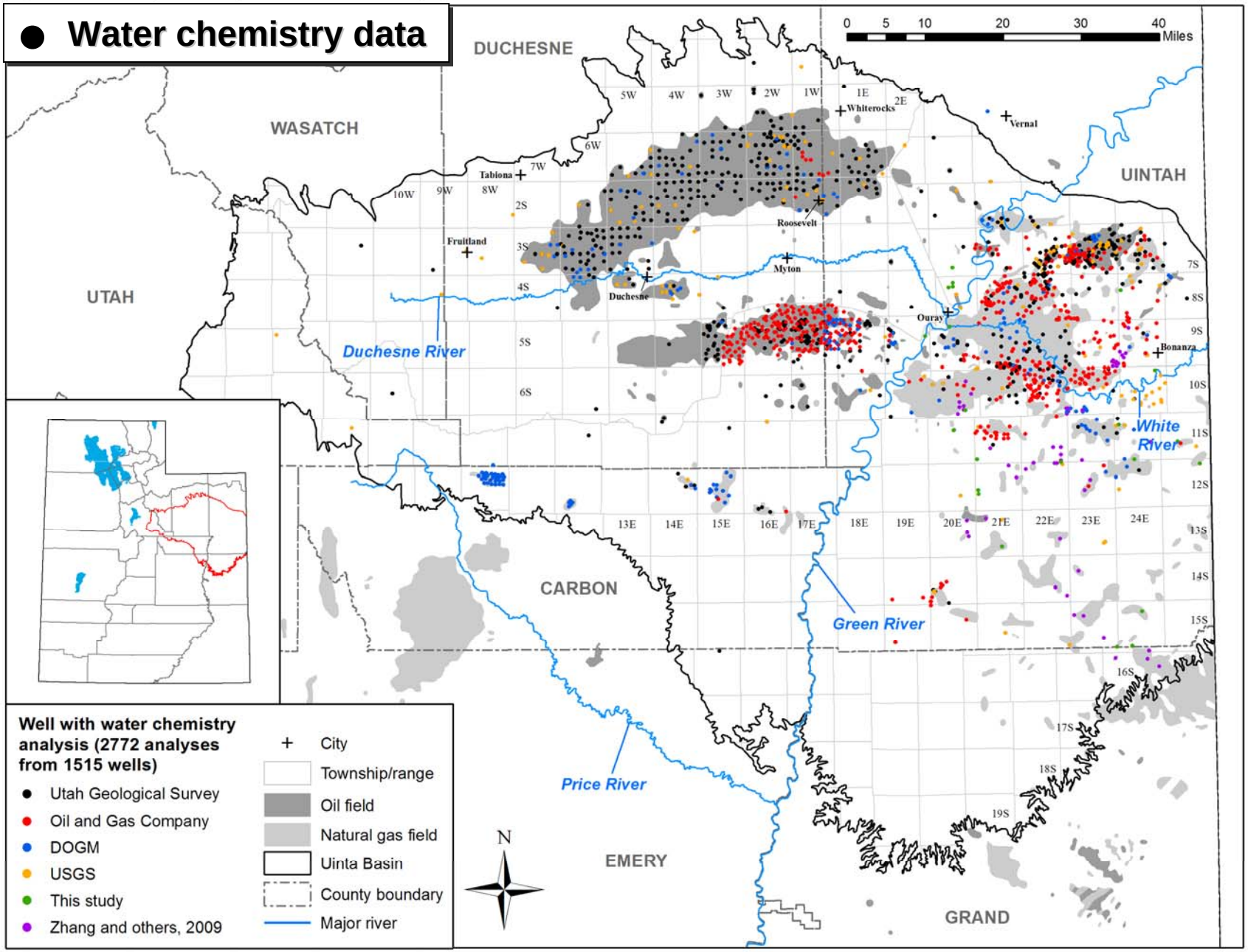
Government / Academia:

- Kansas Geological Survey
- University of Utah
- University of Wyoming
- U.S. Geological Survey
- U.S. Bureau of Land Management
- Utah Division of Oil, Gas, and Mining
- Utah Division of Water Resources

Datasets used in mapping effort:

- Downhole water chemistry
  - "Ground truth"
  - ~2800 analyses from ~1500 different wells
  - Data mostly from oil and gas operators and DOGM well files
- Data from original mapping effort (TP-92)
  - This data was re-evaluated and corrections where made when appropriate
  - Revised mapping rules applied
- Evaluation of geophysical logs from select wells throughout the basin
  - 259 wells were examined
  - Examination of resistivity logs as a proxy for salinity (Archie's equation)
  - Digital log files were donated by companies (70%), the remainder were purchased or digitized in-house

Task 2: Re-map the base of the moderately saline water



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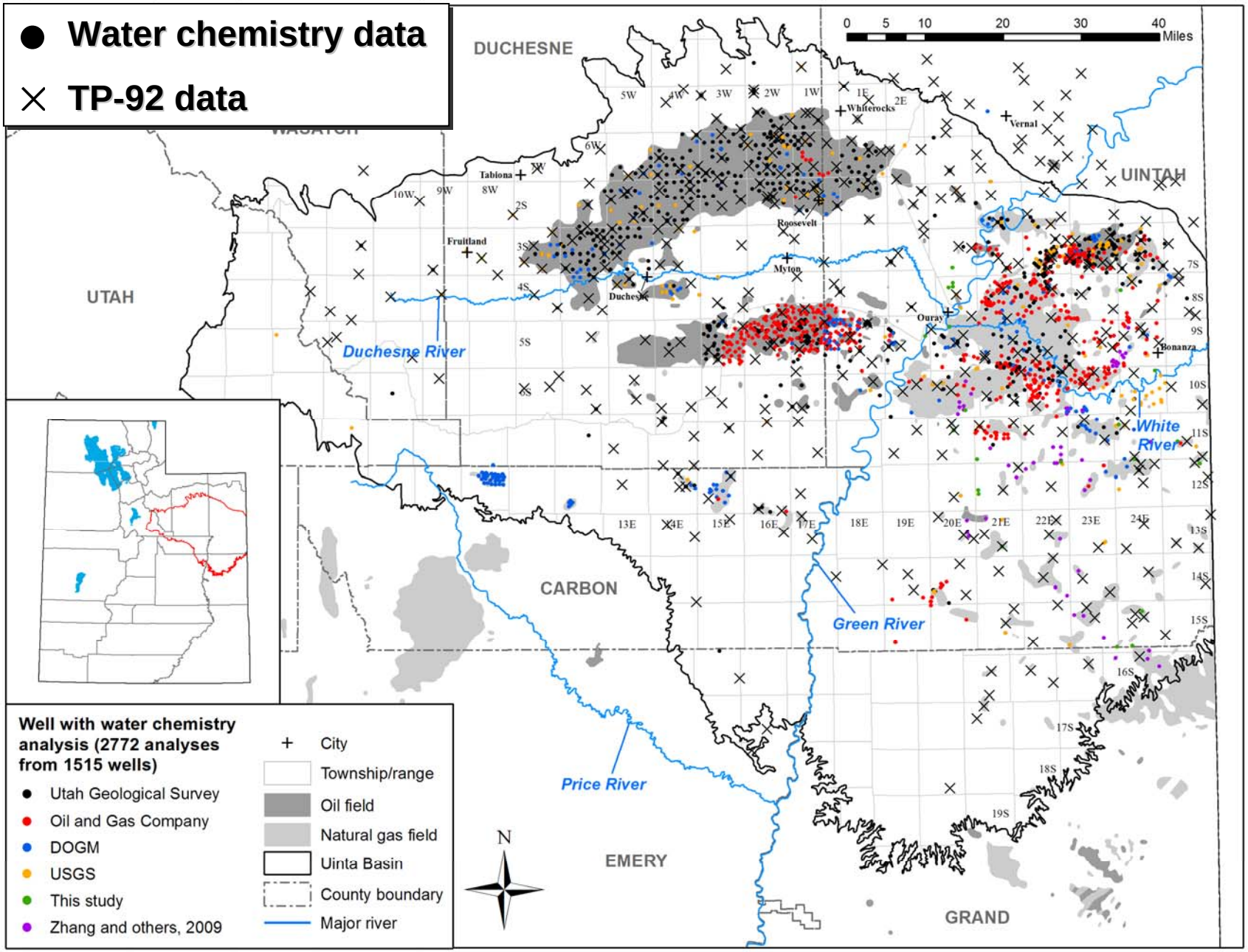
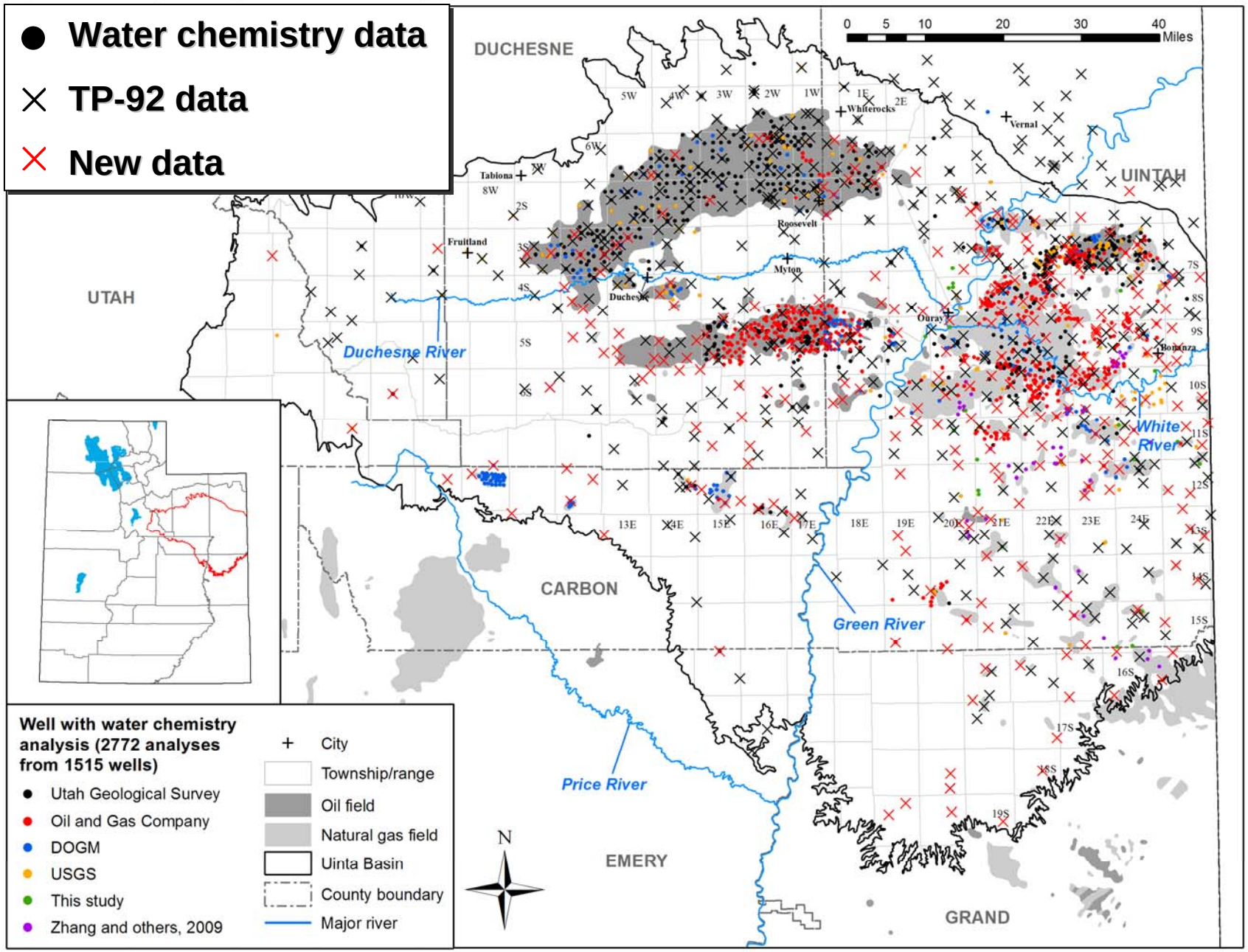
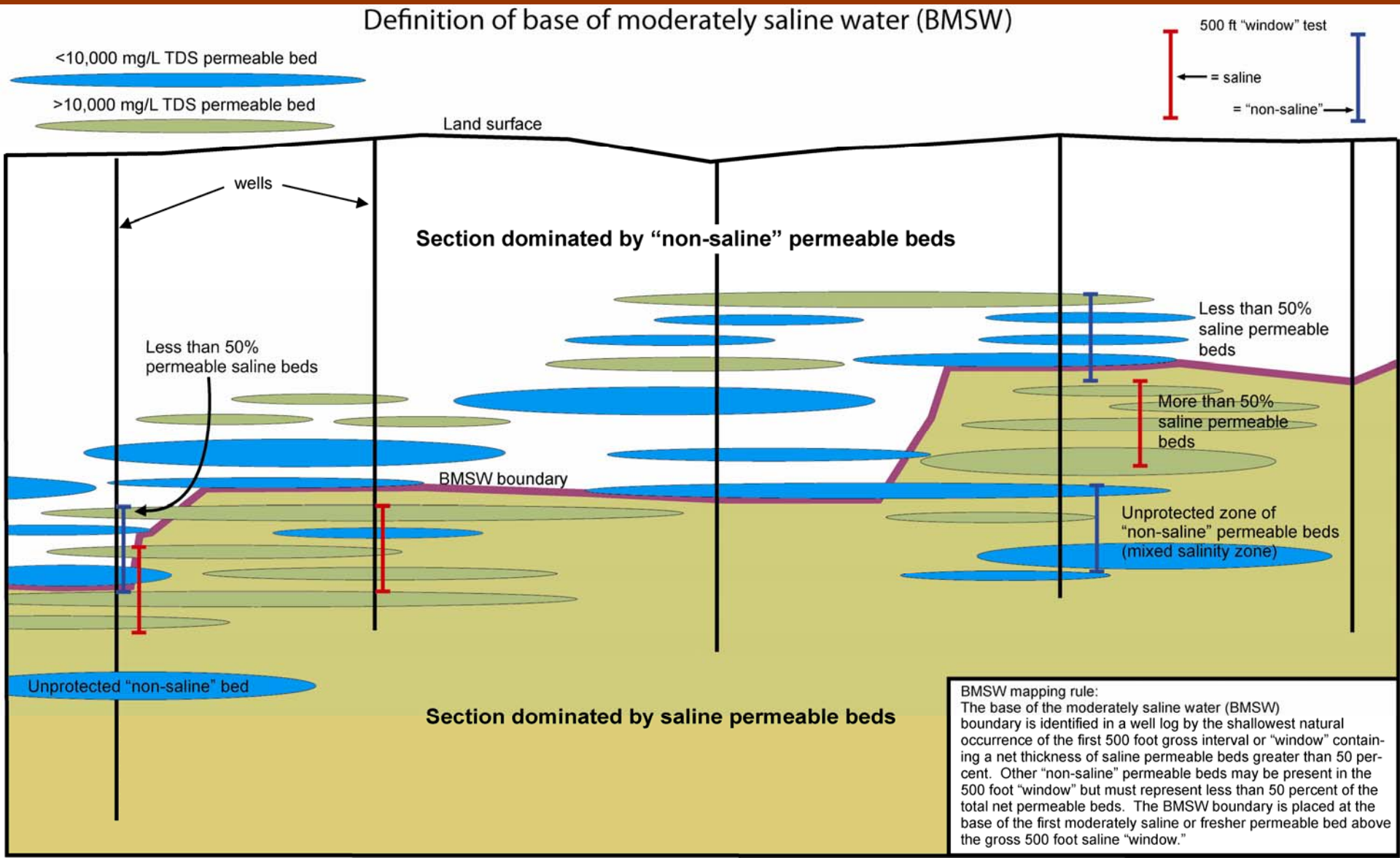


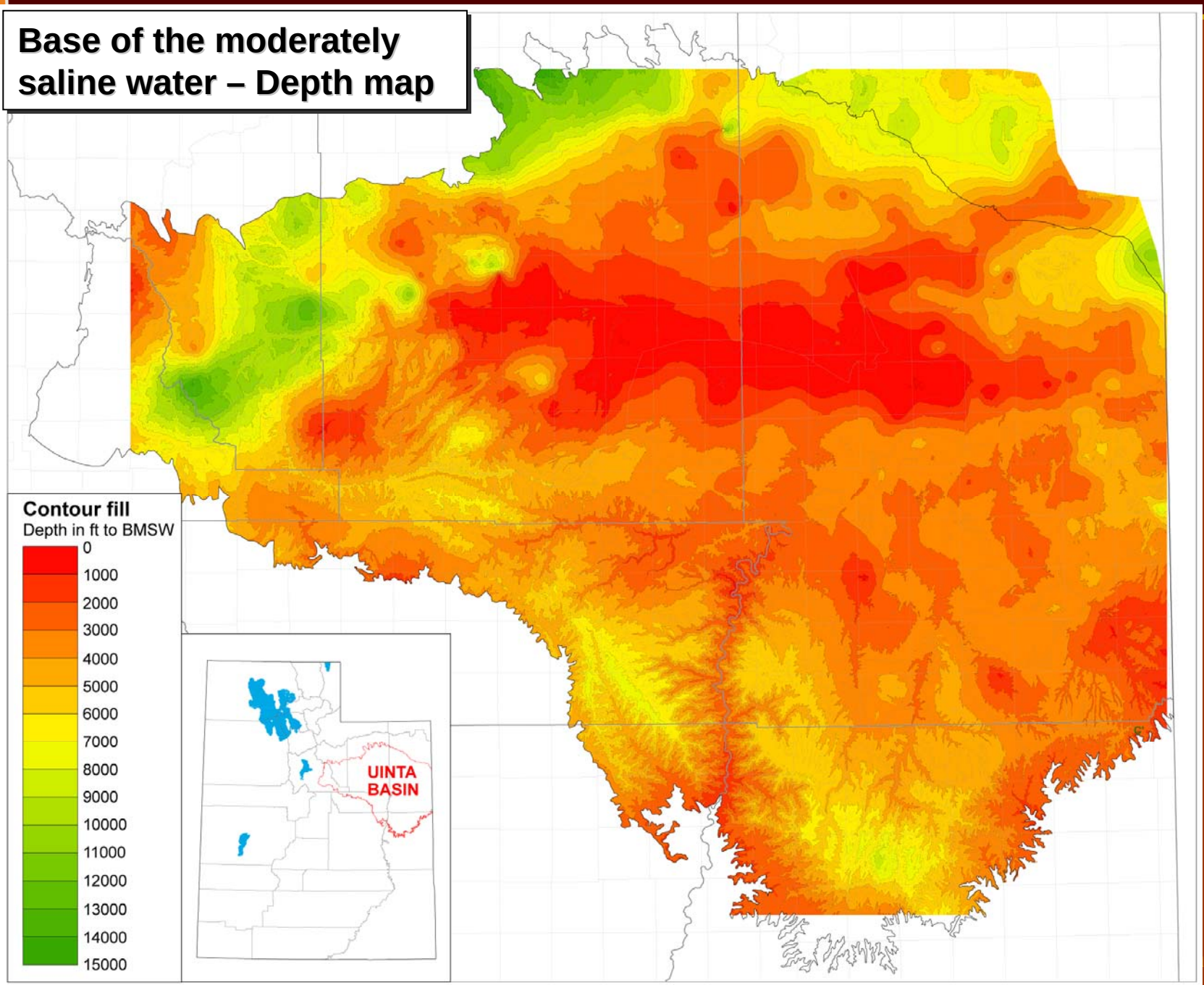
Task 2: Re-map the base of the moderately saline water



How do you pick one boundary in a transition zone?

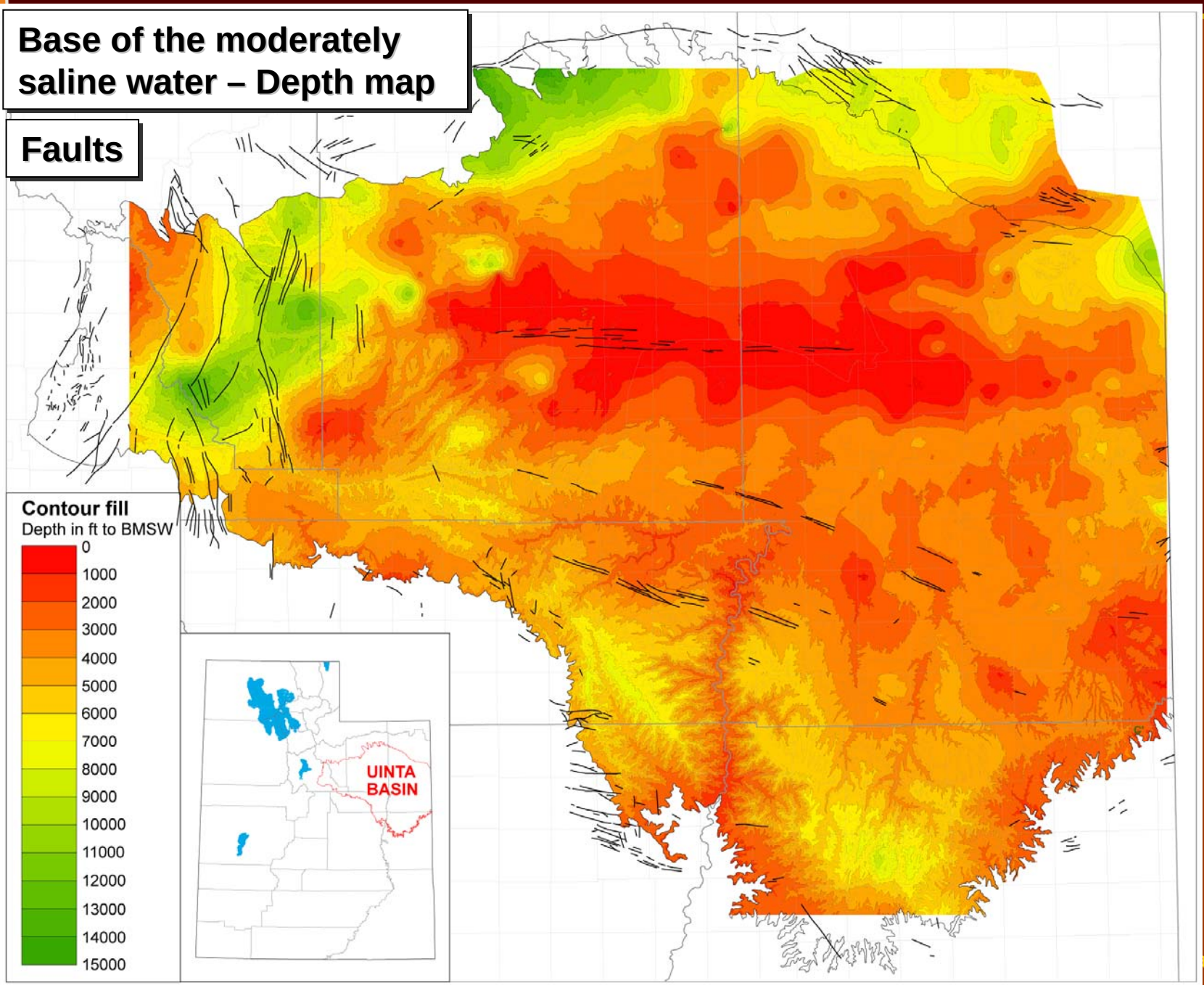


Base of the moderately saline water – Depth map



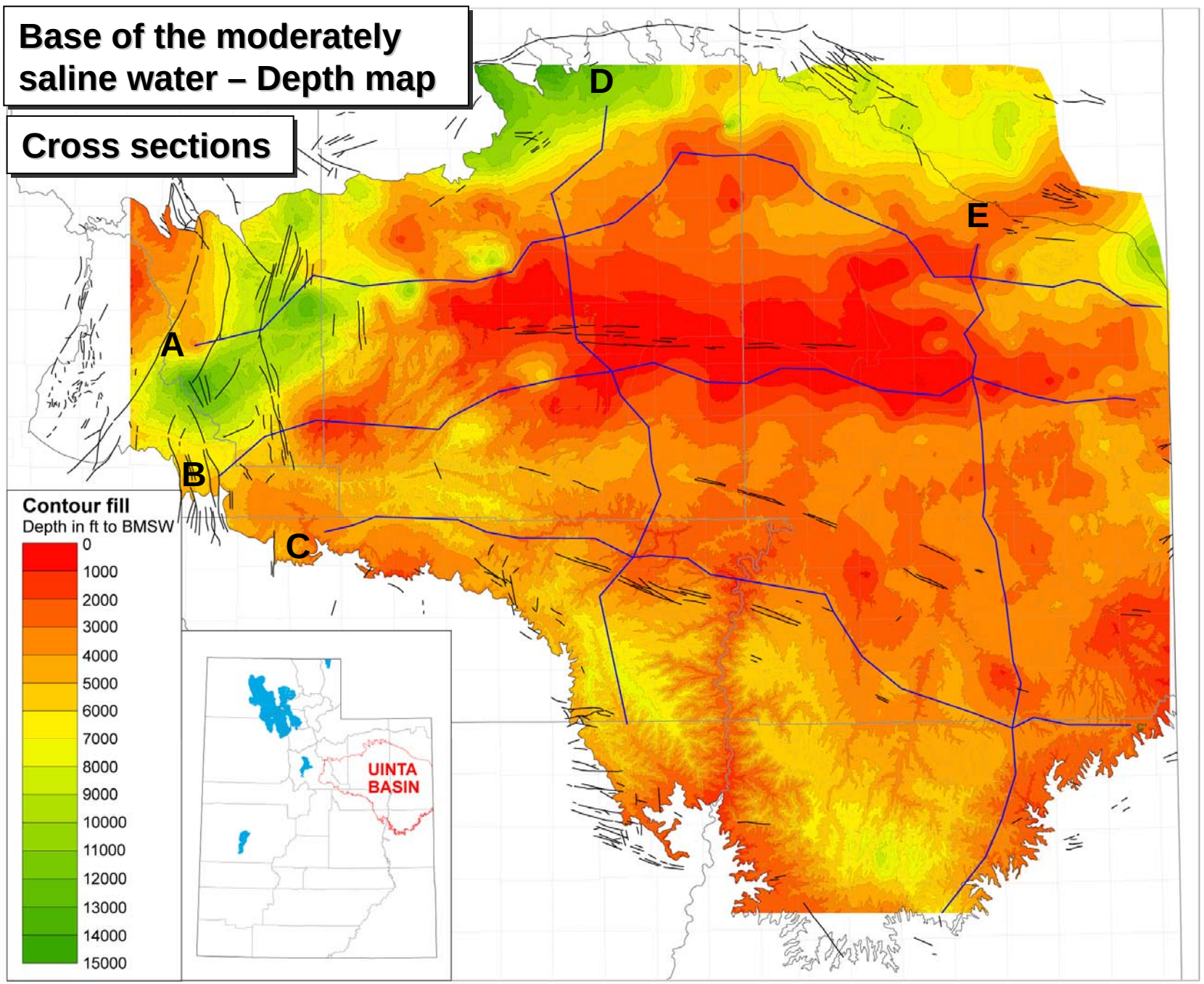
Base of the moderately saline water – Depth map

Faults

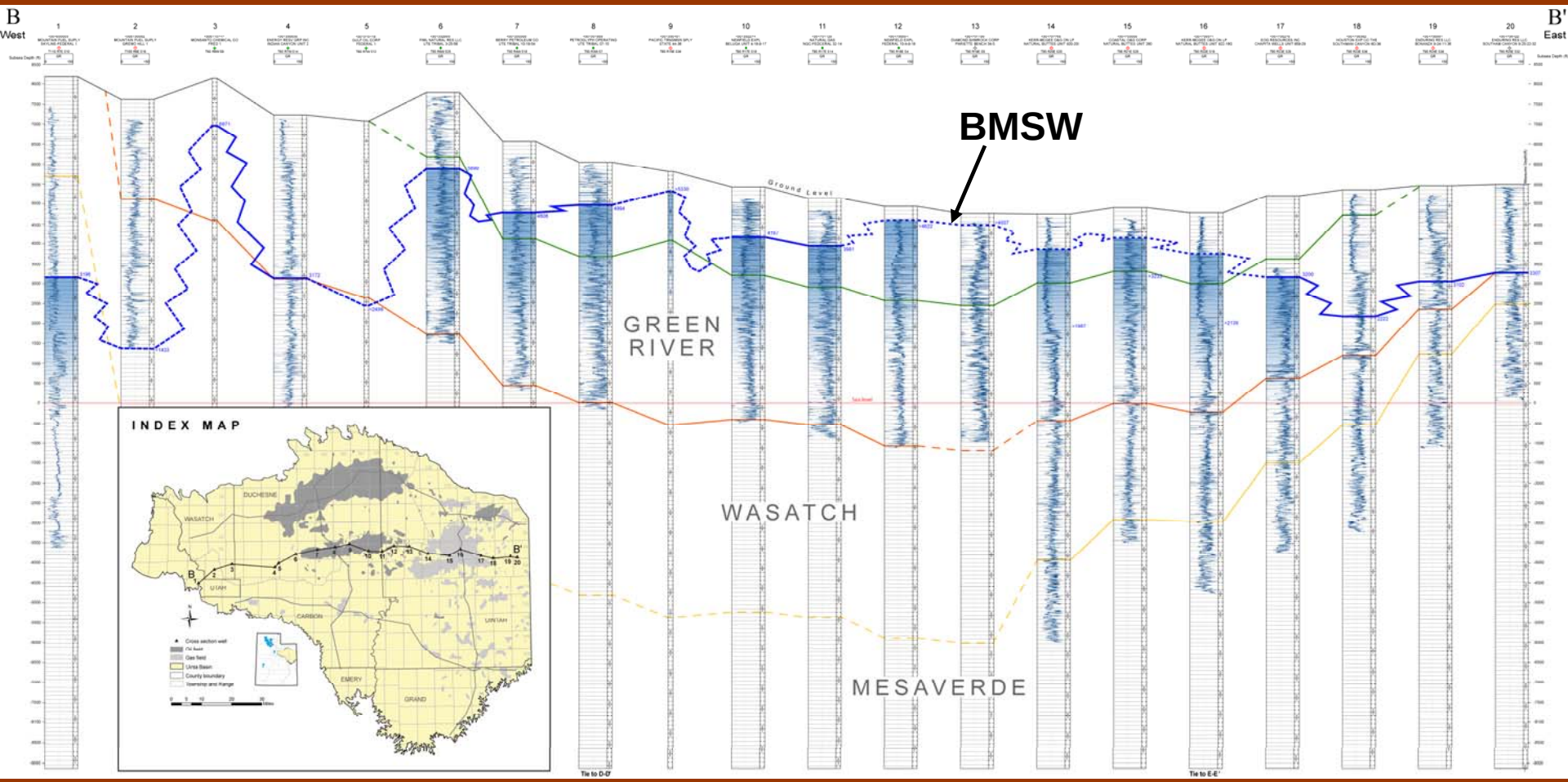


Base of the moderately saline water – Depth map

Cross sections



Task 2: Re-map the base of the moderately saline water



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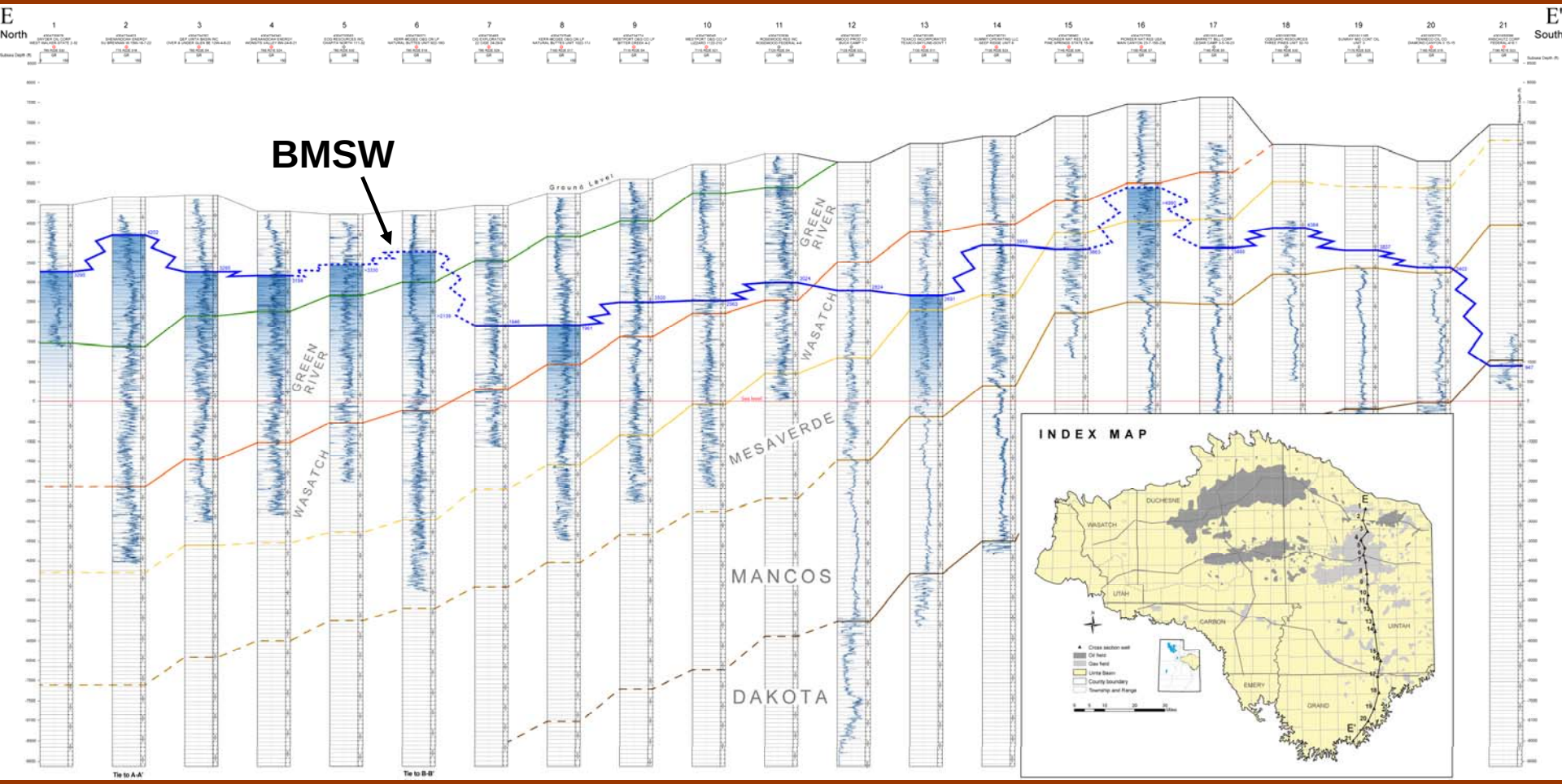
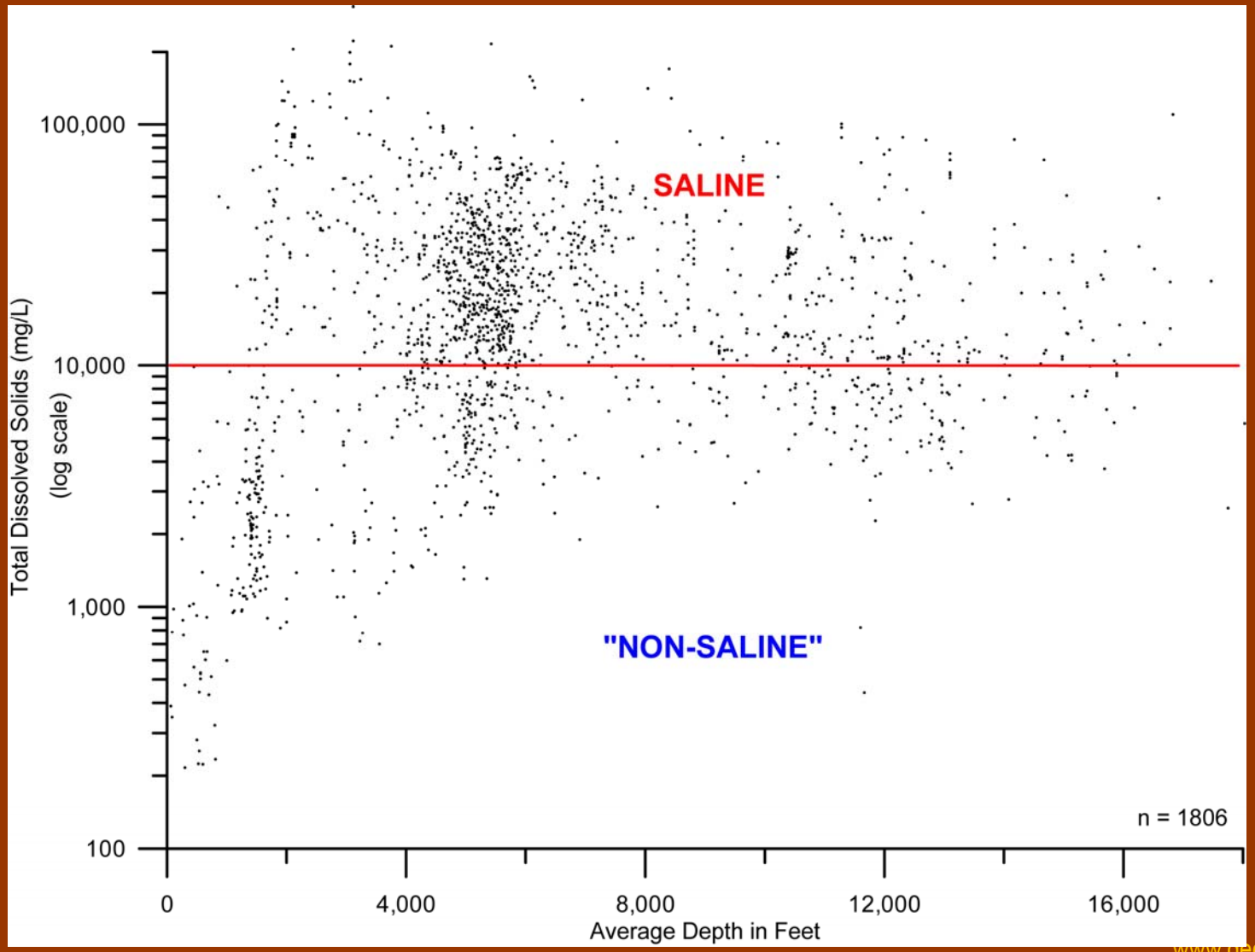
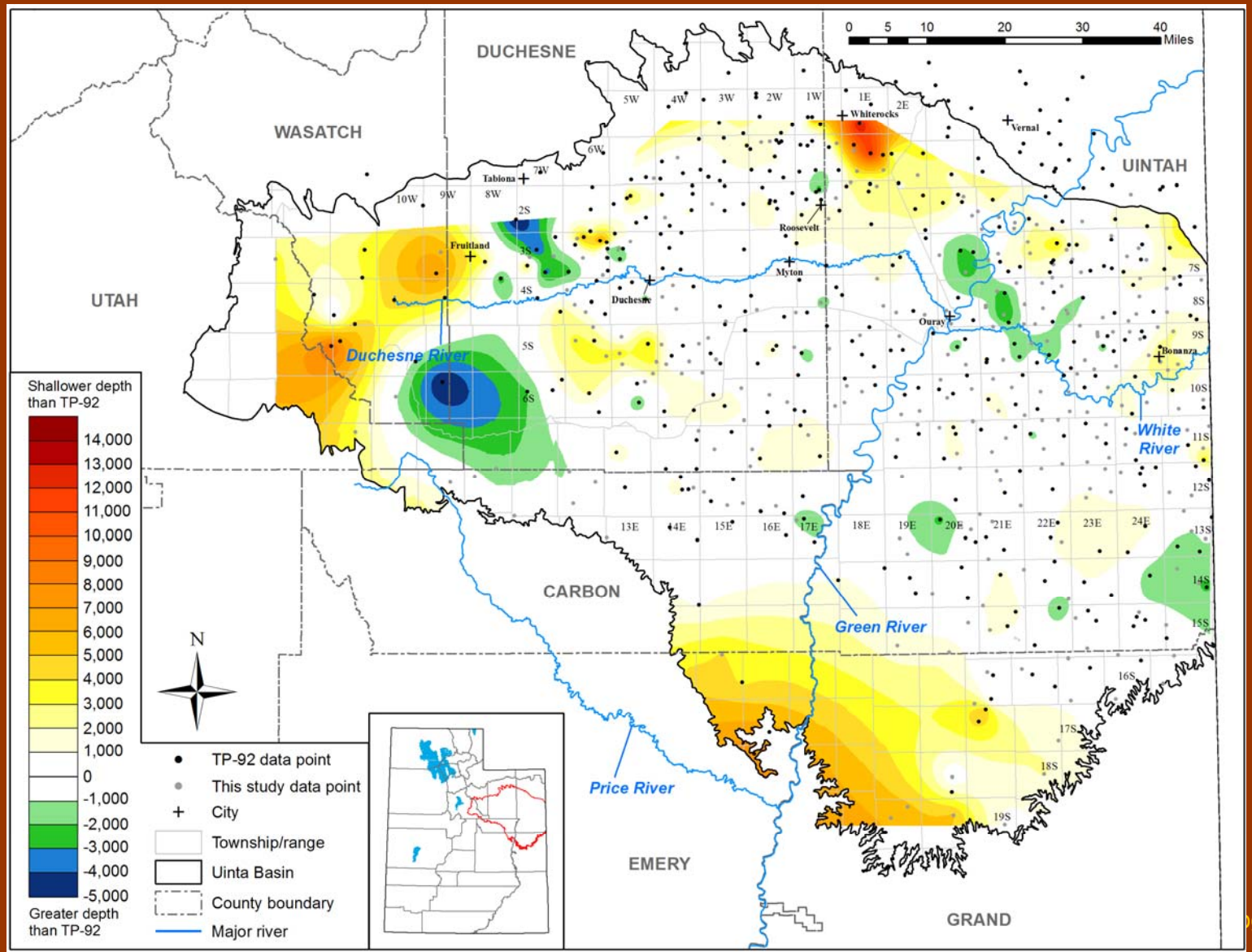


Salinity does not correlate with depth (except in some specific formations)



Differences between old and new maps are attributed to abundant new data and a revision of mapping rules



Conclusions:

- BMSW is a transition zone, not a single boundary
- The BMSW is influenced by:
  - Recharging fresh groundwater (especially in the north)
  - Saline stratigraphy (Birds Nest aquifer, bedded salines in the northwestern Green River Formation)
  - Faults / groundwater flow paths
- Salinity is poorly correlated with depth (except in some specific formations)
- Differences between old and new maps are attributed to abundant new data and a revision of mapping rules
  - Changes in subsurface water chemistry due to abundant saline water disposal over the past 25 years can be demonstrated, but only in a few specific wells and fields
  - The volume of disposed water is very minor compared to the storage space available within the basin, and therefore is not expected to affect large areas
- This new map should be used for planning purposes, as a first-pass guide to finding appropriate depths for saline water disposal, but should always be accompanied by water chemistry analyses from the proposed disposal intervals

Task 3:
Geologic characterization of the Birds Nest aquifer

Problem:

The Birds Nest aquifer has been identified by Uintah County natural gas producers as a zone suitable for large-scale saline water disposal; however, this aquifer is poorly understood and needs further study to determine potential impacts of proposed/active disposal

- Unresolved questions at the beginning of the study:
  - Geologic character of the aquifer
  - Areal extent
  - Thickness
  - Water chemistry
  - Potential disposal related impacts to oil shale deposits
  - Impact of cross-cutting gilsonite veins

Solution:

Detailed geologic characterization using well data, cores, outcrops, and available water chemistry

Research / Deliverables:

- Annotated bibliography
  - 38 references (very limited data)
- Well information database – aquifer tops, formation tops, etc.
  - 322 oil/gas and oil shale wells evaluated
- Water chemistry database
  - 208 analyses from 161 different wells (majority of data from Anadarko)
- 21 detailed core descriptions – including photos
- 4 measured sections and numerous field observations in other locations
- 5 detailed regional cross sections
- Maps – outcrop, areal extent, thickness, water quality, overburden, interburden

Not your typical aquifer!

The Birds Nest aquifer formed from the dissolution of saline minerals (mostly nahcolite) within the upper Green River Formation oil shale zone

Not your typical aquifer!

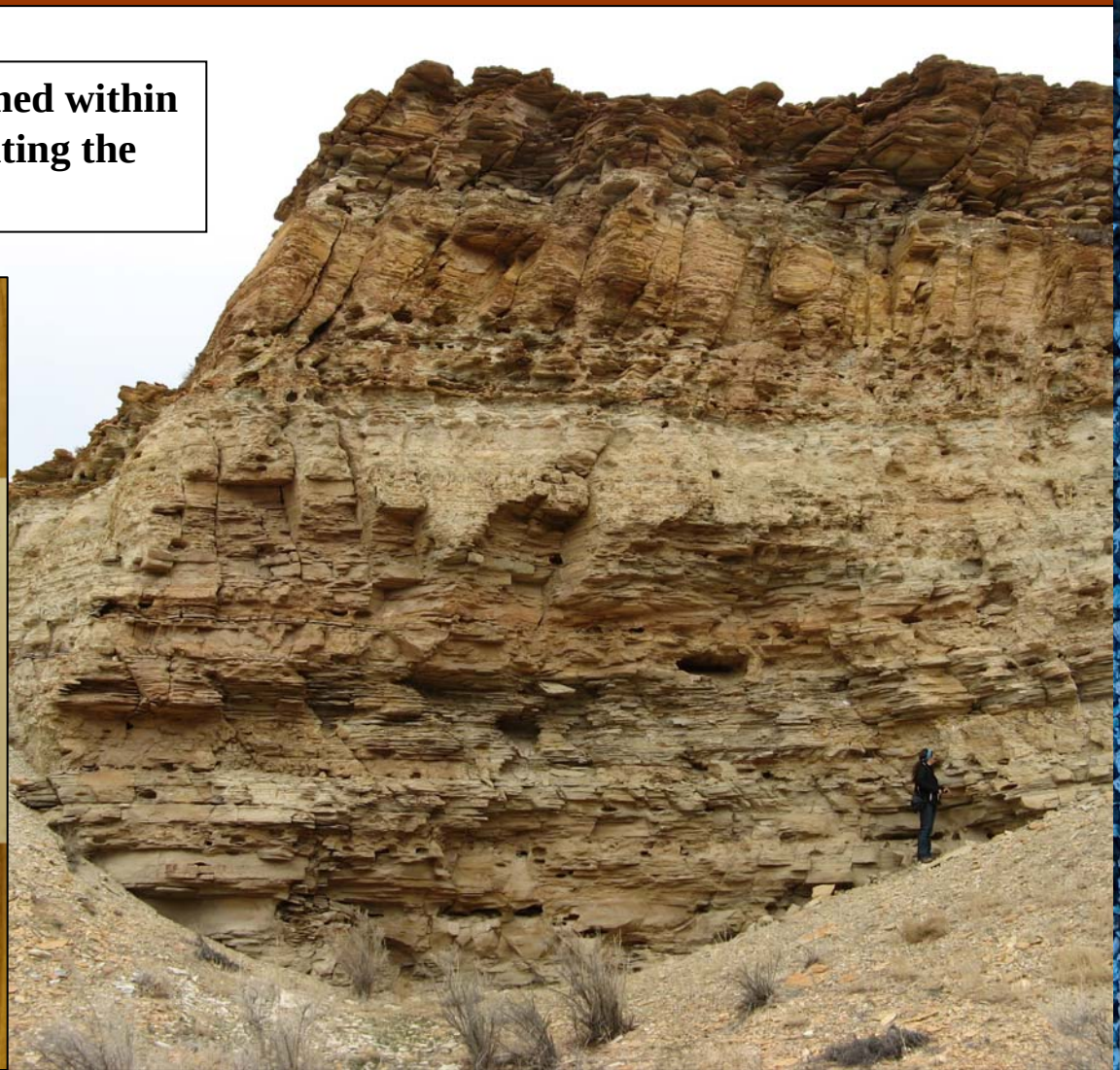
The Birds Nest aquifer formed from the dissolution of saline minerals (mostly nahcolite) within the upper Green River Formation oil shale zone

Each circle represents a 0.5- to 1-foot gap

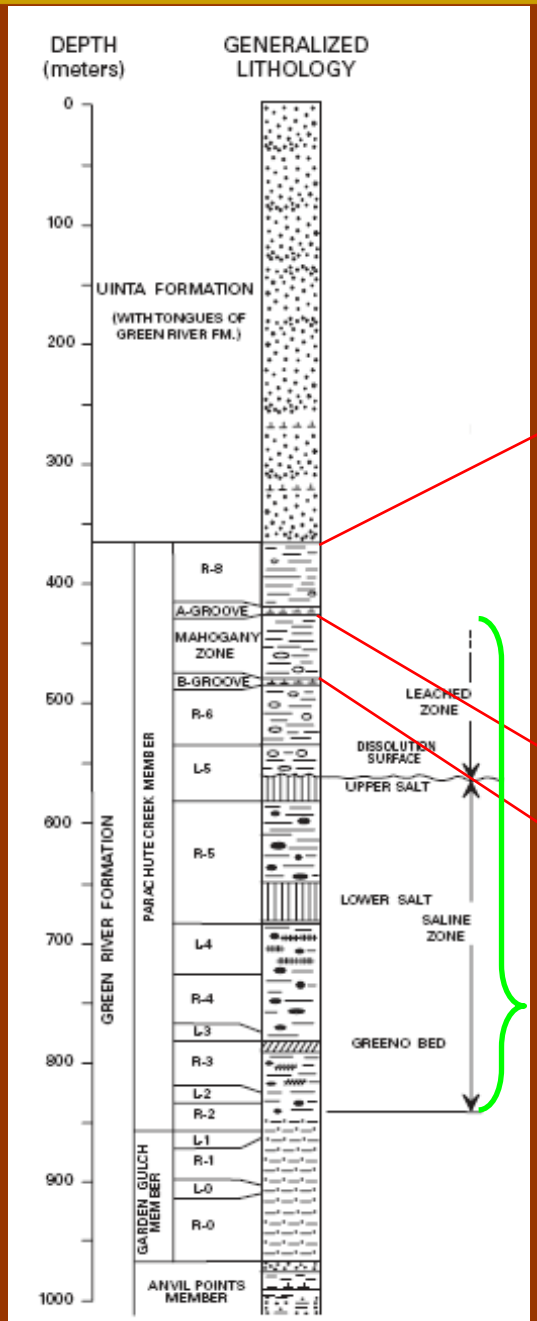
Not your typical aquifer!

The Birds Nest aquifer formed from the dissolution of saline minerals (mos nahcolite) within the upper Green River Formation oil shale zone

Extensive fractures formed within the weakened rock, creating the aquifer's permeability

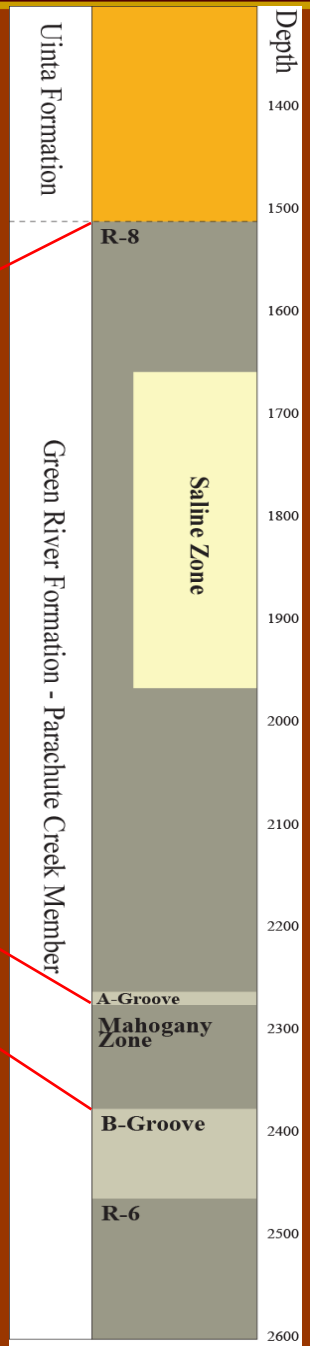


Colorado Stratigraphy
(from Dyni, 2006)



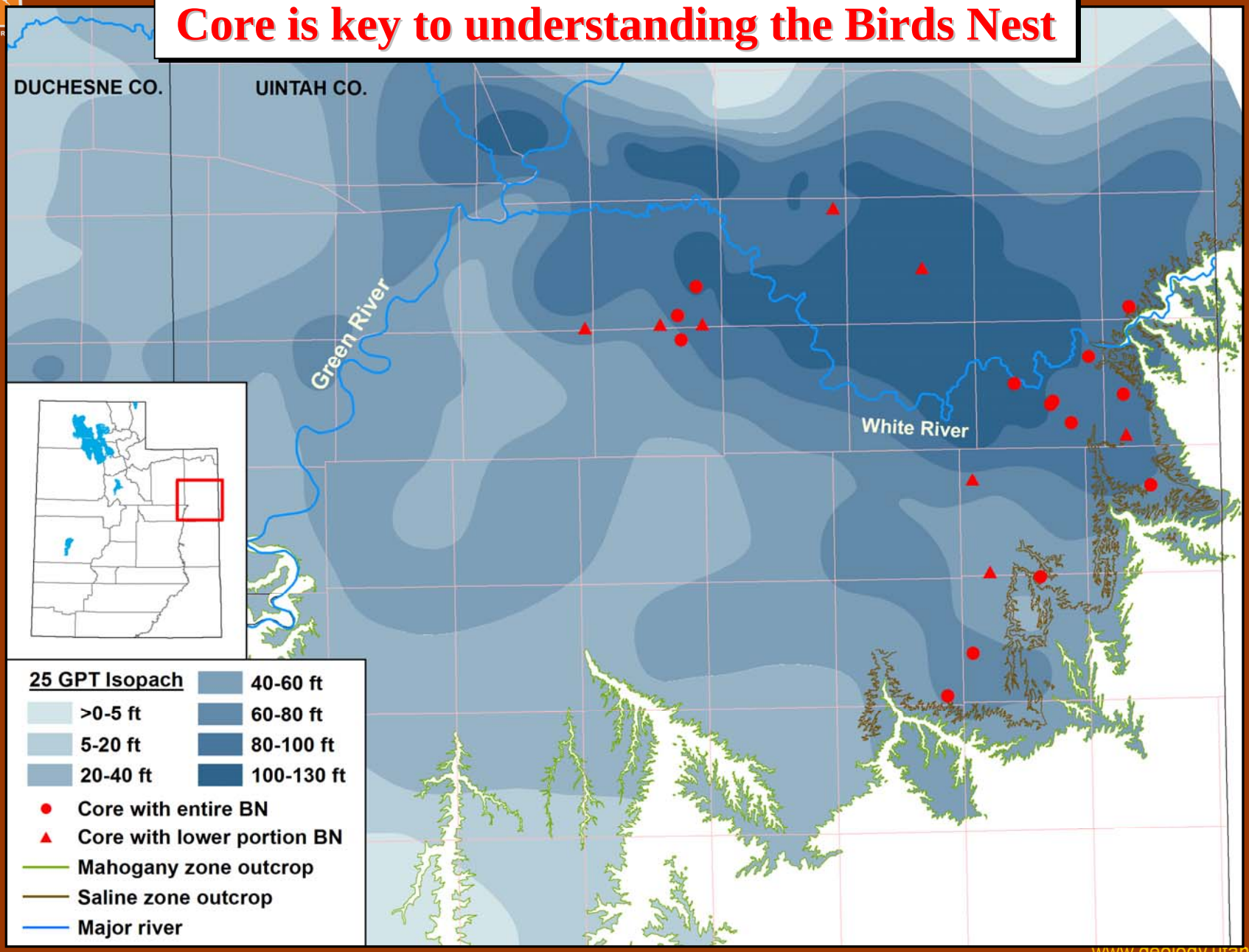
Mahogany Zone

Saline zone

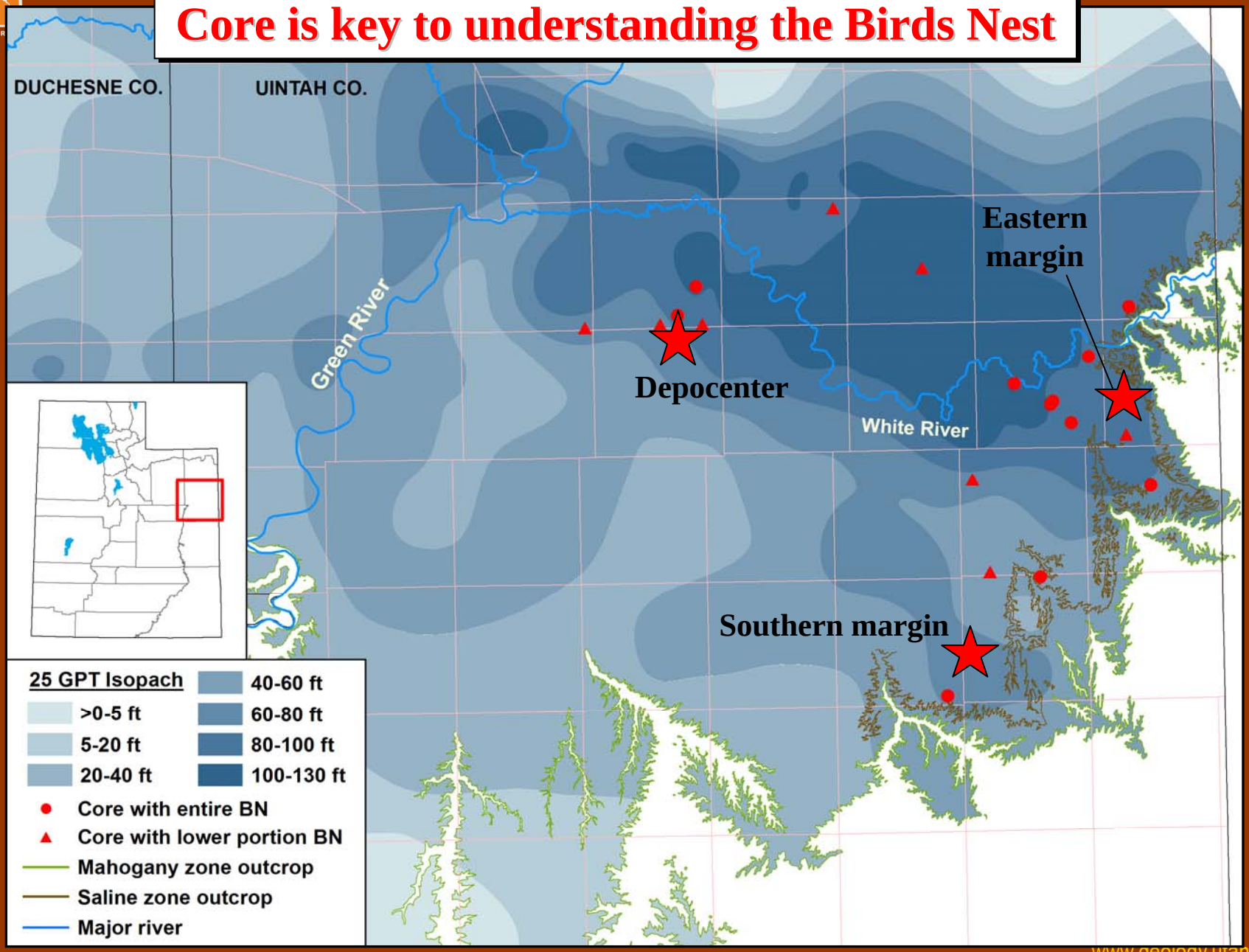


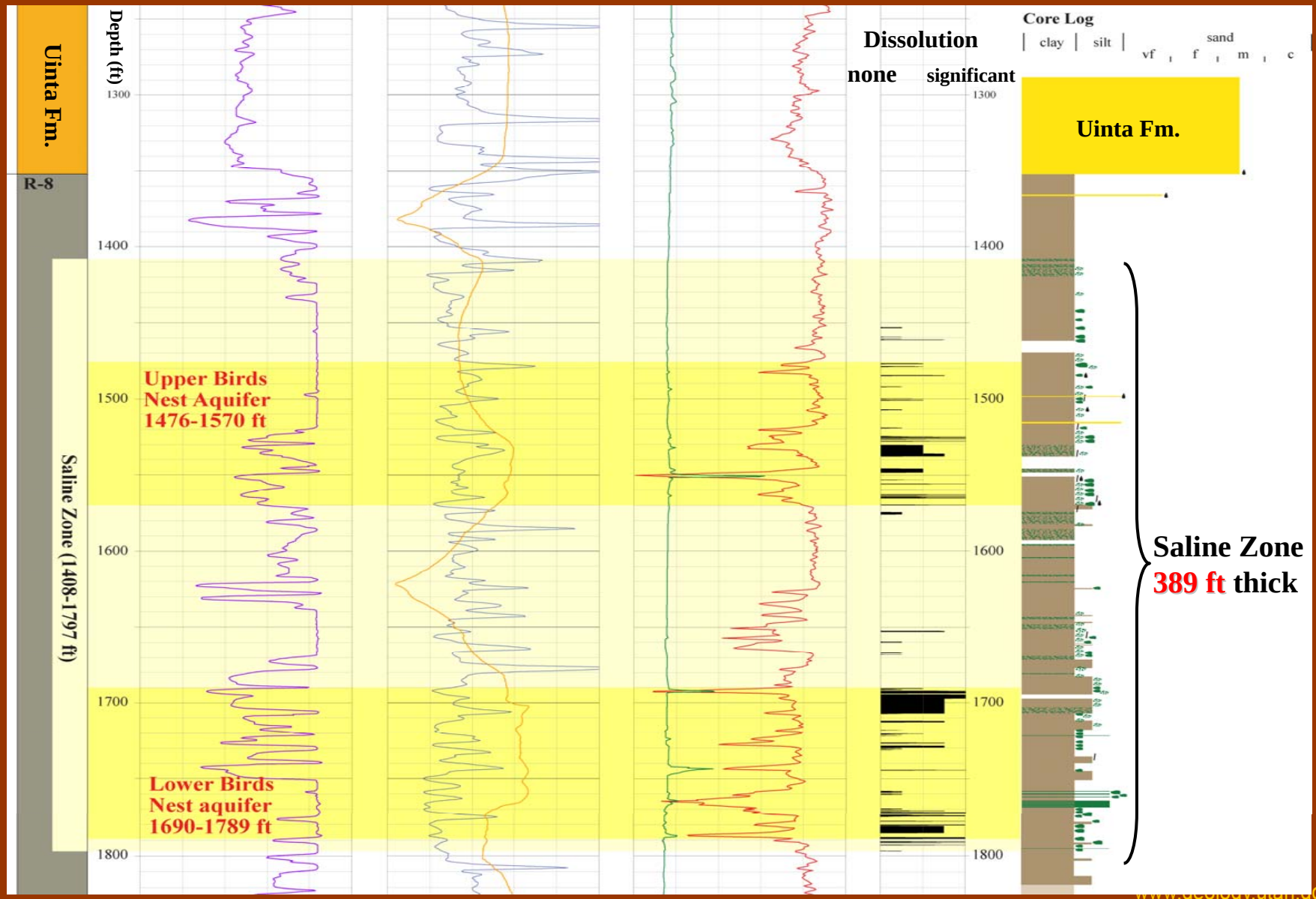
Utah Stratigraphy
(based on Utah State 1 core, center of basin)

Core is key to understanding the Birds Nest

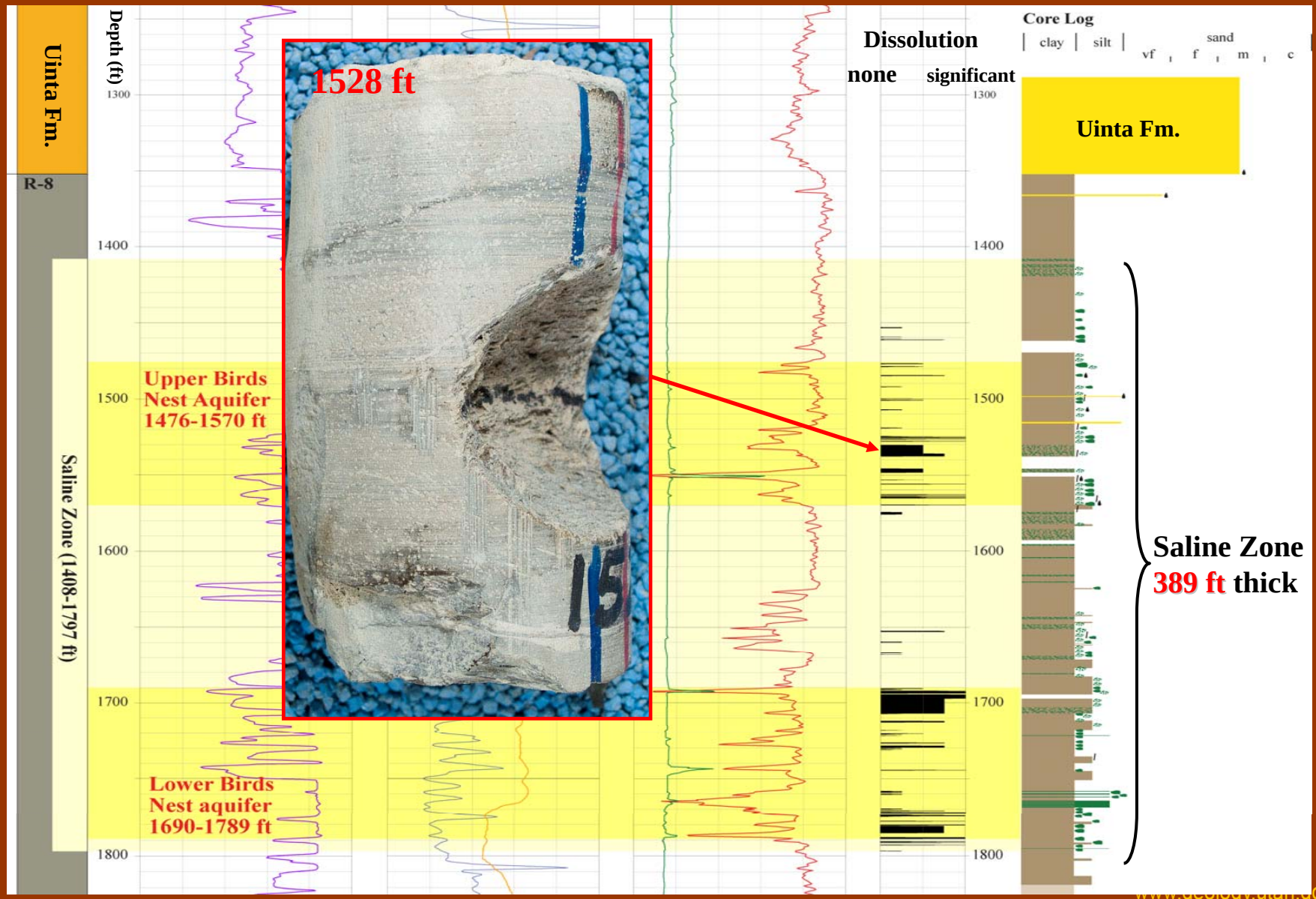


Core is key to understanding the Birds Nest





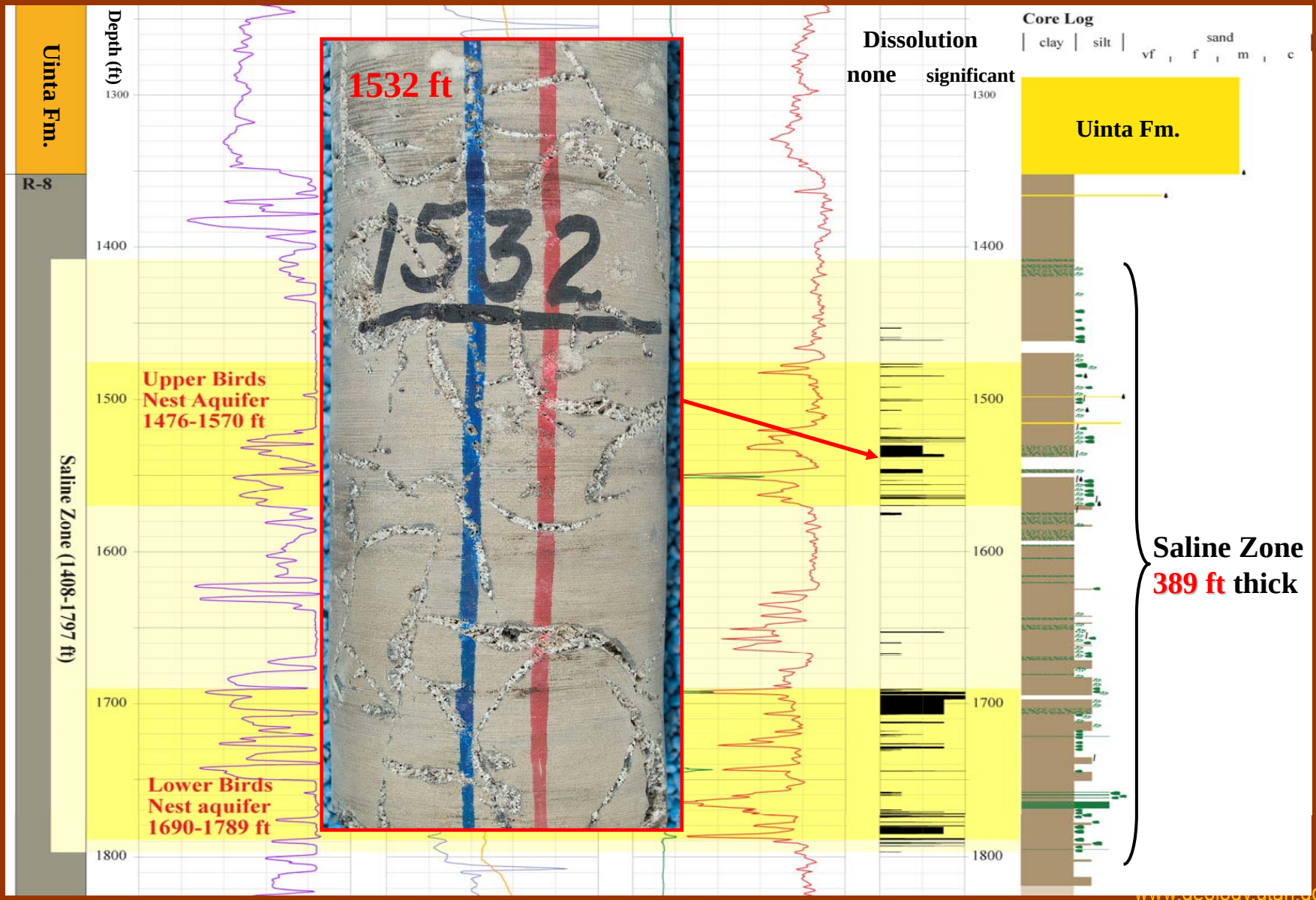
Depocenter: 13X-2 - 10S 21E sec 2

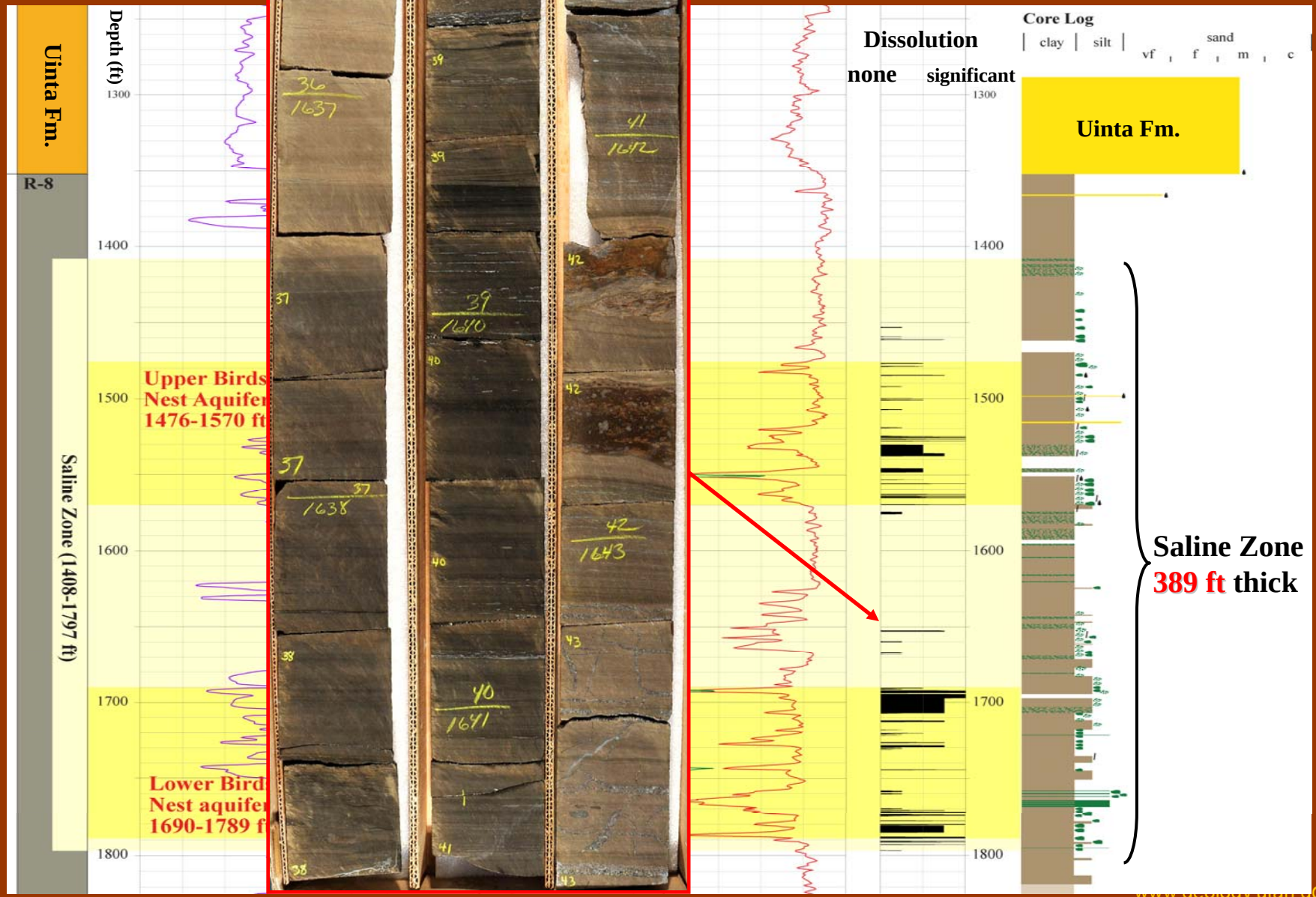


Depocenter: 13X-2 - 10S 21E sec 2

Resistivity 0.1 – 10000 | Gamma Ray 0 – 300 | Bulk density 1.7 – 2.7

Depocenter: 13X-2 - 10S 21E sec 2





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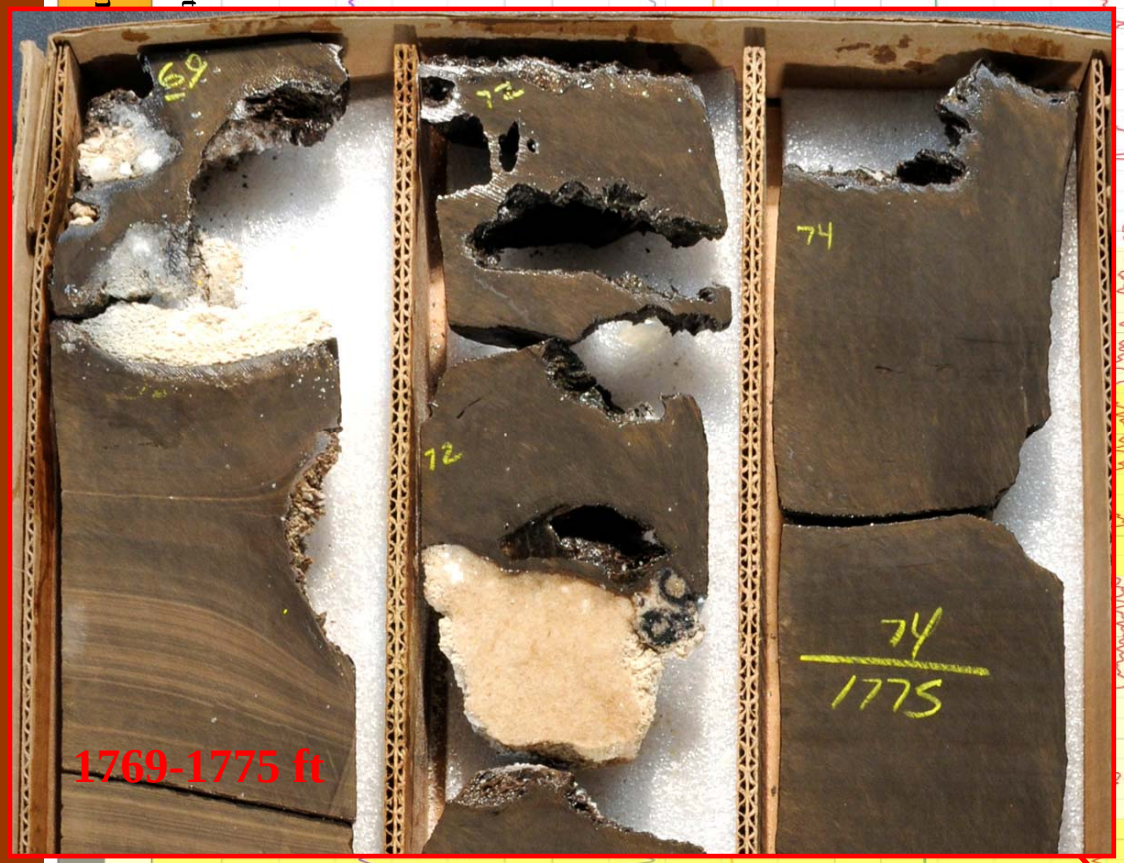


Dissolution
none significant

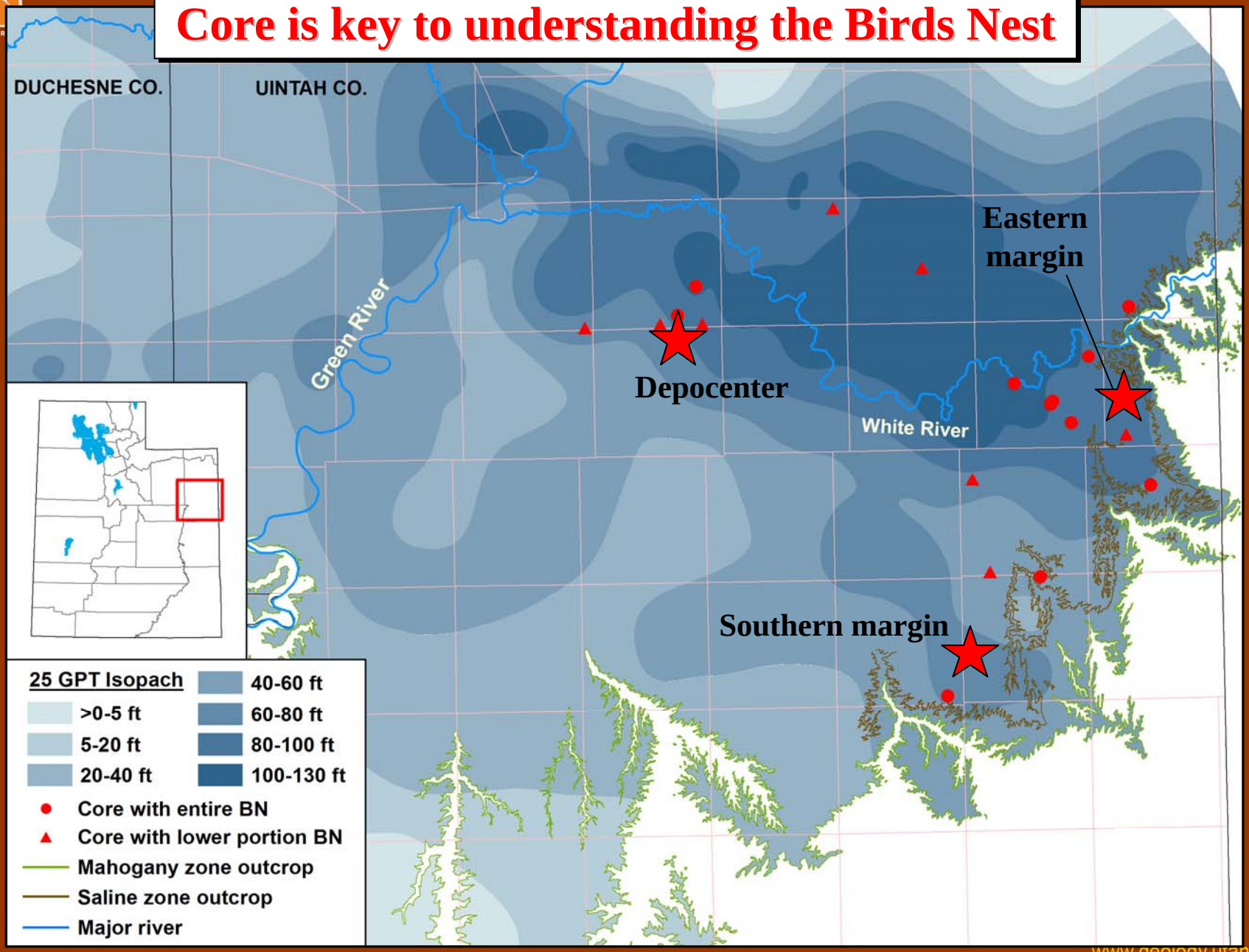
Core Log
clay | silt | sand (vf, f, m, c)

1300
Uinta Fm.
1400
1500
1600
1700
1800

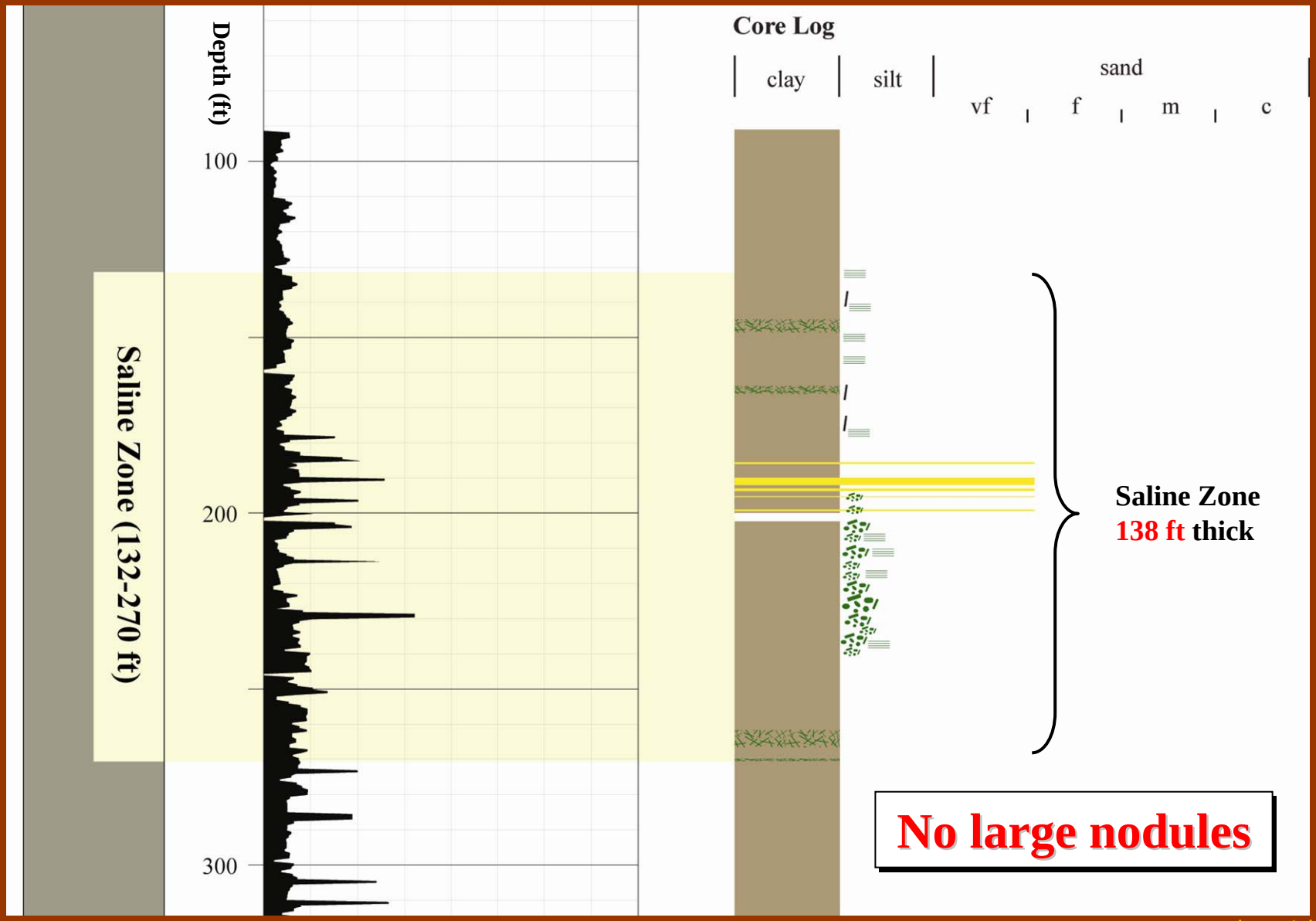
Lower Birds Nest aquifer 1690-1789 ft

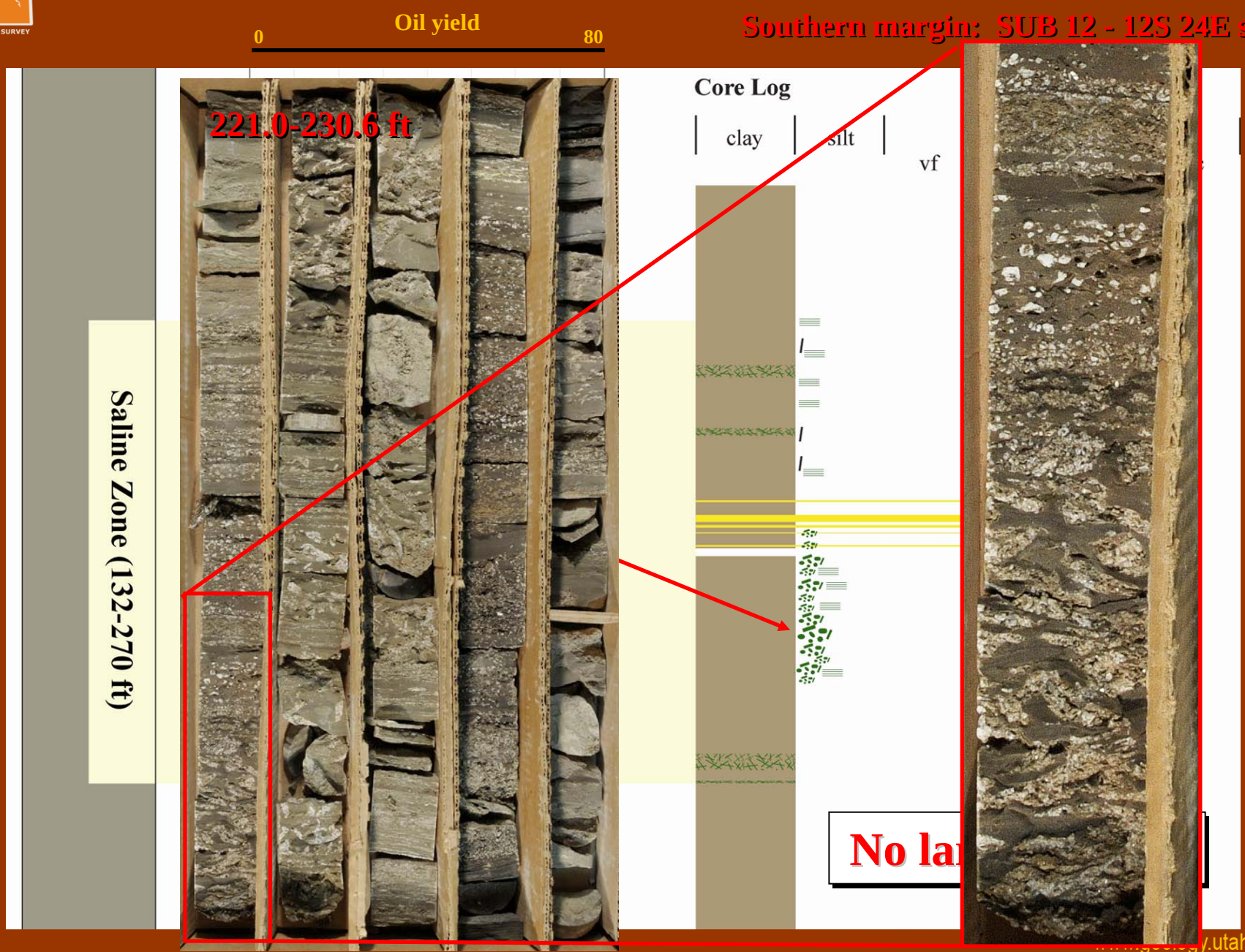
Saline Zone
389 ft thick

Core is key to understanding the Birds Nest

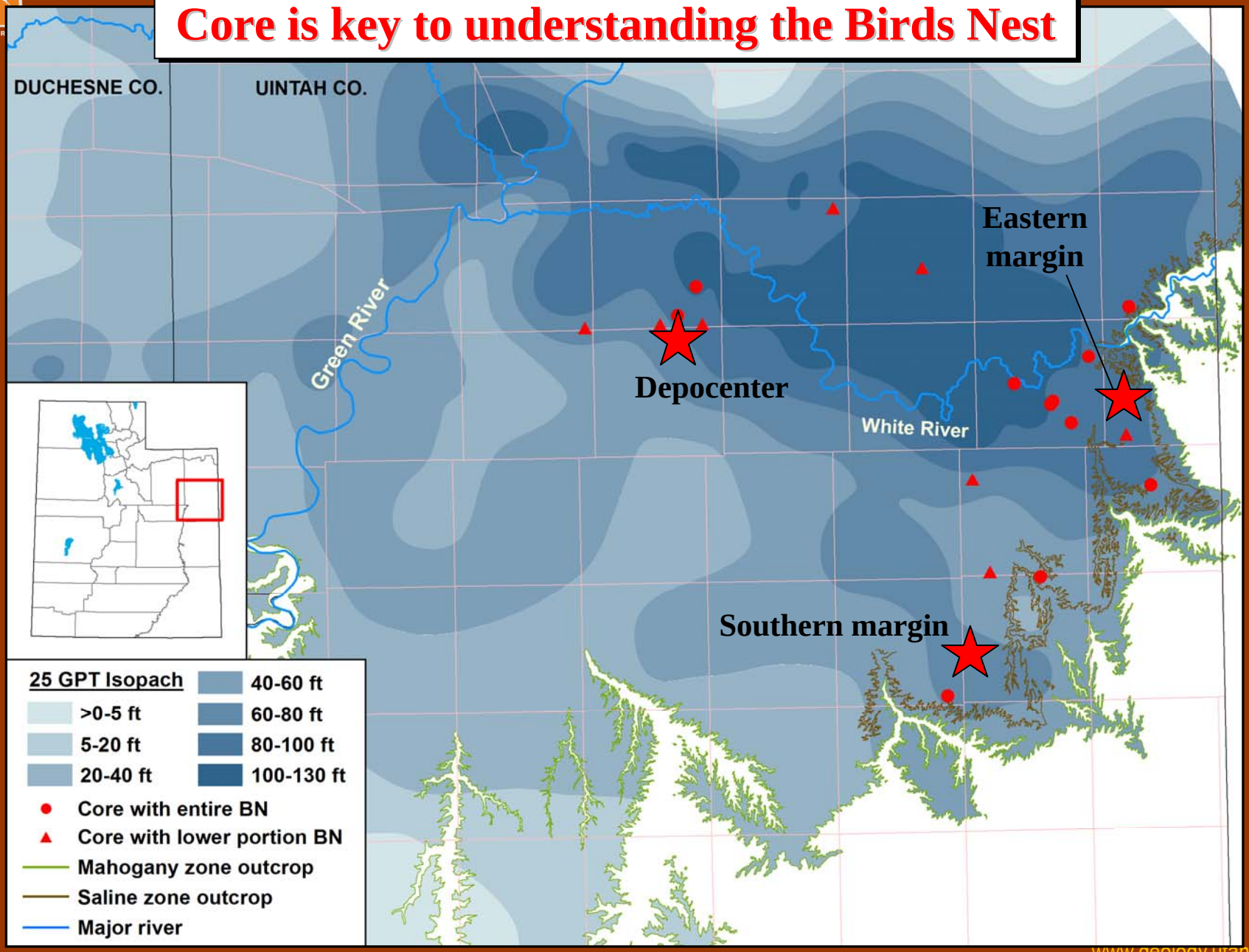


Southern margin: SUB 12 - 12S 24E sec 19

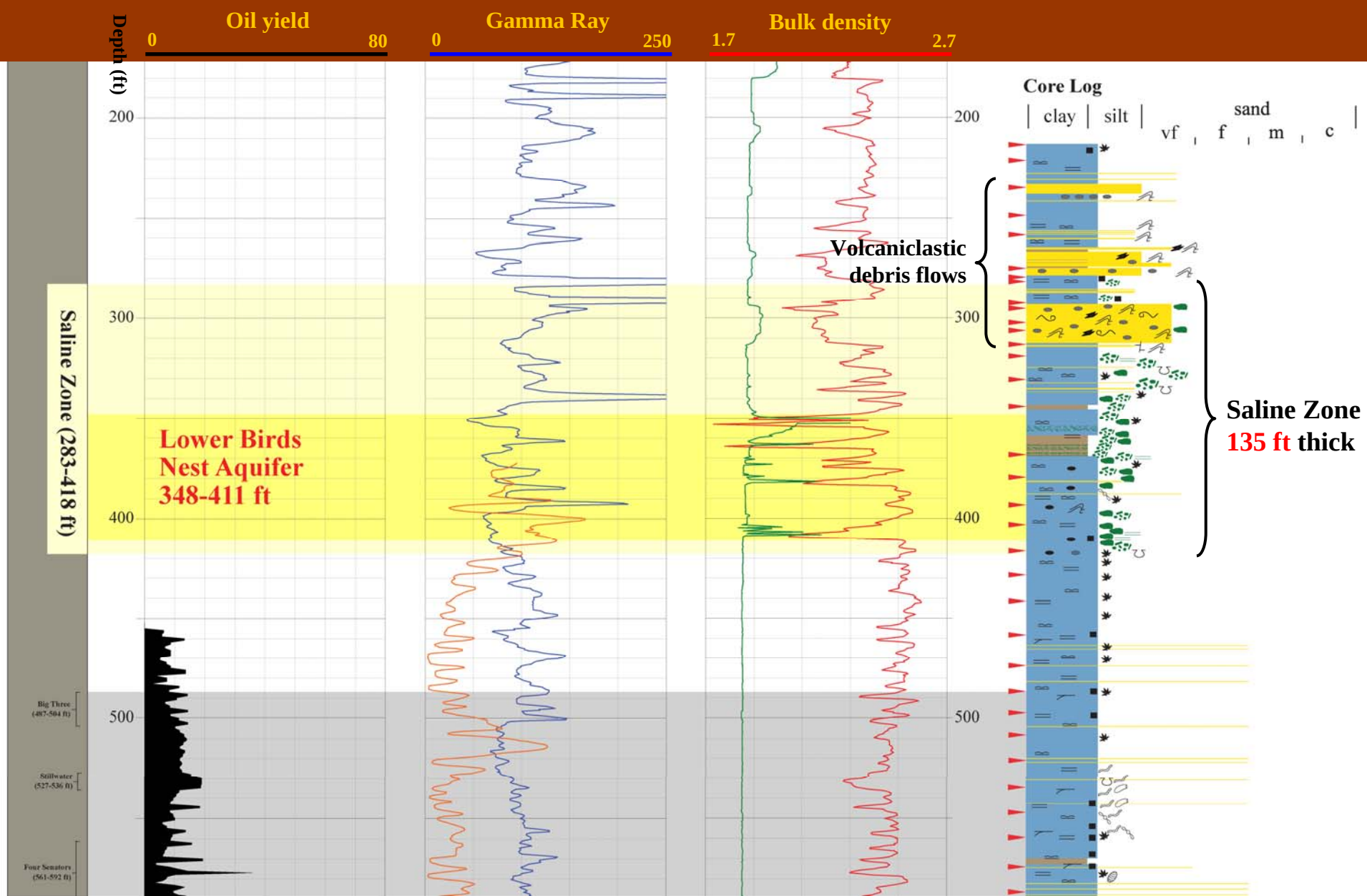



Oil yield
0
80
Southern margin: SUB 12 - 12S 24E sec 19
221.0-230.6 ft
Core Log
clay
silt
vf
Saline Zone (132-270 ft)
No la

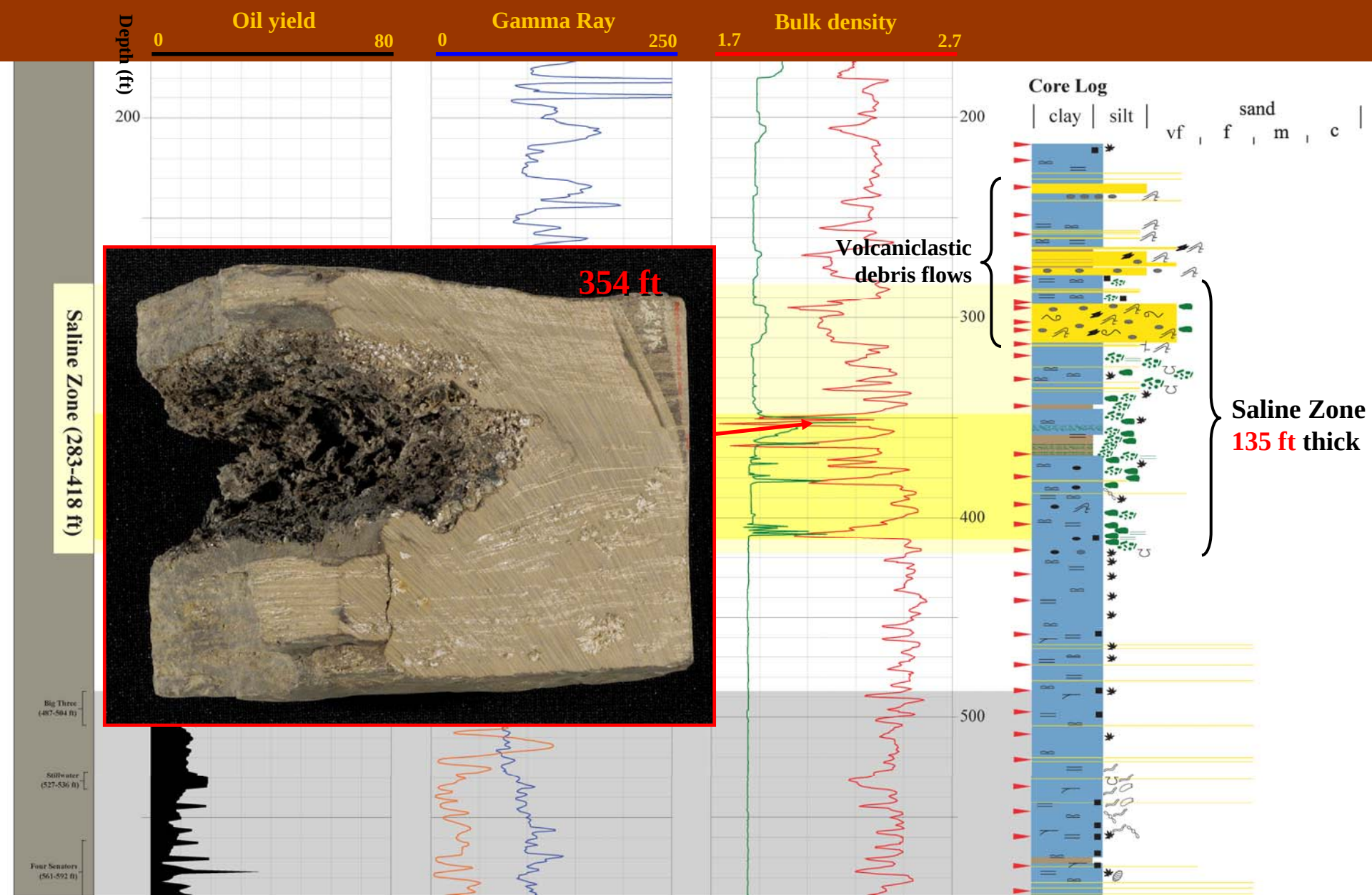
Core is key to understanding the Birds Nest



Eastern margin: P-4 - 10S 25E sec. 19

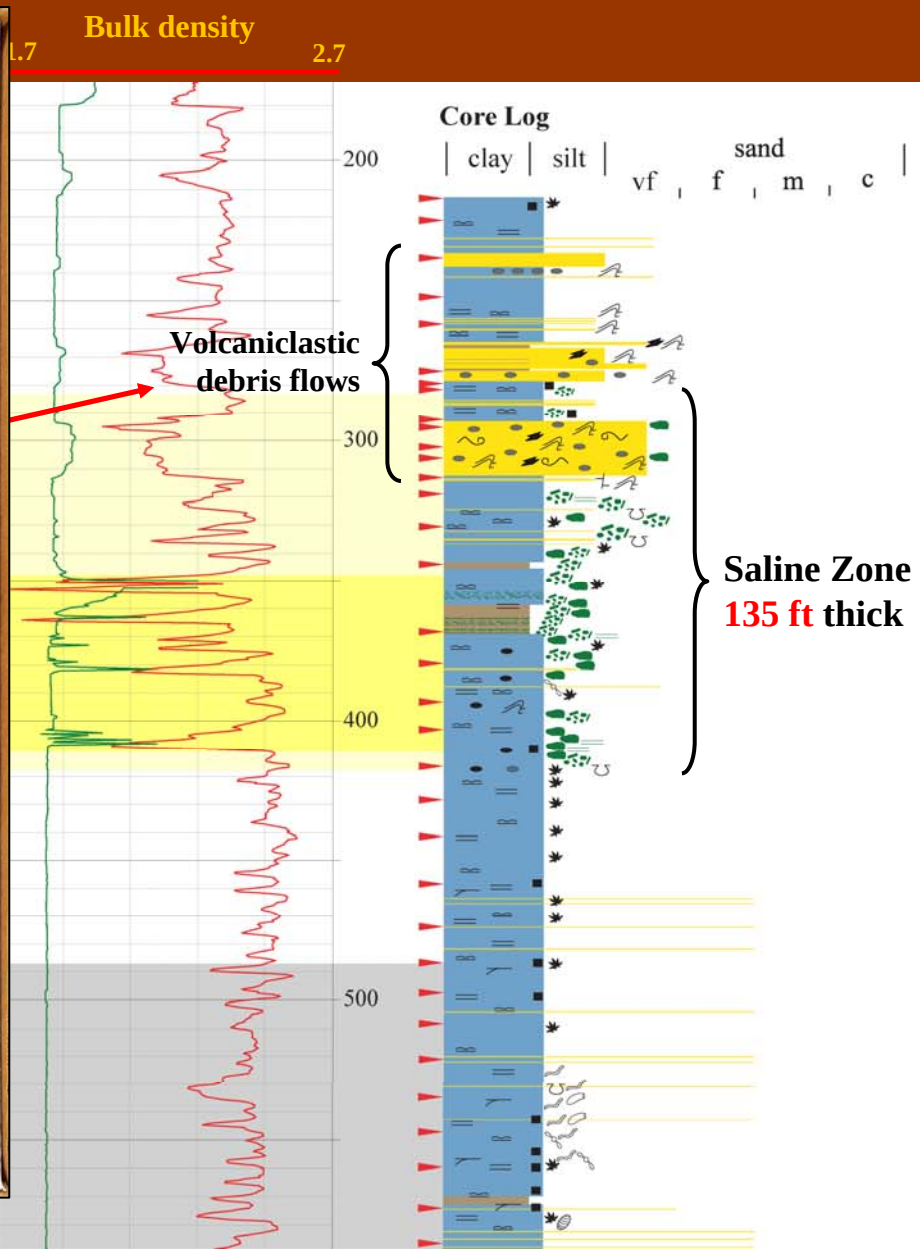


Eastern margin: P-4 - 10S 25E sec. 19

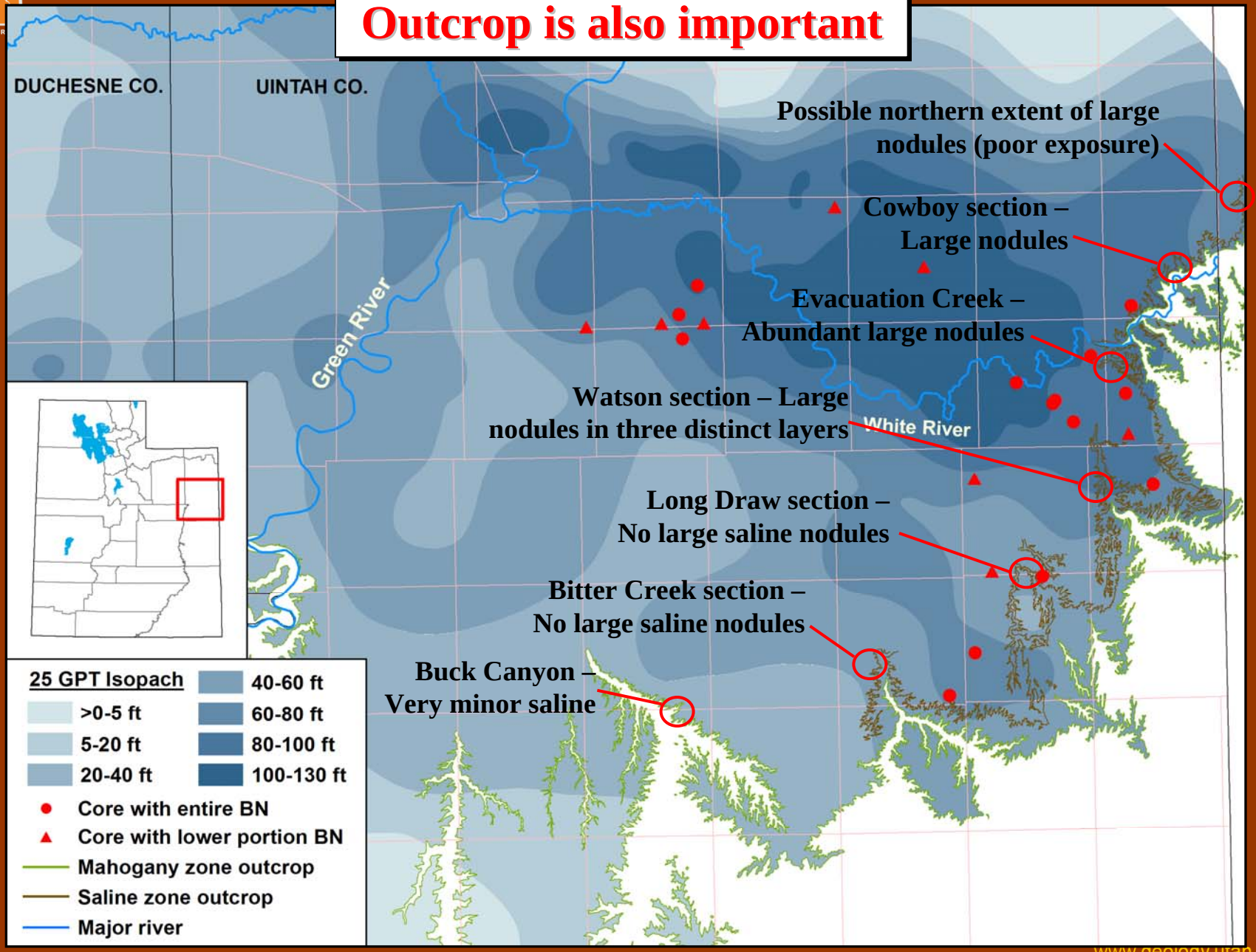


Eastern margin: P-4 - 10S 25E sec. 19

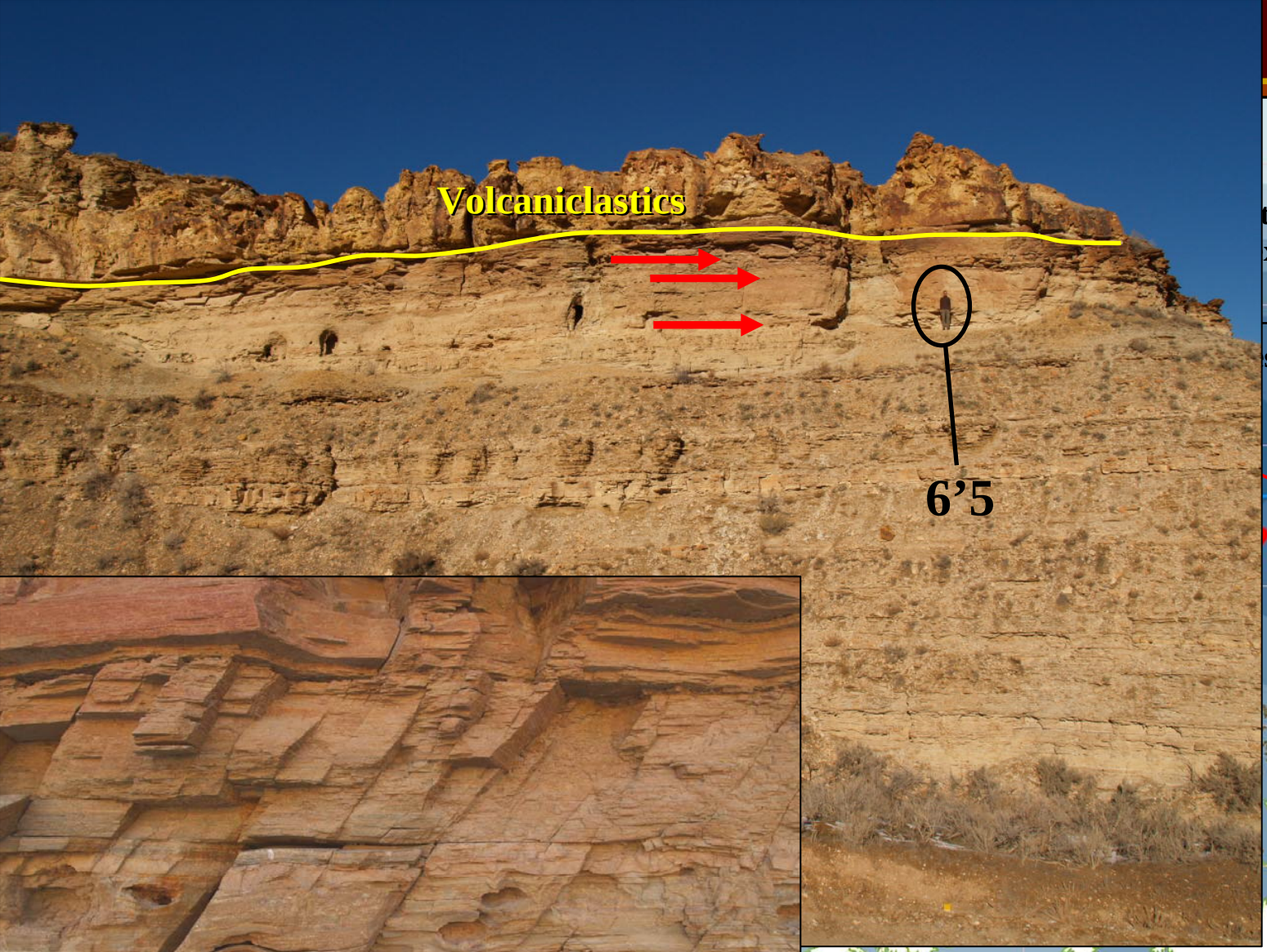
Eastern margin: P-4 - 10S 25E sec. 19



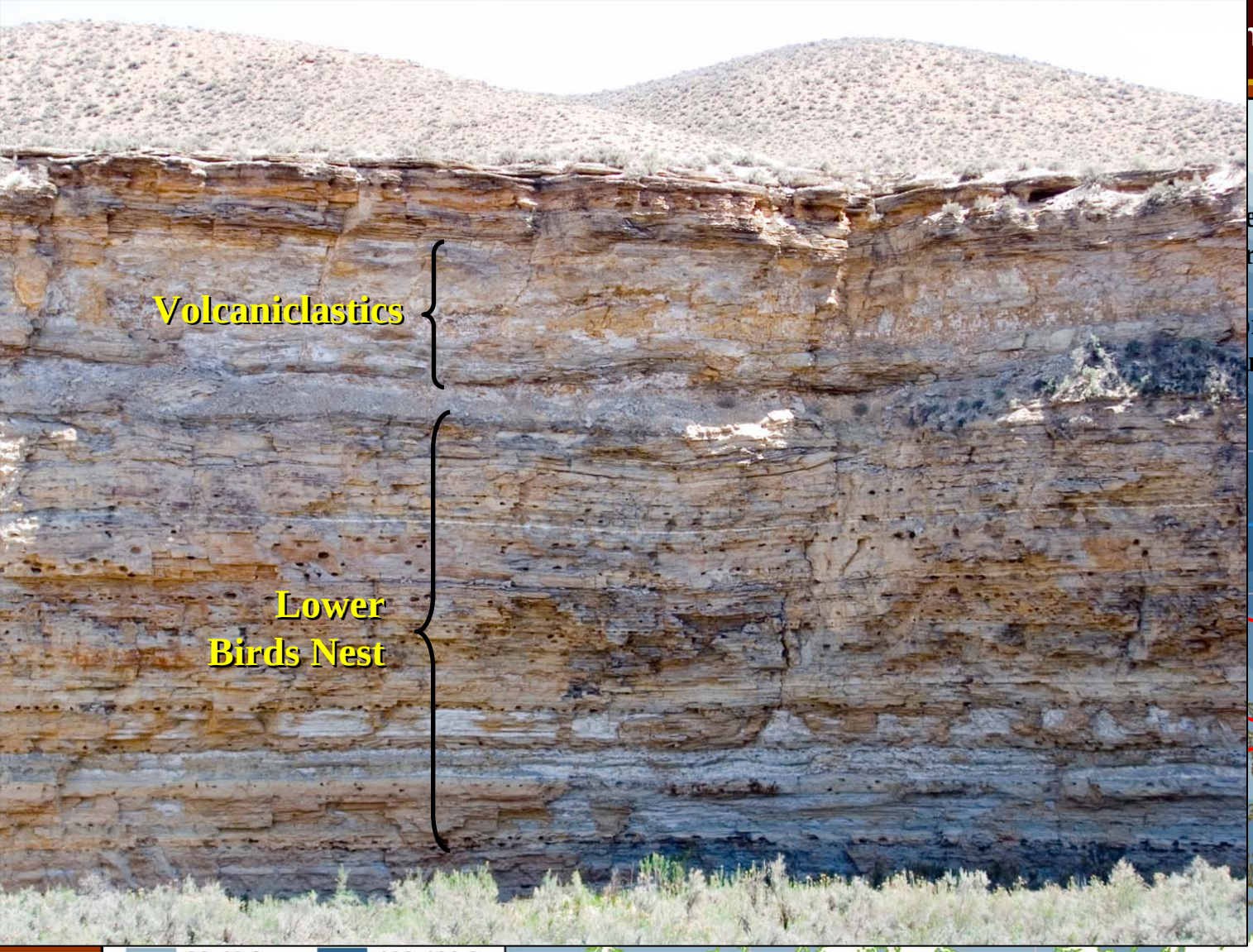
Outcrop is also important



aracterization of the Birds Nest aquifer



Watson section – Large nodules in three distinct layers



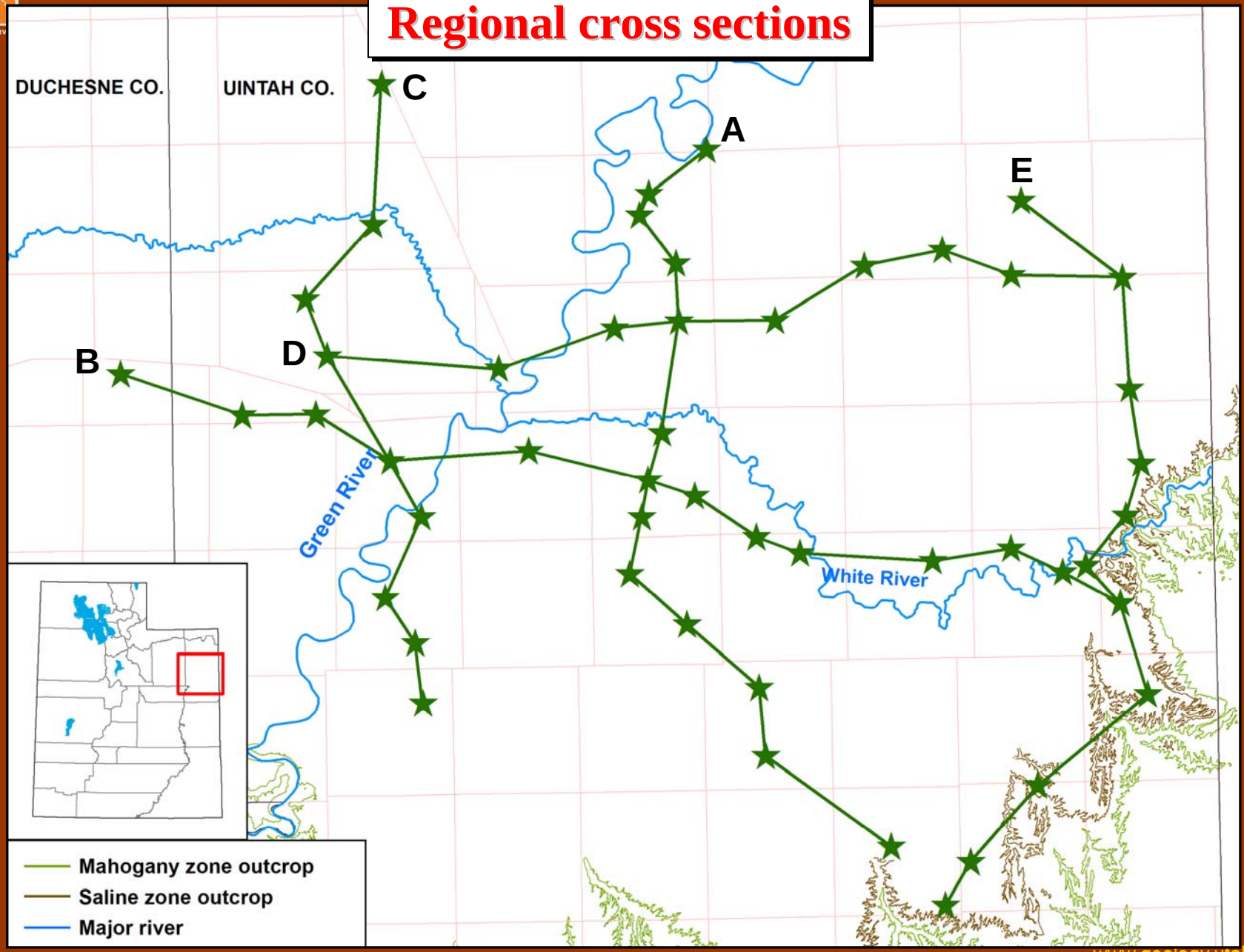
ent of large
r exposure)

n –
ules

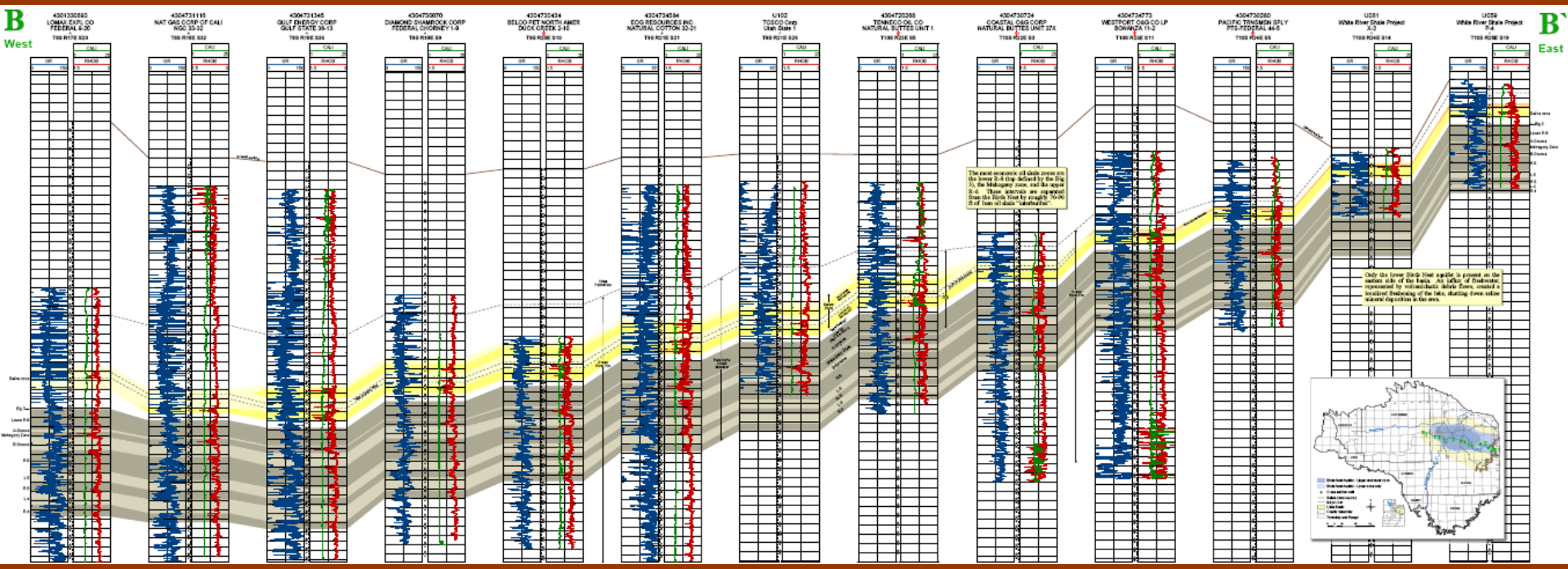
20-40 ft
100-130 ft
Core with entire BN
Core with lower portion BN
Mahogany zone outcrop
Saline zone outcrop
Major river

Evacuation Creek –
Abundant large nodules

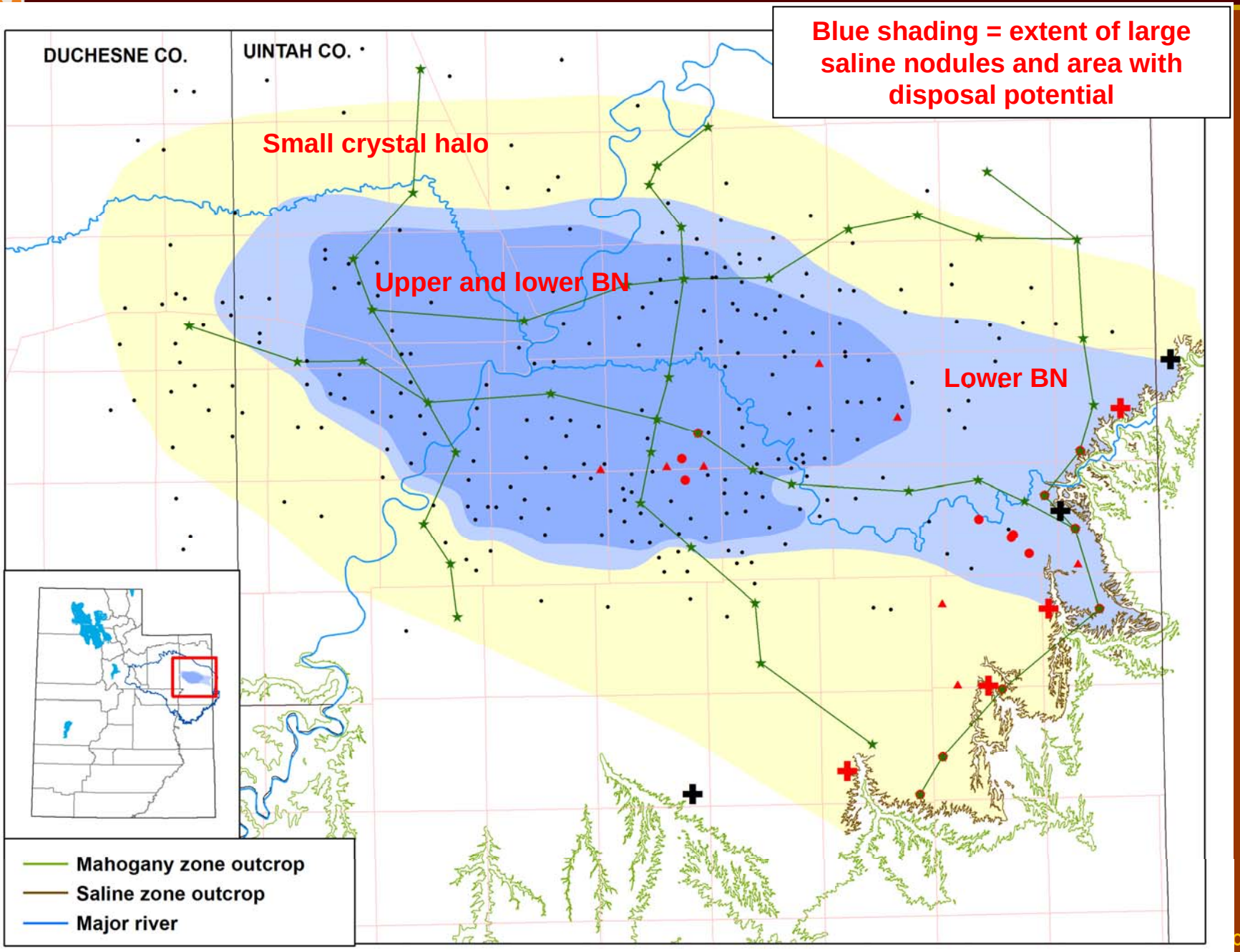
Regional cross sections

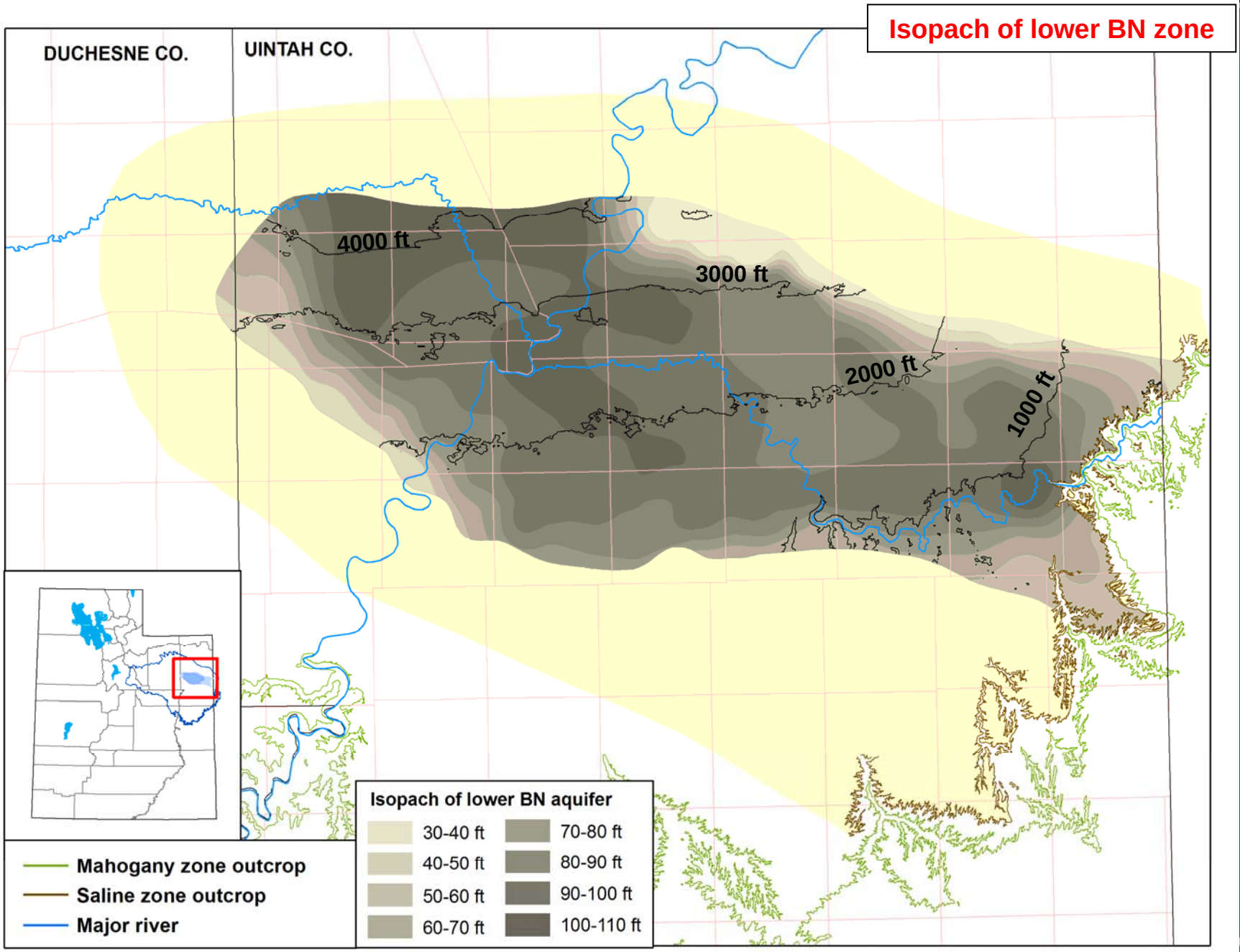


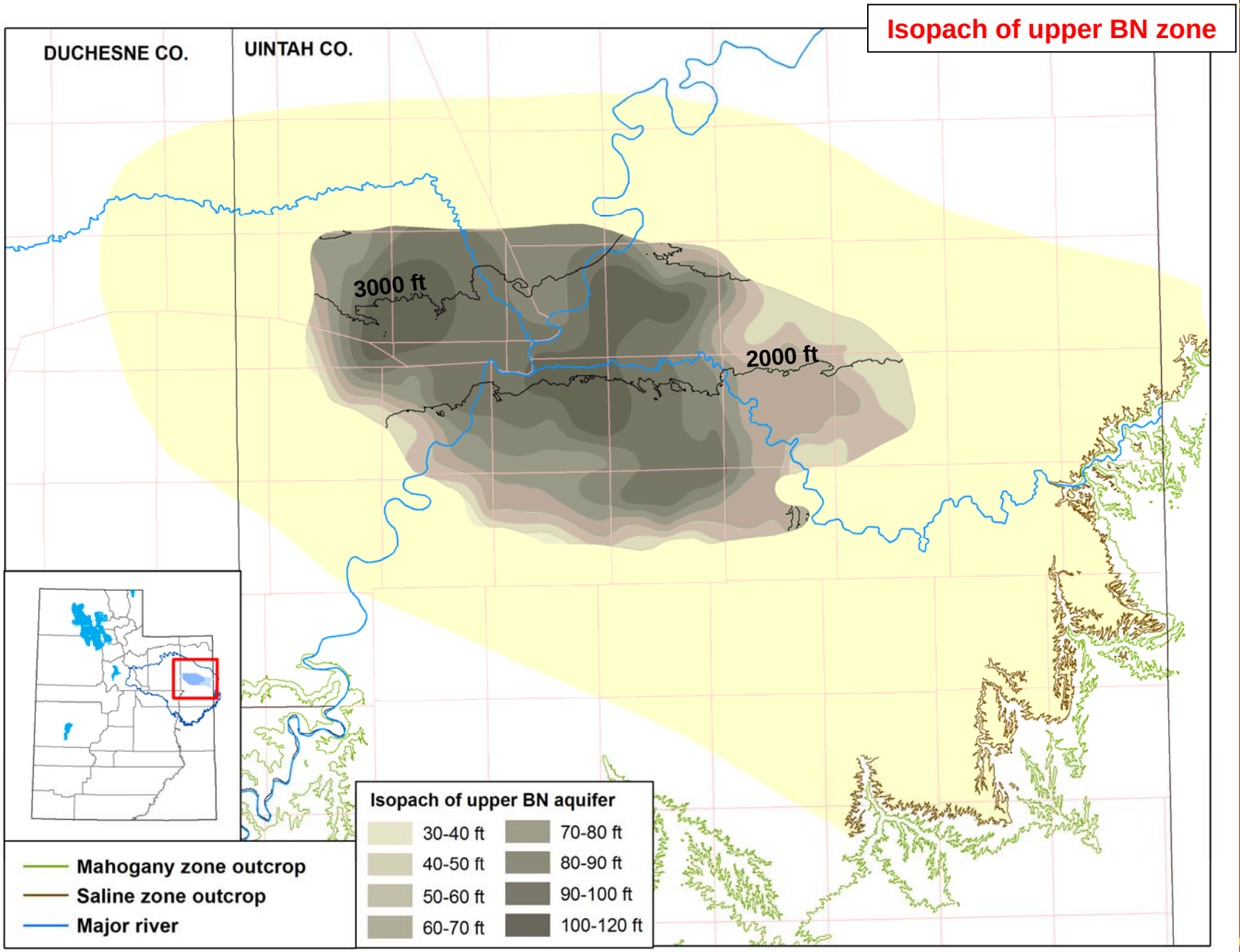
Regional cross sections

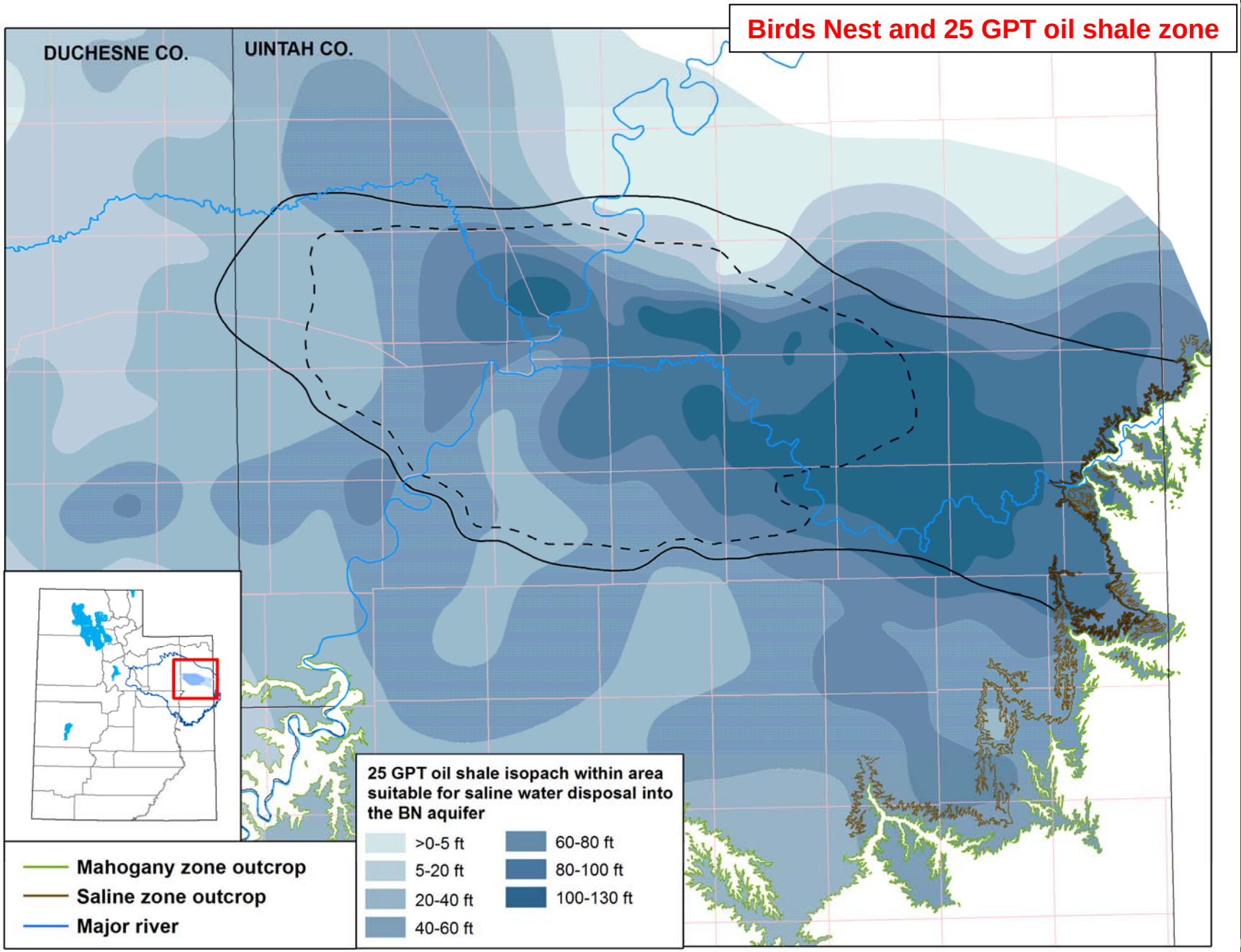


Task 3: Geologic Characterization of the Birds Nest aquifer

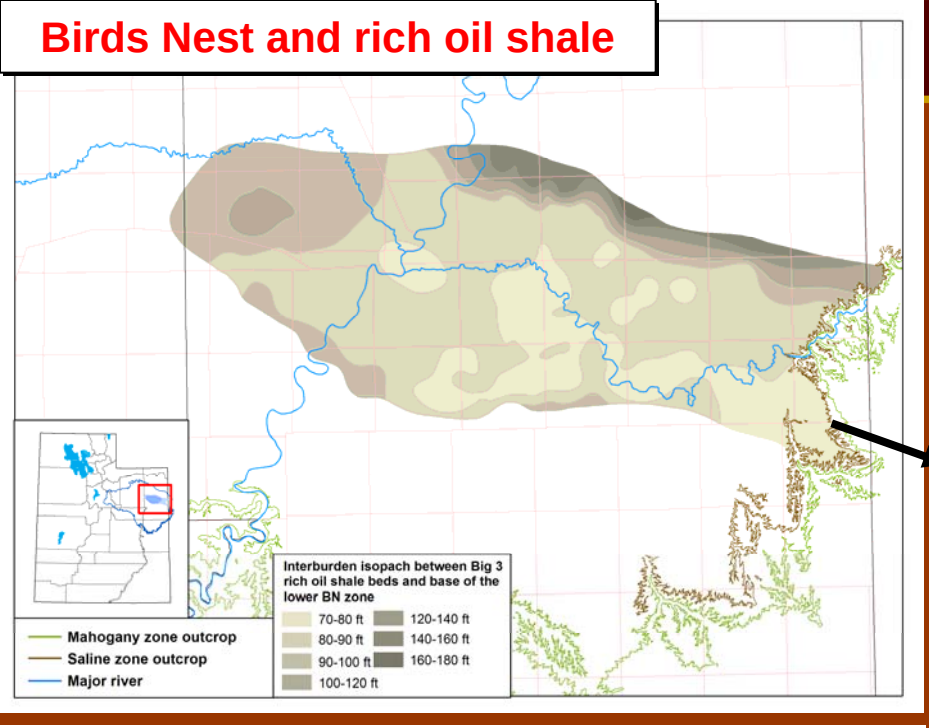


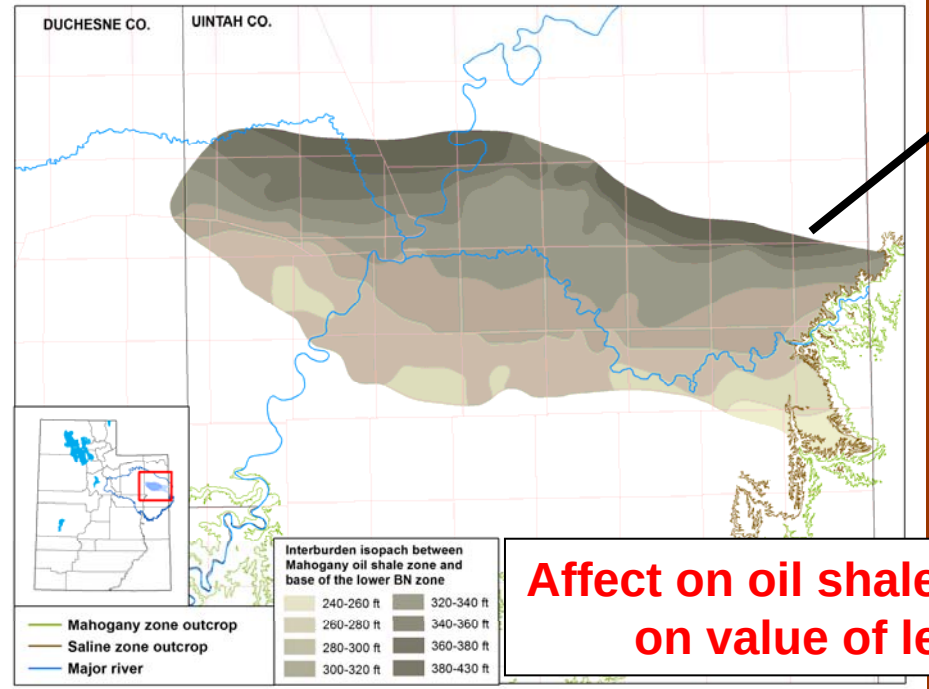

Isopach of lower BN zone
DUCHESNE CO.
UINTAH CO.
4000 ft
3000 ft
2000 ft
1000 ft
Isopach of lower BN aquifer
30-40 ft
40-50 ft
50-60 ft
60-70 ft
70-80 ft
80-90 ft
90-100 ft
100-110 ft
Mahogany zone outcrop
Saline zone outcrop
Major river


Isopach of upper BN zone
DUCHESNE CO.
UINTAH CO.
3000 ft
2000 ft
Isopach of upper BN aquifer
30-40 ft
40-50 ft
50-60 ft
60-70 ft
70-80 ft
80-90 ft
90-100 ft
100-120 ft
Mahogany zone outcrop
Saline zone outcrop
Major river


Birds Nest and 25 GPT oil shale zone
DUCHESNE CO.
UINTAH CO.
25 GPT oil shale isopach within area suitable for saline water disposal into the BN aquifer
>0-5 ft
5-20 ft
20-40 ft
40-60 ft
60-80 ft
80-100 ft
100-130 ft
Mahogany zone outcrop
Saline zone outcrop
Major river

Birds Nest and rich oil shale



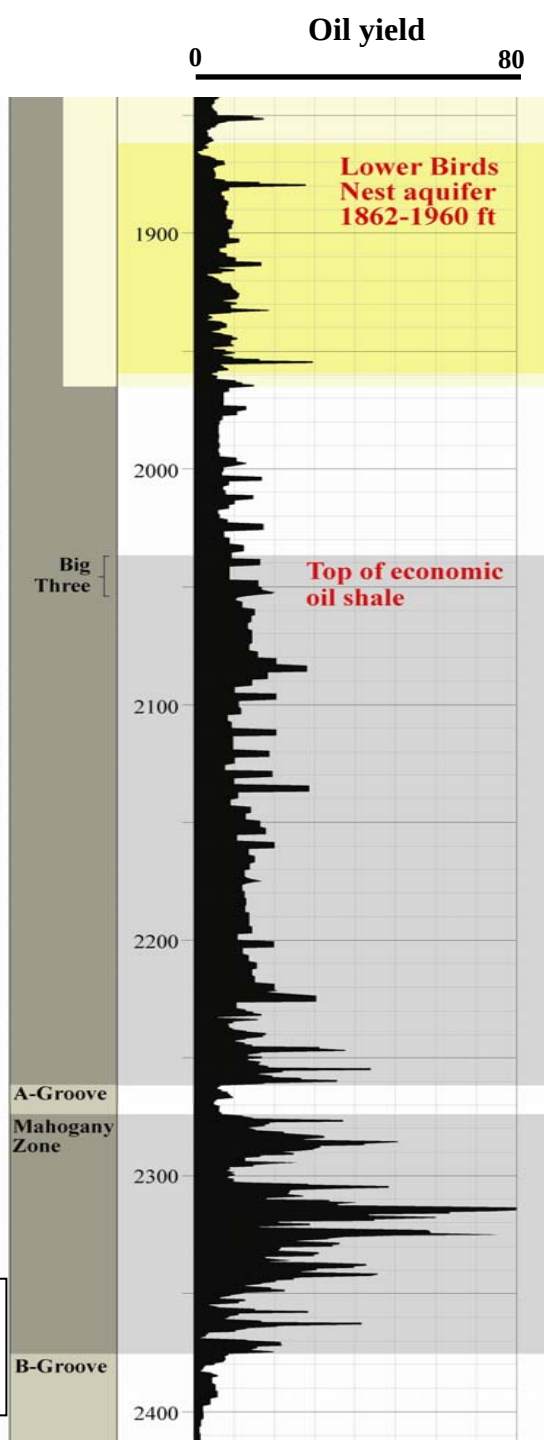


Geologic Characteri

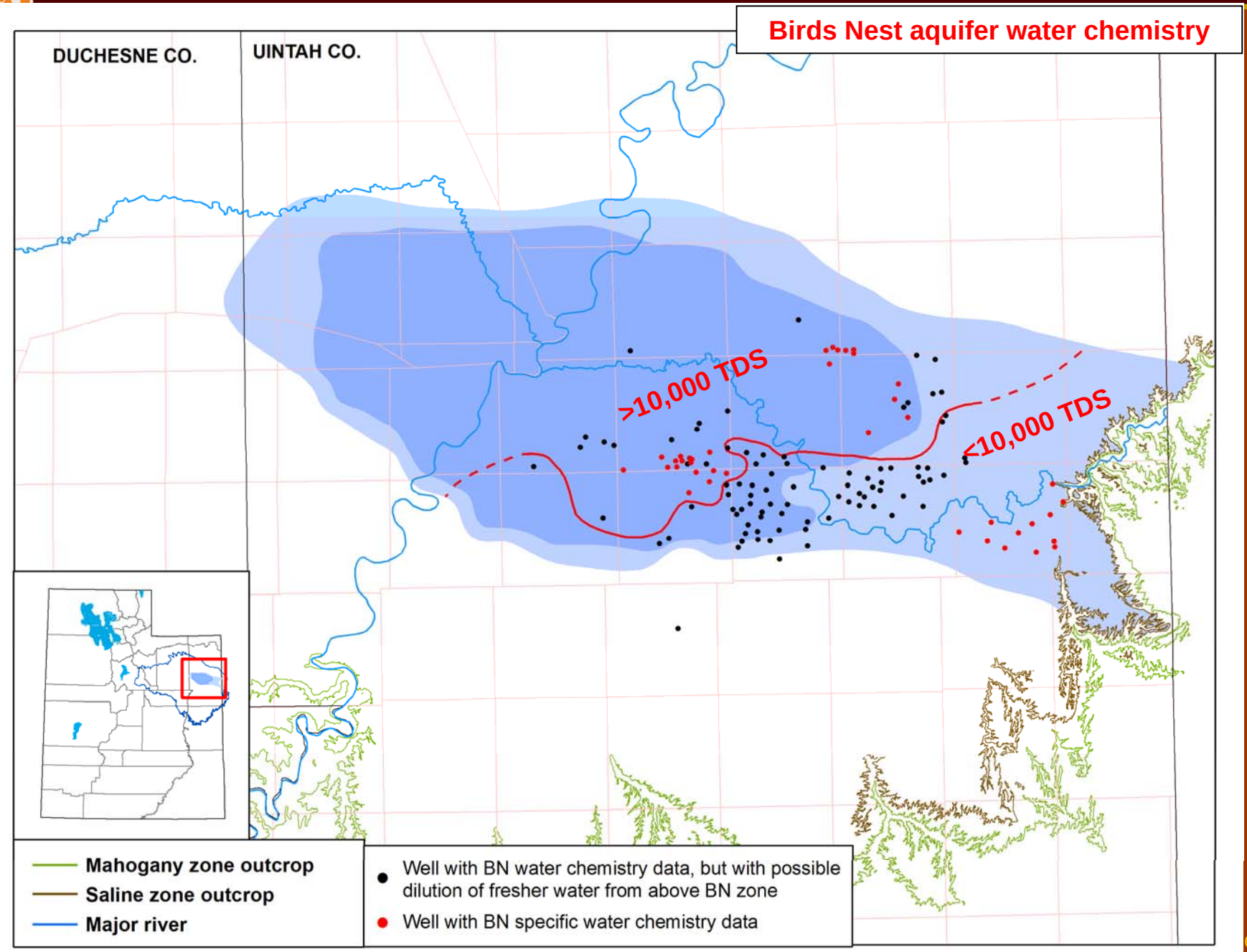
Interburden – base of lower BN to Big 3

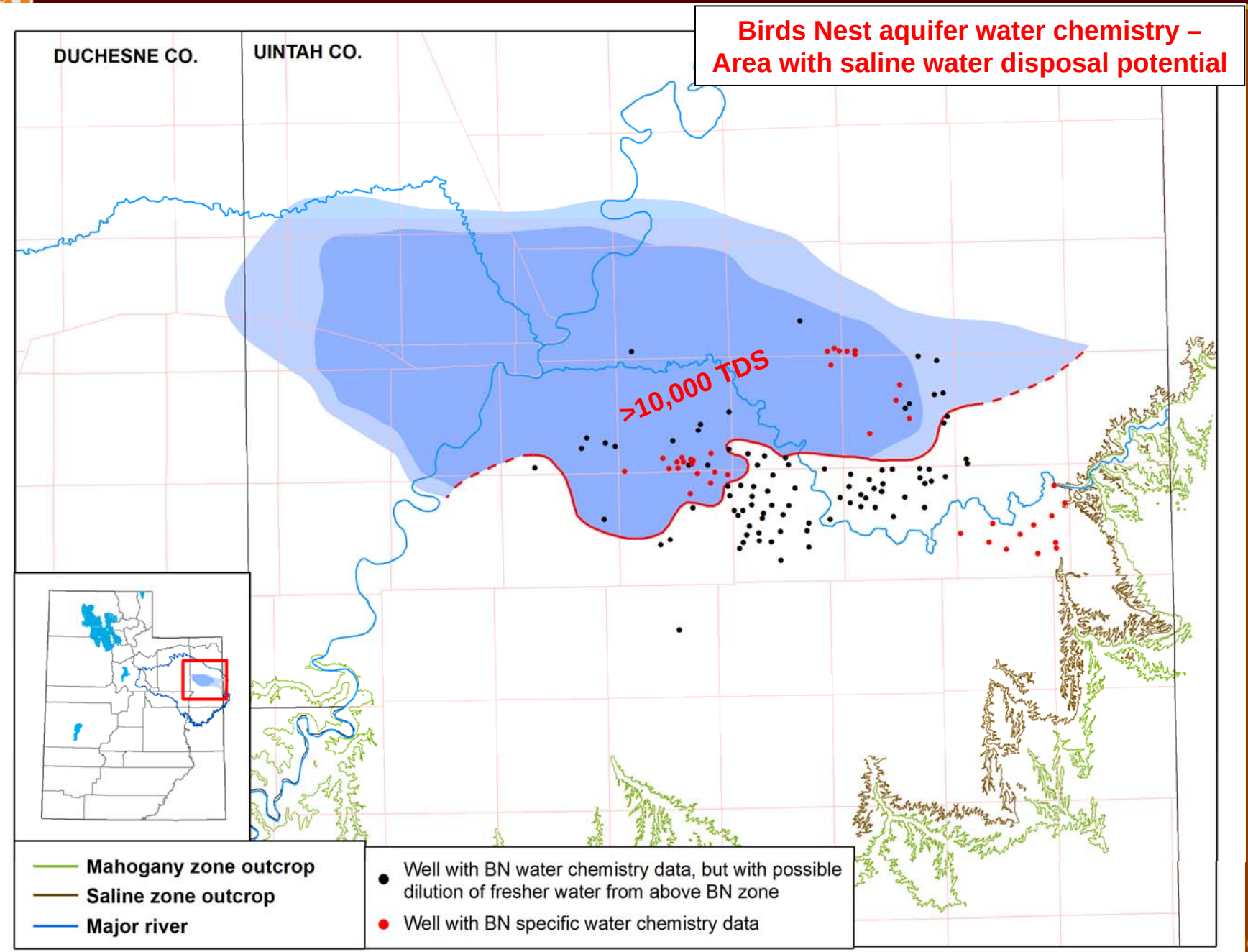
Interburden – base of lower BN to MZ

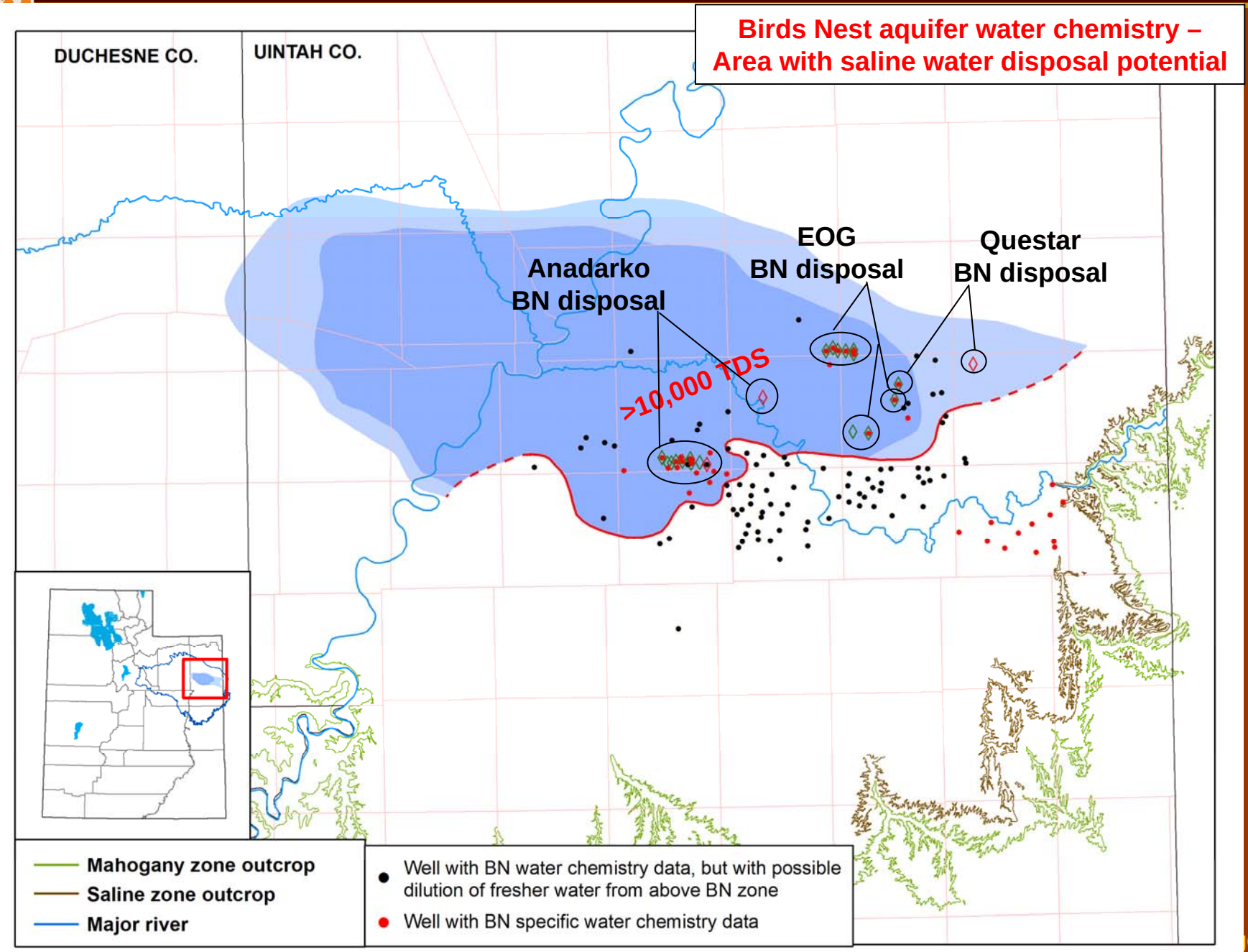
Green River Formation - Parachute Creek Member



Affect on oil shale deposits depends on value of leaner deposits

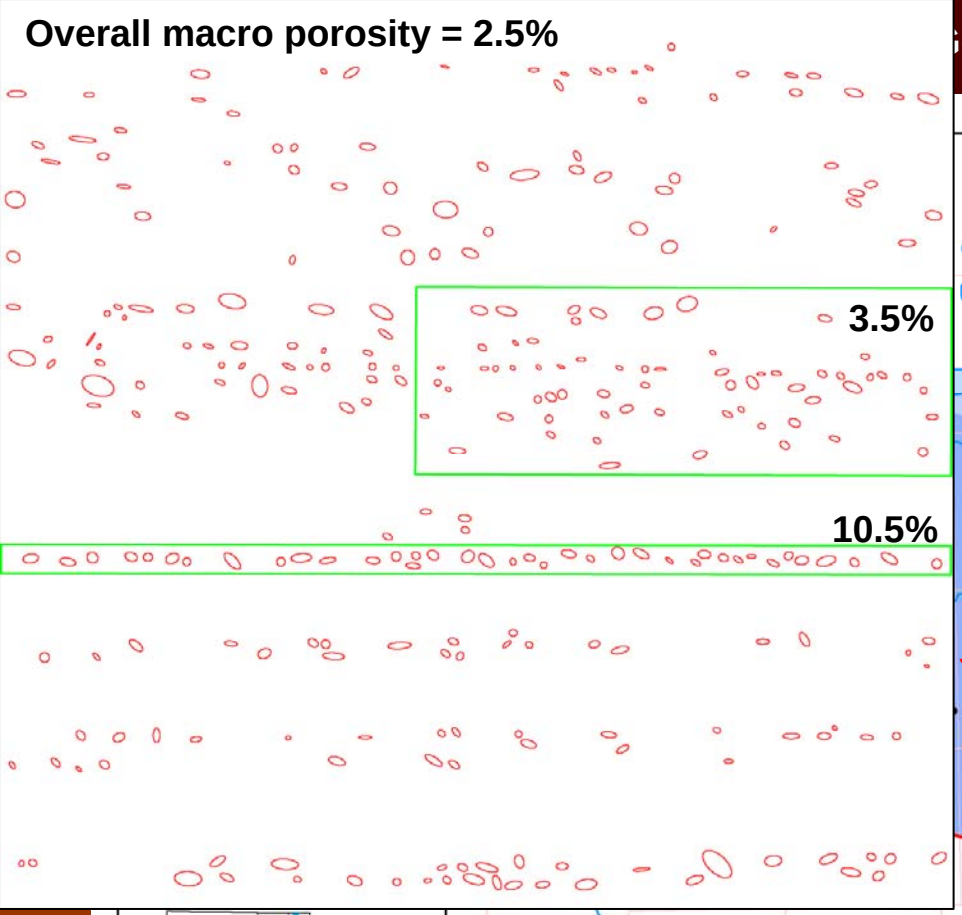

Birds Nest aquifer water chemistry
DUCHESNE CO.
UINTAH CO.
>10,000 TDS
<10,000 TDS
Mahogany zone outcrop
Saline zone outcrop
Major river
Well with BN water chemistry data, but with possible dilution of fresher water from above BN zone
Well with BN specific water chemistry data


Birds Nest aquifer water chemistry –
Area with saline water disposal potential
DUCHESNE CO.
UINTAH CO.
>10,000 TDS
Mahogany zone outcrop
Saline zone outcrop
Major river
Well with BN water chemistry data, but with possible dilution of fresher water from above BN zone
Well with BN specific water chemistry data


Birds Nest aquifer water chemistry –
Area with saline water disposal potential
DUCHESNE CO.
UINTAH CO.
Anadarko
BN disposal
EOG
BN disposal
Questar
BN disposal
>10,000 TDS
Mahogany zone outcrop
Saline zone outcrop
Major river
Well with BN water chemistry data, but with possible dilution of fresher water from above BN zone
Well with BN specific water chemistry data

Birds Nest aquifer water chemistry – Volume calculations

Birds Nest aquifer water chemistry – Volume calculations



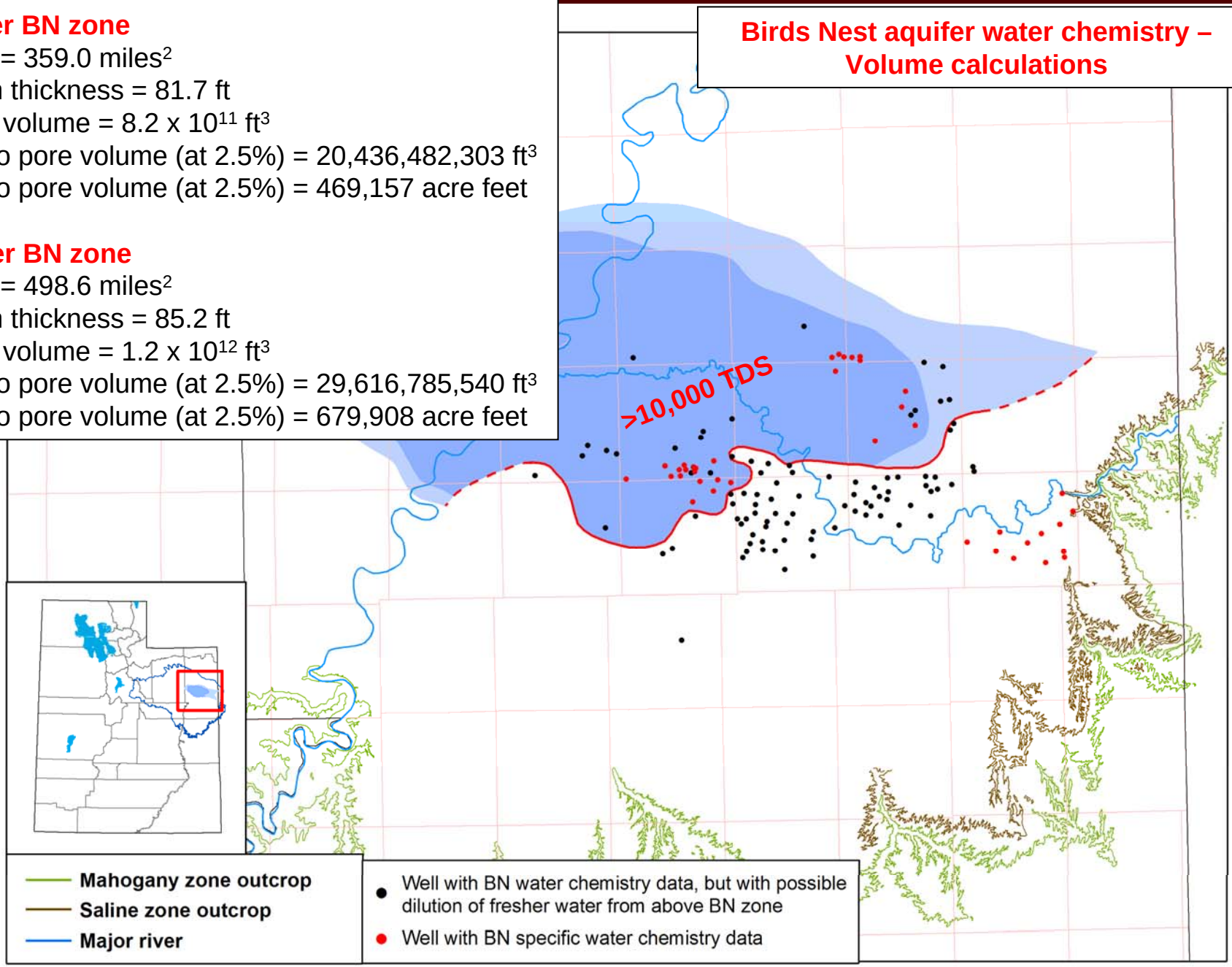
Birds Nest aquifer water chemistry – Volume calculations

Approximate space for saline water:

Upper BN zone
Area = 359.0 miles^2
Mean thickness = 81.7 ft
Total volume = 8.2 x 10^{11} ft^3
Macro pore volume (at 2.5%) = 20,436,482,303 ft^3
Macro pore volume (at 2.5%) = 469,157 acre feet

Lower BN zone
Area = 498.6 miles^2
Mean thickness = 85.2 ft
Total volume = 1.2 x 10^{12} ft^3
Macro pore volume (at 2.5%) = 29,616,785,540 ft^3
Macro pore volume (at 2.5%) = 679,908 acre feet

Birds Nest aquifer water chemistry – Volume calculations



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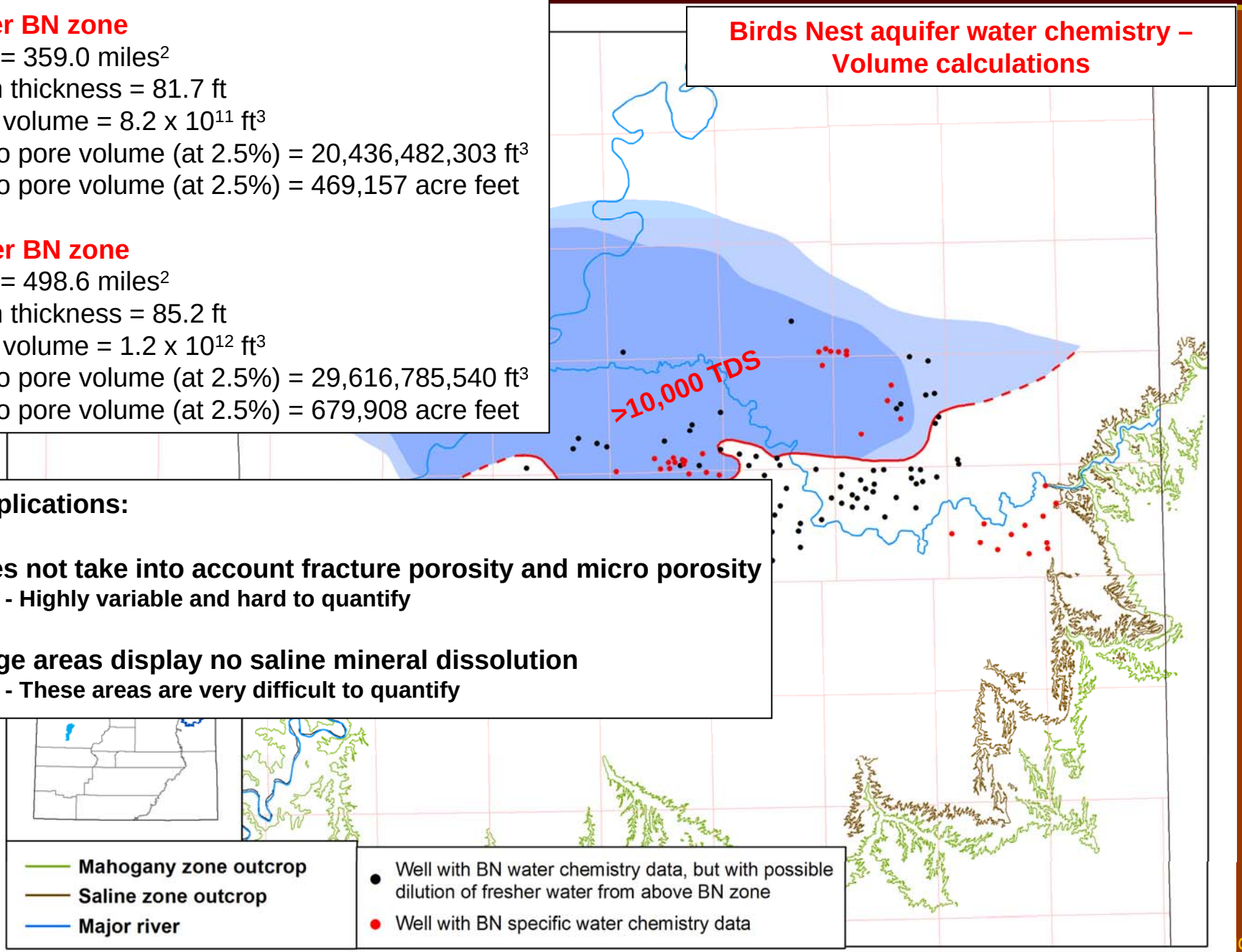
Birds Nest aquifer water chemistry – Volume calculations



Complications:

- **Does not take into account fracture porosity and micro porosity**
  - **Highly variable and hard to quantify**
- **Large areas display no saline mineral dissolution**
  - **These areas are very difficult to quantify**

Gilsonite veins – Conduits or barriers?

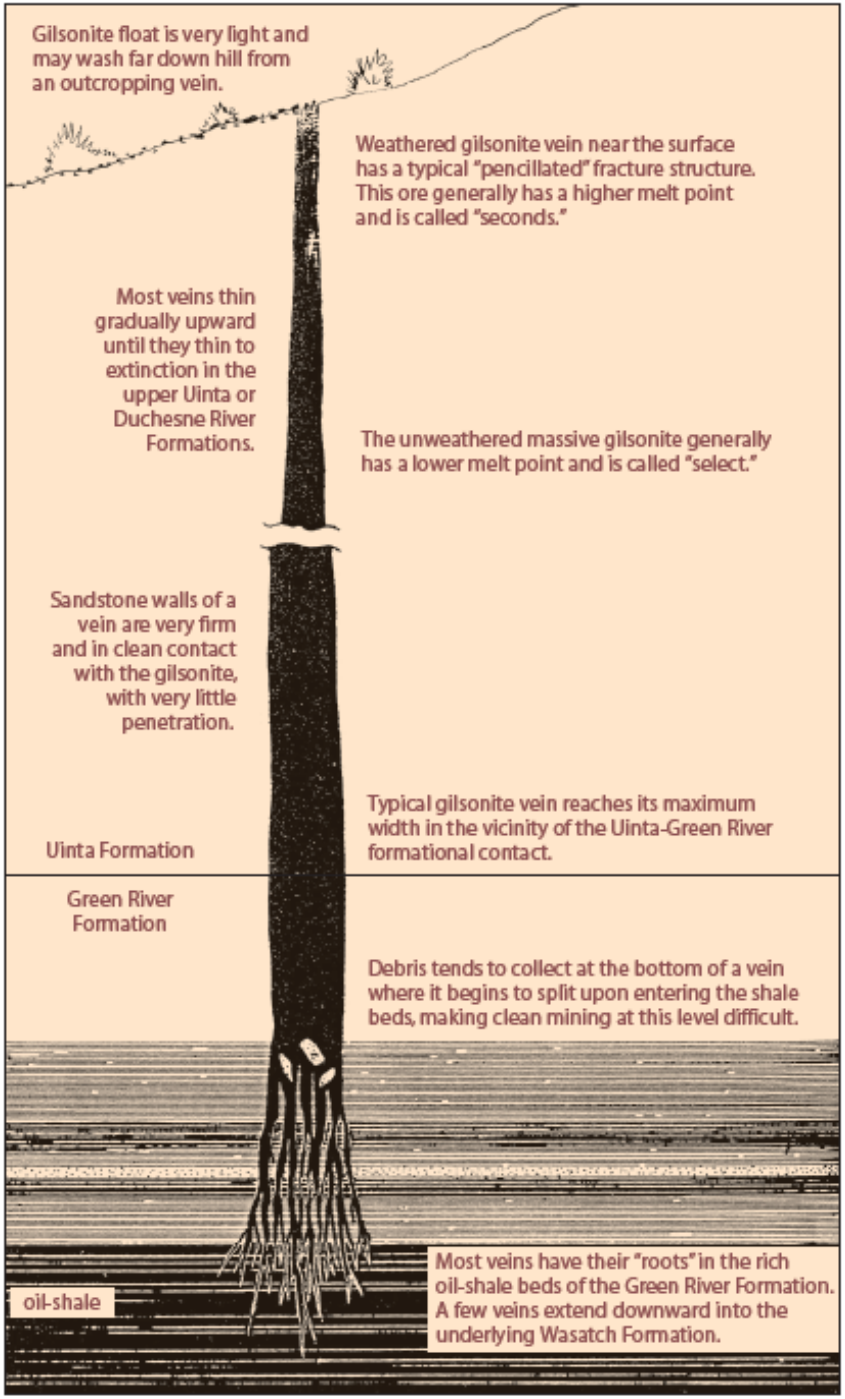
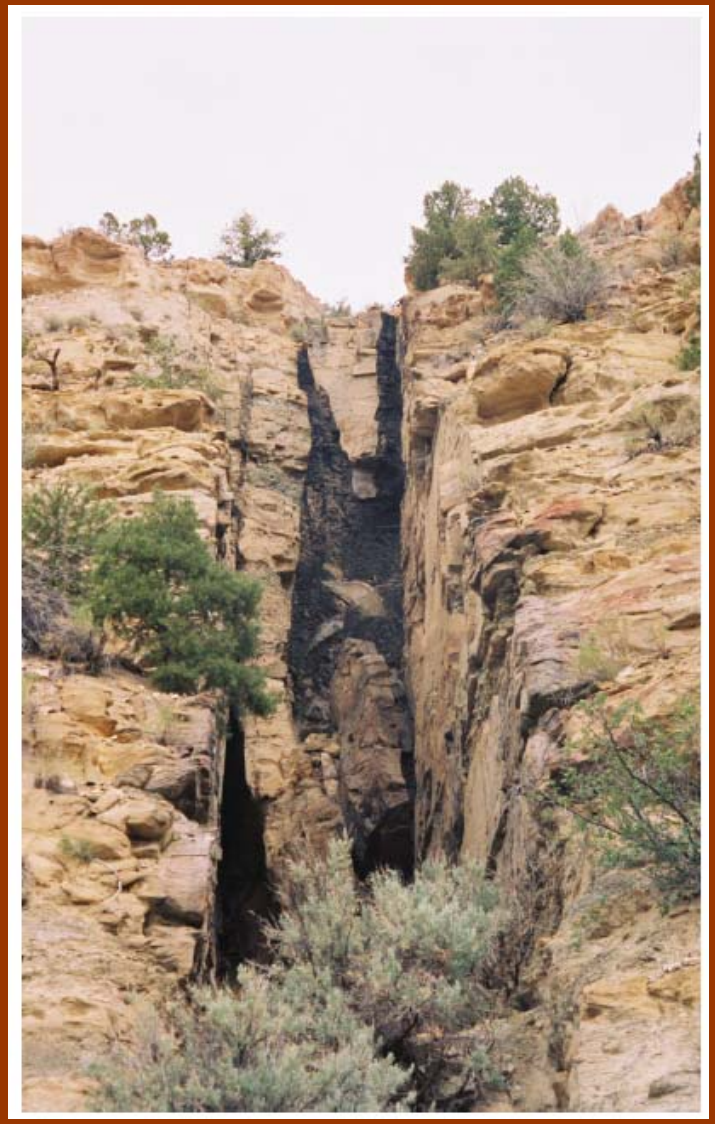


Figure 6. Cross section of a typical gilsonite vein (from Eldridge, 1901).

Birds Nest Aquifer



Gilsonite veins – Conduits or barriers?

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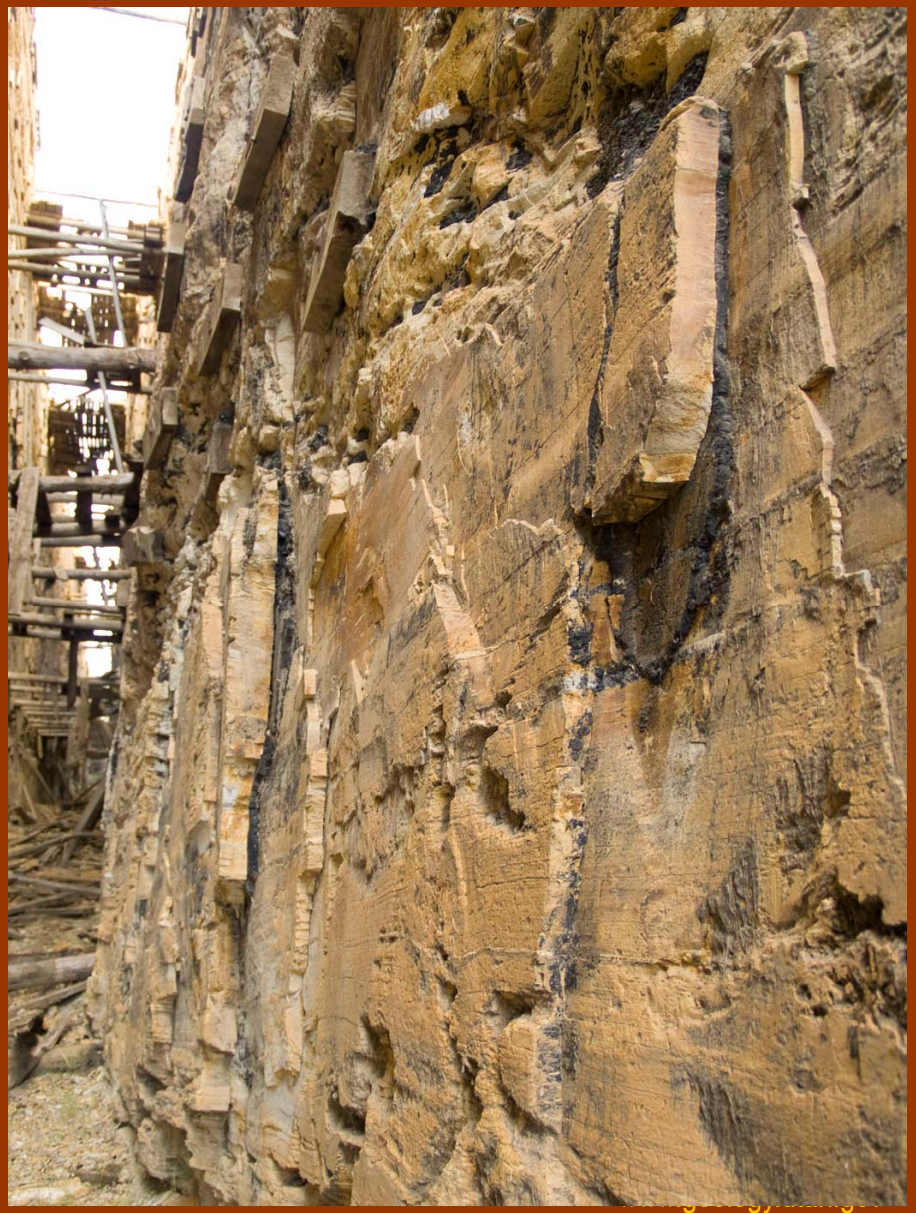
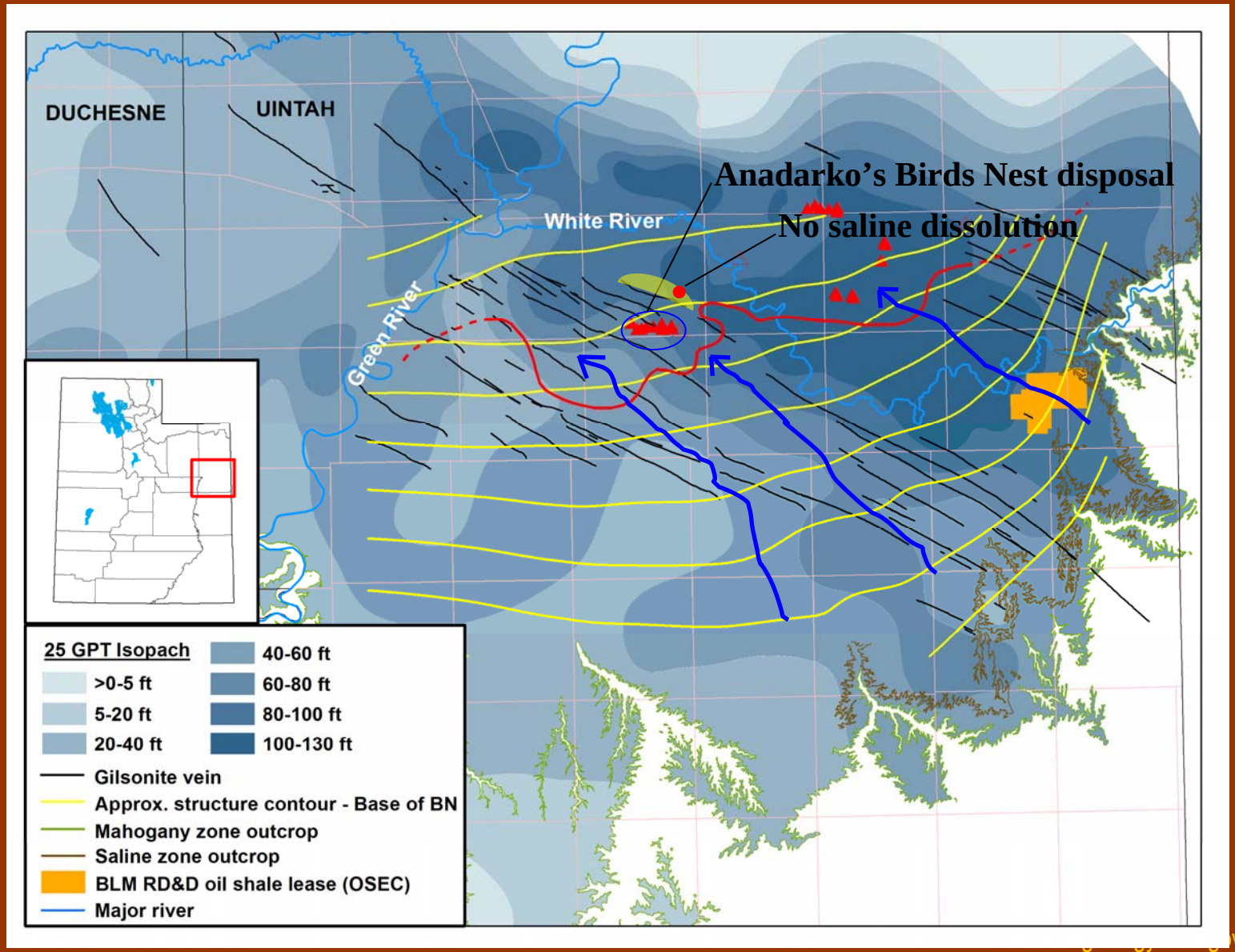
Gilsonite veins – Conduits or barriers?

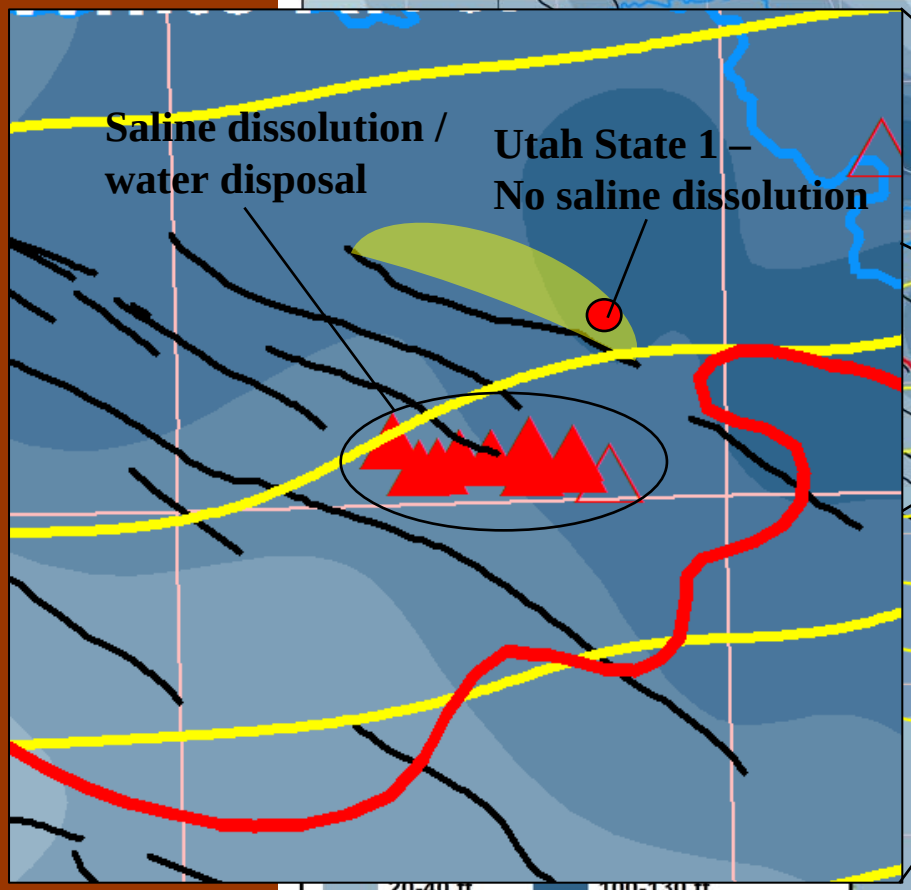


Gilsonite veins and associated fracture zones

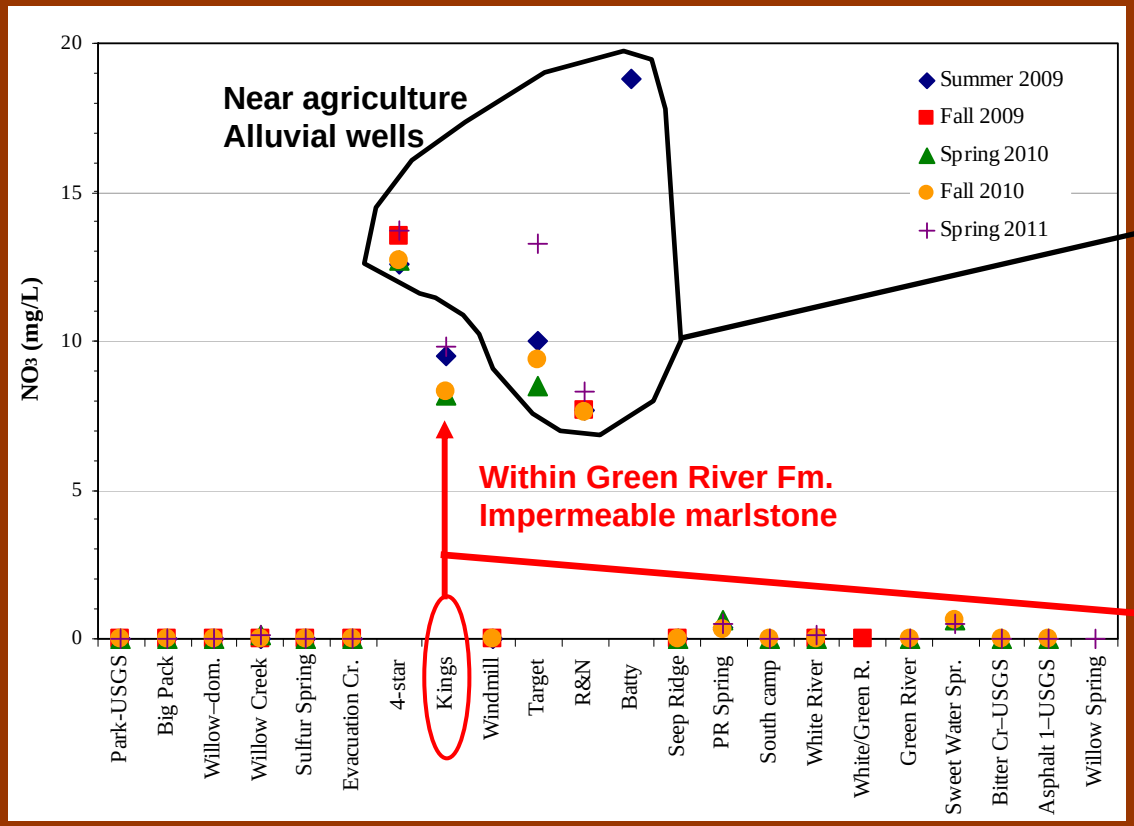
Gilsonite veins – Evidence for groundwater barrier

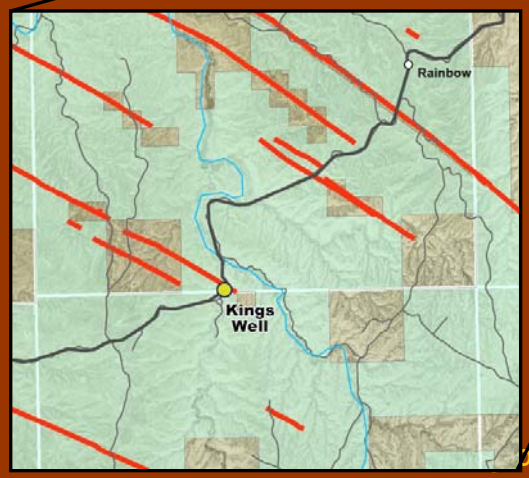


Gilsonite veins – Evidence for groundwater barrier



Gilsonite veins – Evidence for groundwater conduit

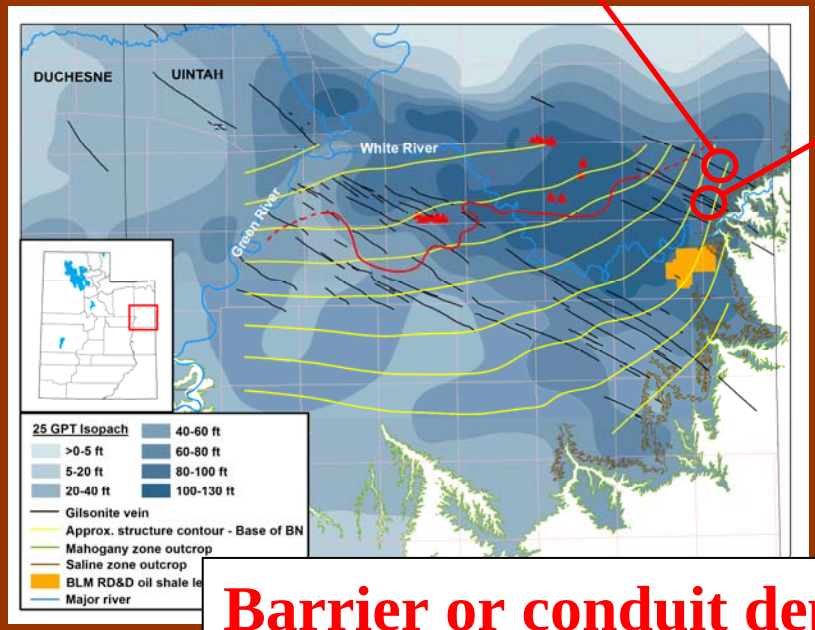


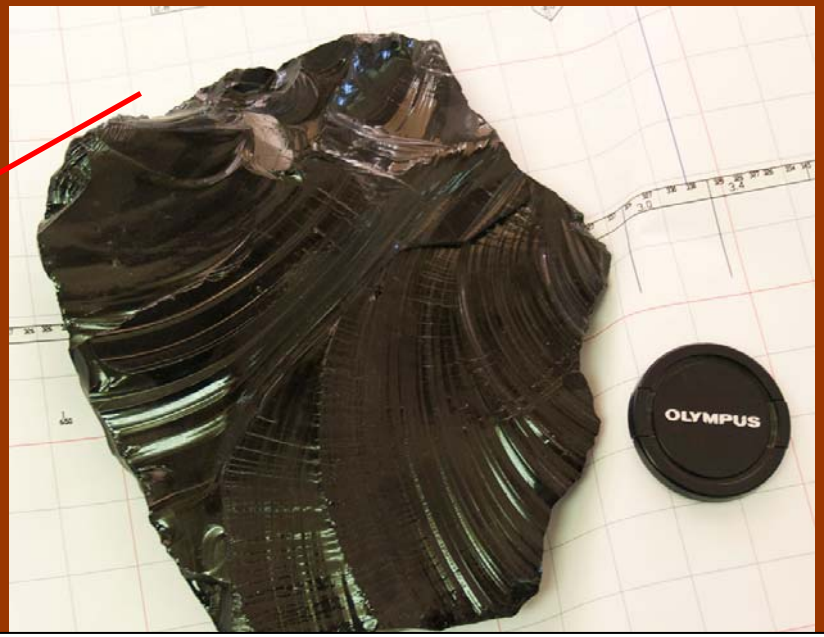


- Kings well is used for watering stock
- Wastewater from the cows/sheep could be using the gilsonite vein to travel into the groundwater aquifer

Bonanza Vein
- Highly fractured gilsonite
- 630 ft depth (Uinta Fm)
- Lots of water infiltration (from wall rock and vein)

Independent Vein
- "Solid" gilsonite
- 230 ft depth (Uinta Fm)
- Minor water infiltration (from wall rock)





Barrier or conduit depends on type and thickness of vein

Conclusions:

- The Birds Nest aquifer has significant potential as a saline water disposal zone…
  - Currently contains highly saline water in northern areas
  - Large amount of storage space (on a vacuum) due to the dissolution of saline minerals
  - Shallow (good or bad?)
  - Located close to significant drilling activity
  - Should only affect leaner oil shale deposits with marginal economic potential
- But poses unique challenges and risks:
  - Large areas with no dissolution, reduces potential
  - Cross-cutting gilsonite veins (and associated fractures) could transmit water vertically through the section, posing risks to “fresh” water aquifers and oil shale operations
  - Monitoring wells will be key, but add expense

Task 4:
Baseline water chemistry database for lands with oil shale development potential

Problem:

There is a regulatory need for baseline water quality data from lands identified by the BLM as having oil shale development potential

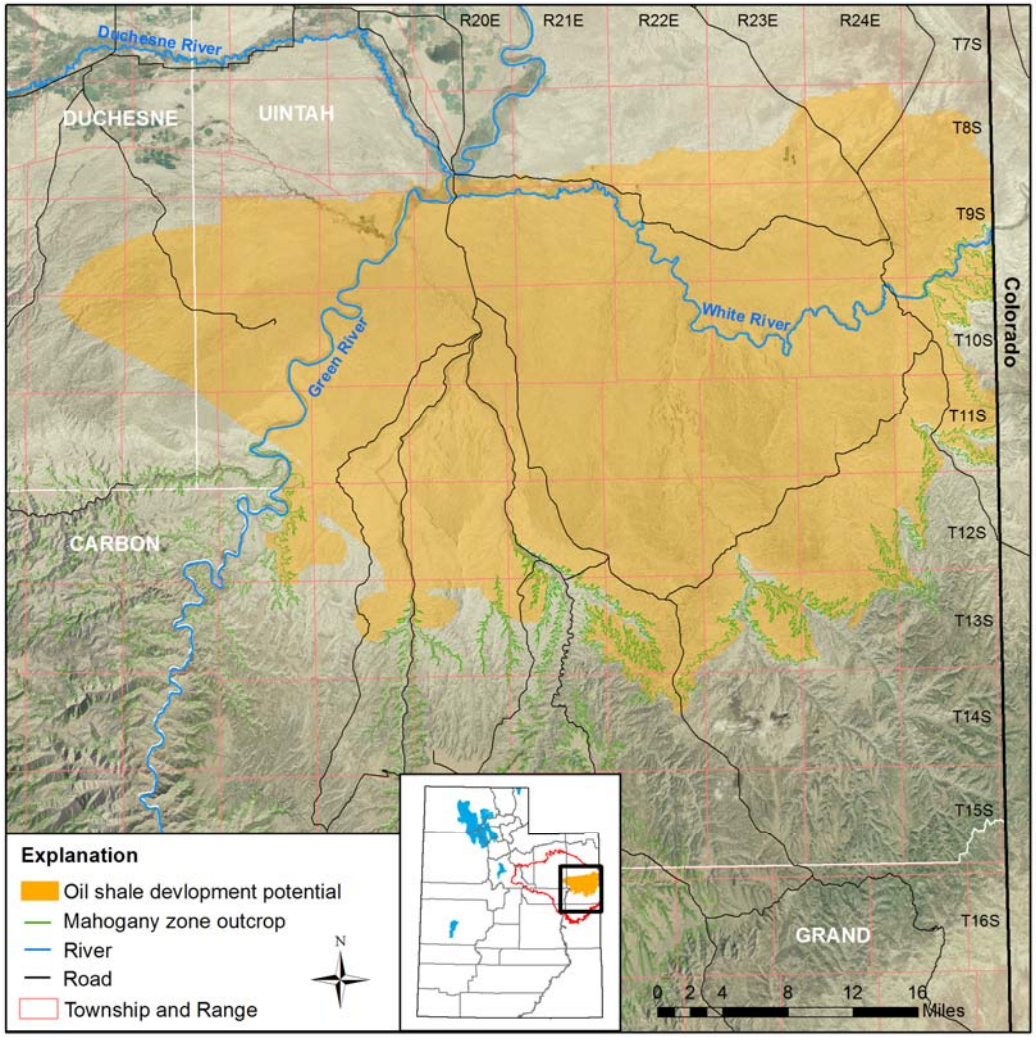
- Pre-oil shale development, surface and shallow bedrock aquifer water quality
- Groundwater from greater depths in the oil and gas producing zones is more well known and was not the focus of this study

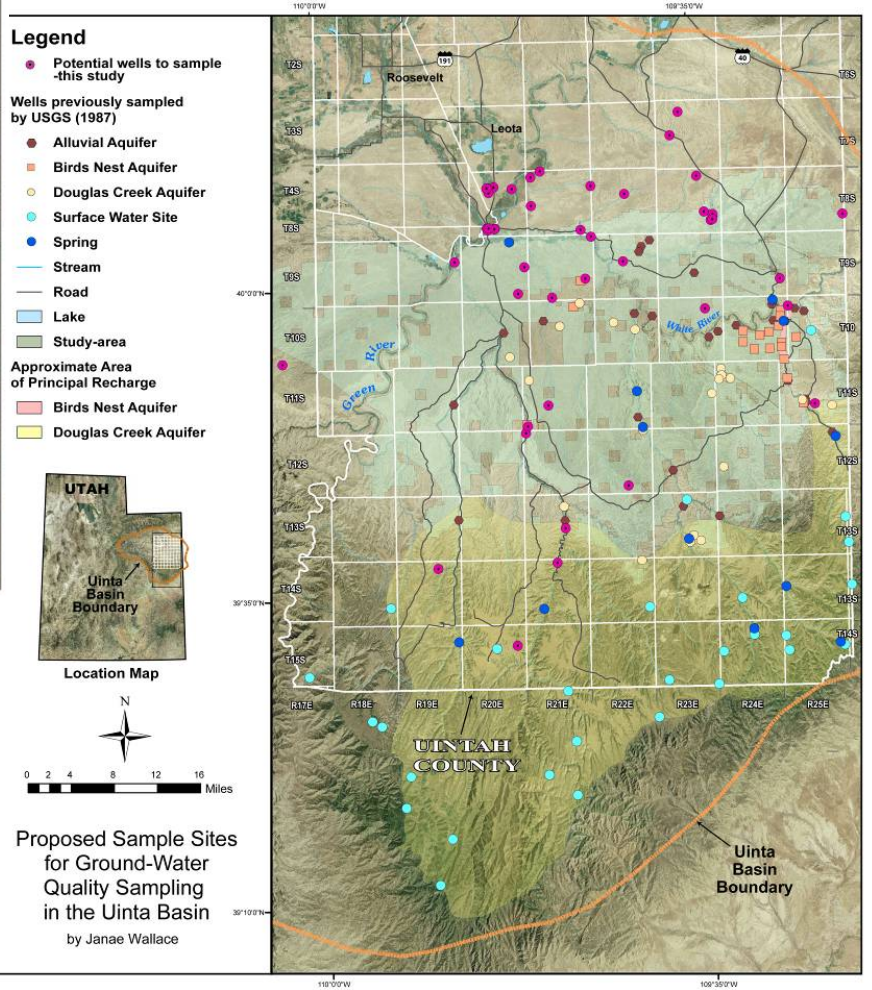
Research / Deliverables:

- Sample water from wells and surface sites bi-annually (5 rounds)
- Database of water quality analyses including:
  - general chemistry
  - nutrients
  - dissolved oxygen
  - dissolved metals
  - volatile organic compounds
  - total organic carbon

Task 4: Baseline water chemistry database

Lands identified by the BLM as having oil shale development potential (2008/2012 PEIS)





Original sampling plan (Oct. 2008)

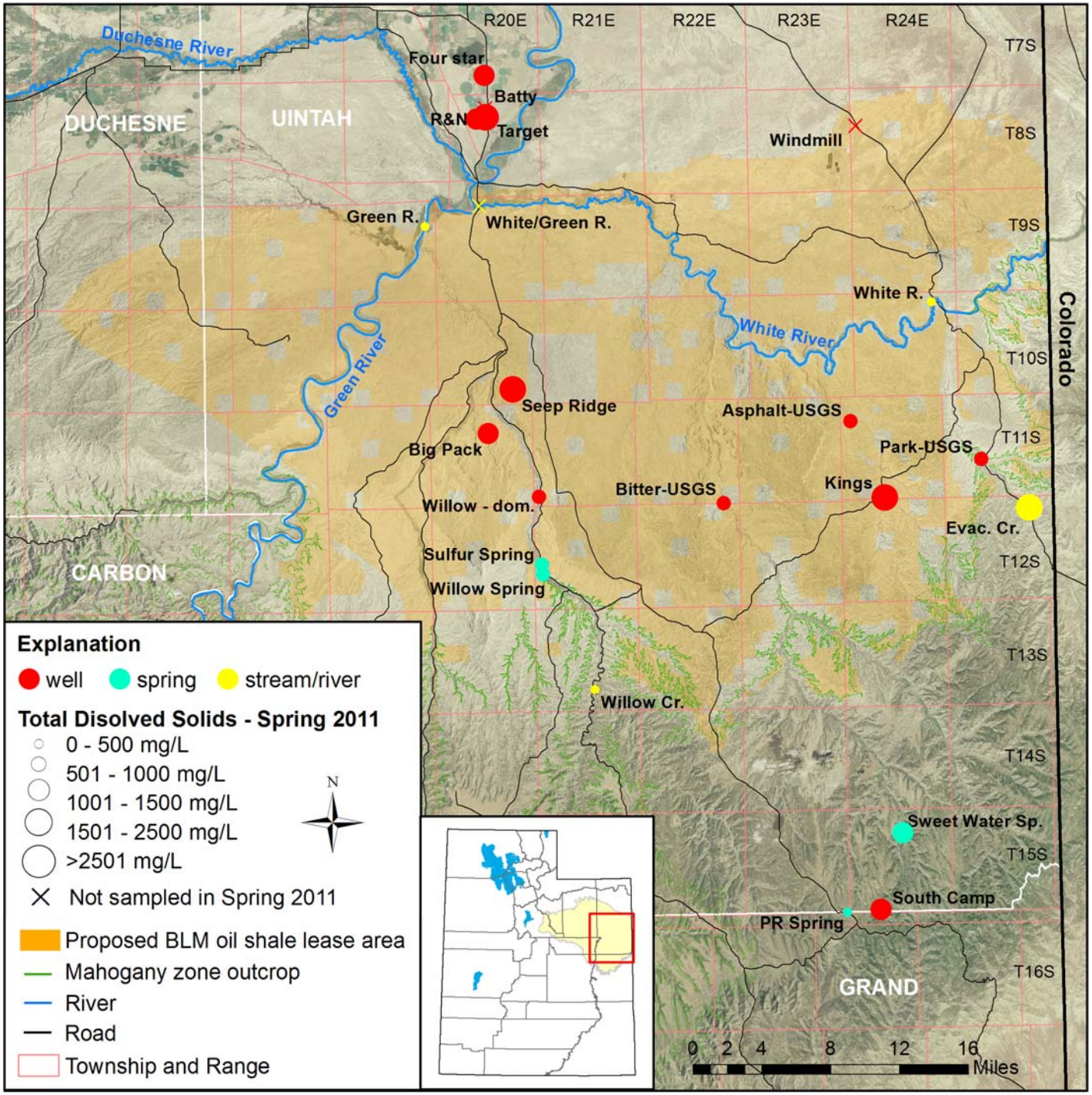
~50 sampling sites

UTAH GEOLOGICA

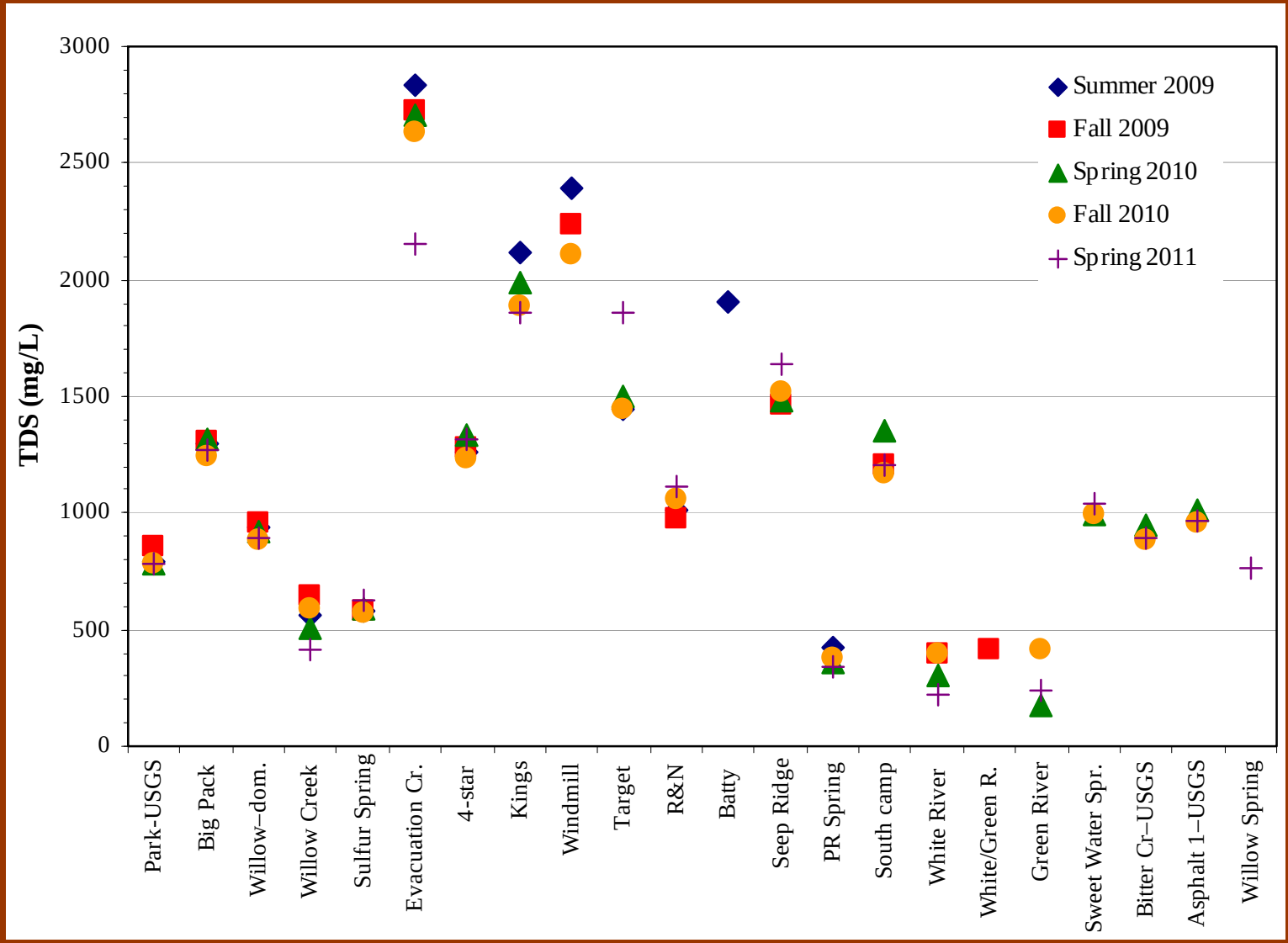
Only 24 sites were suitable for sampling

UTAH GEOLOGIC

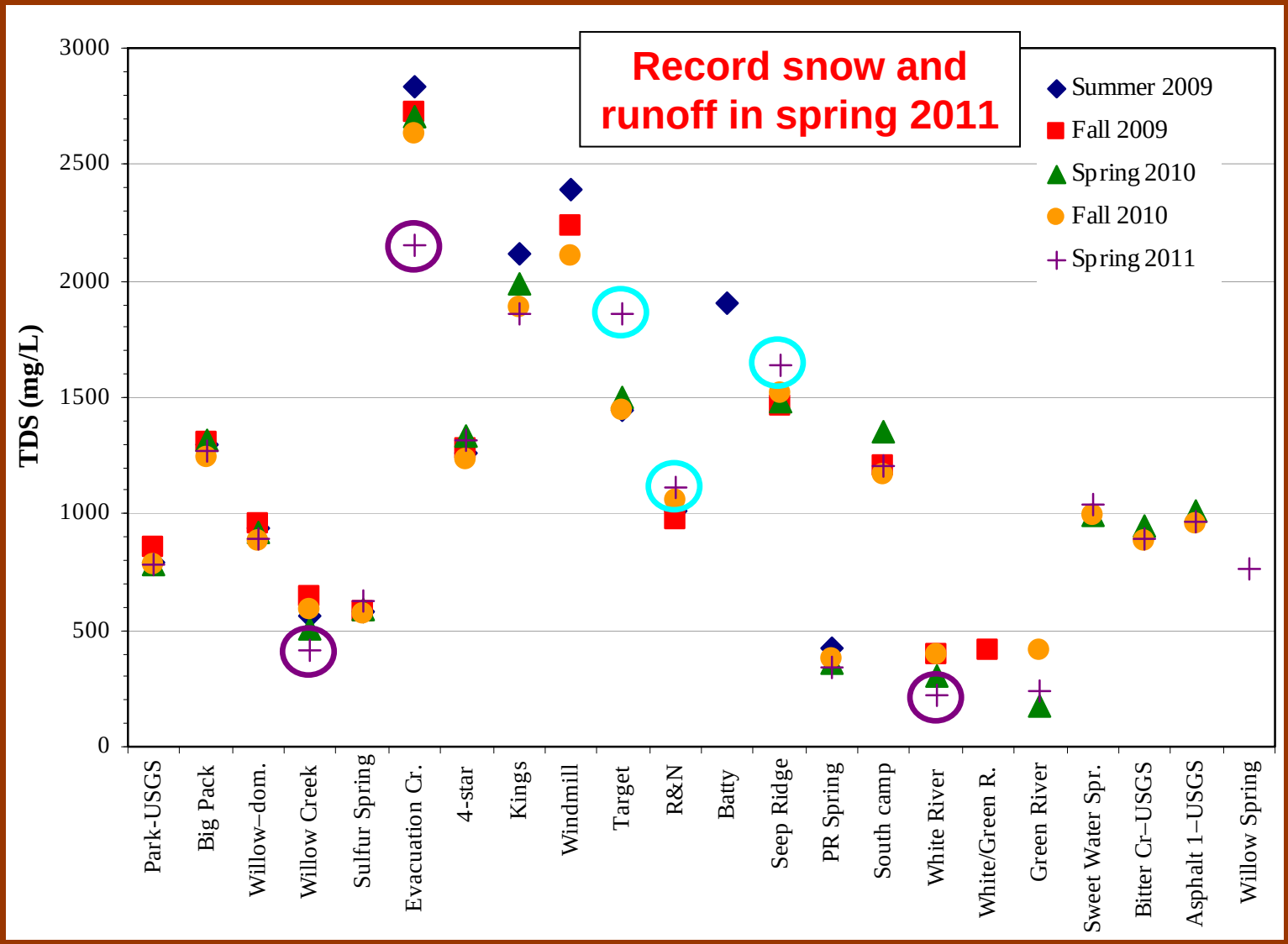
TDS for sites sampled spring 2011

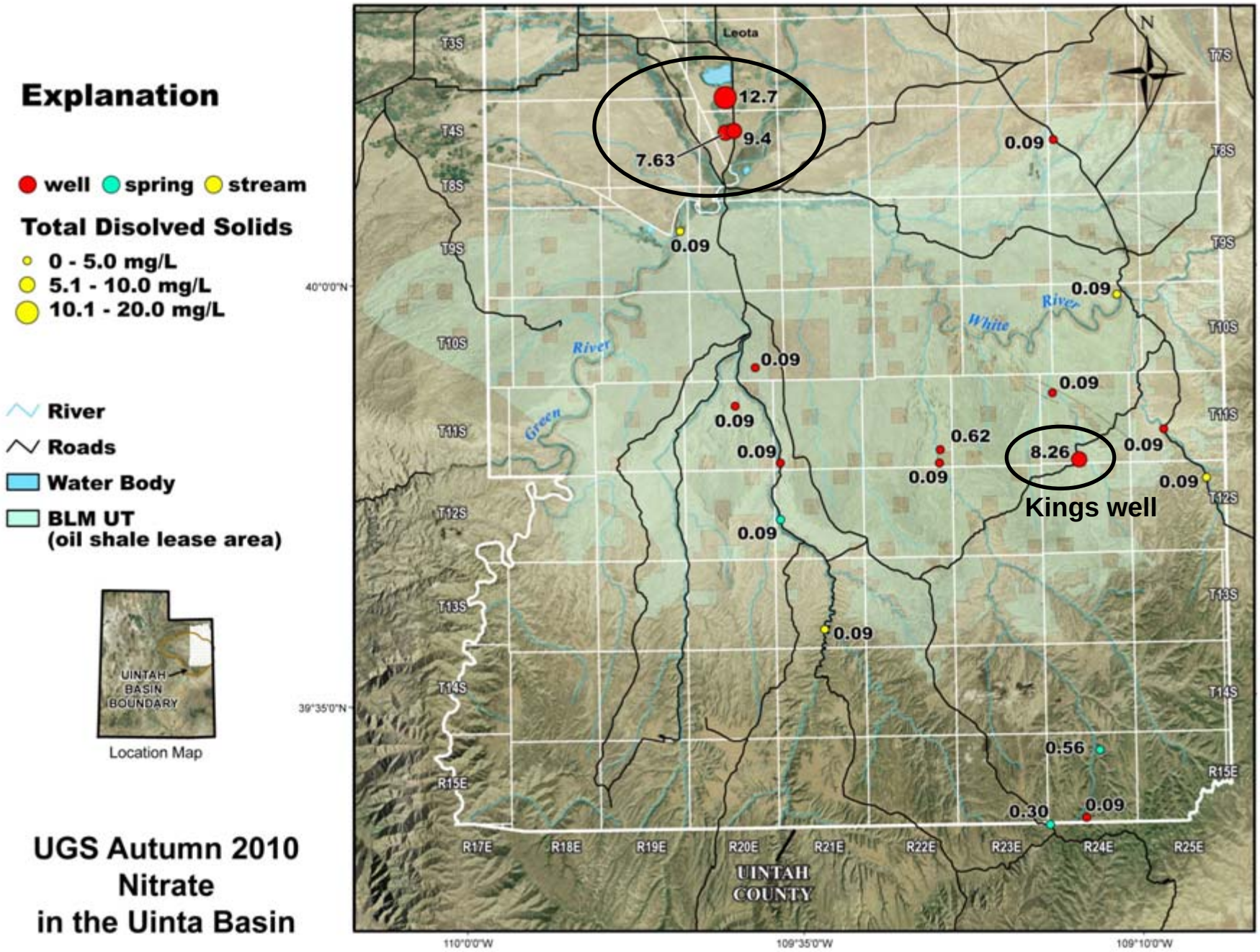


Bi-annual TDS water chemistry for all sites – minimal variation

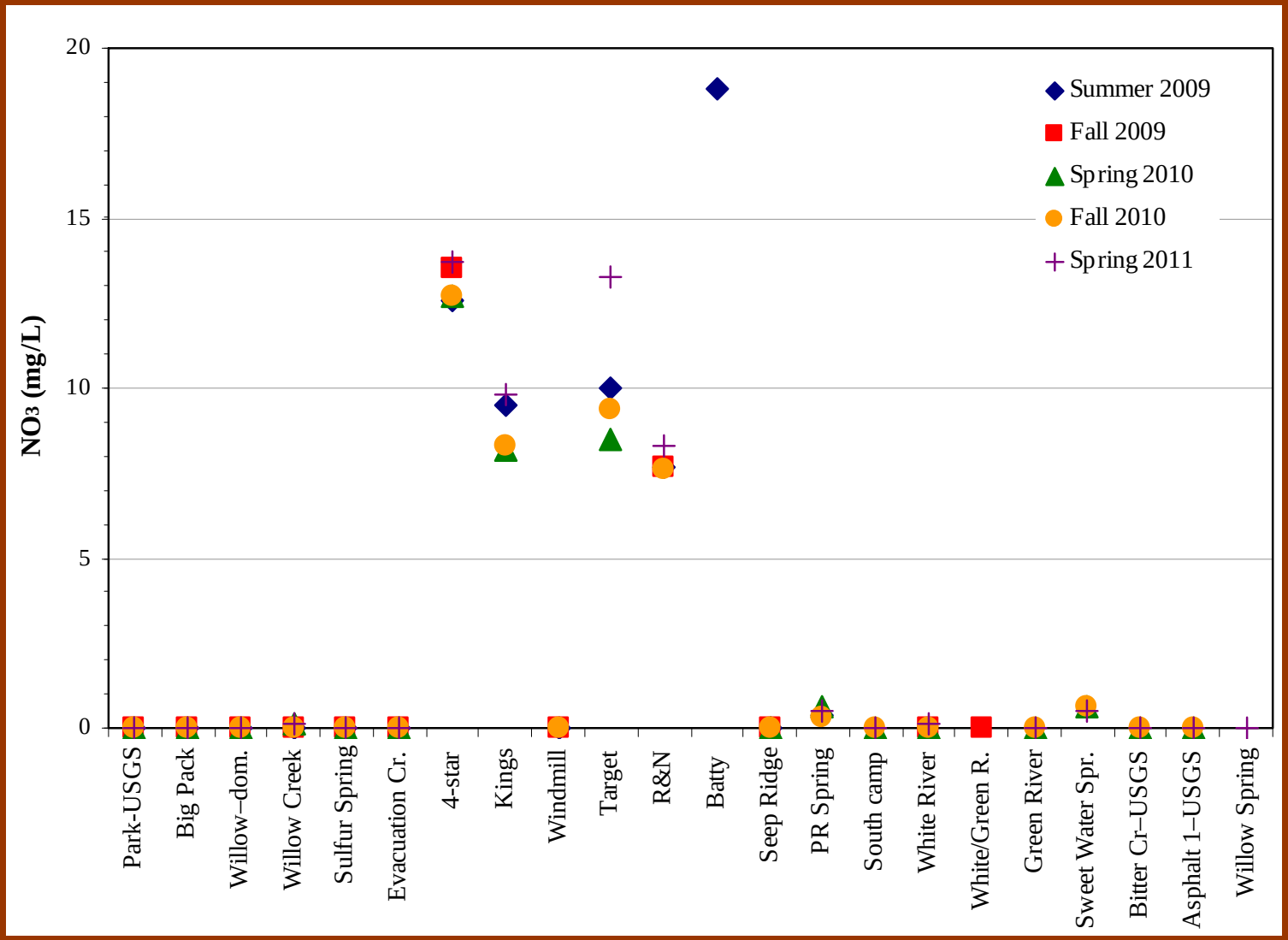


Bi-annual TDS water chemistry for all sites – minimal variation

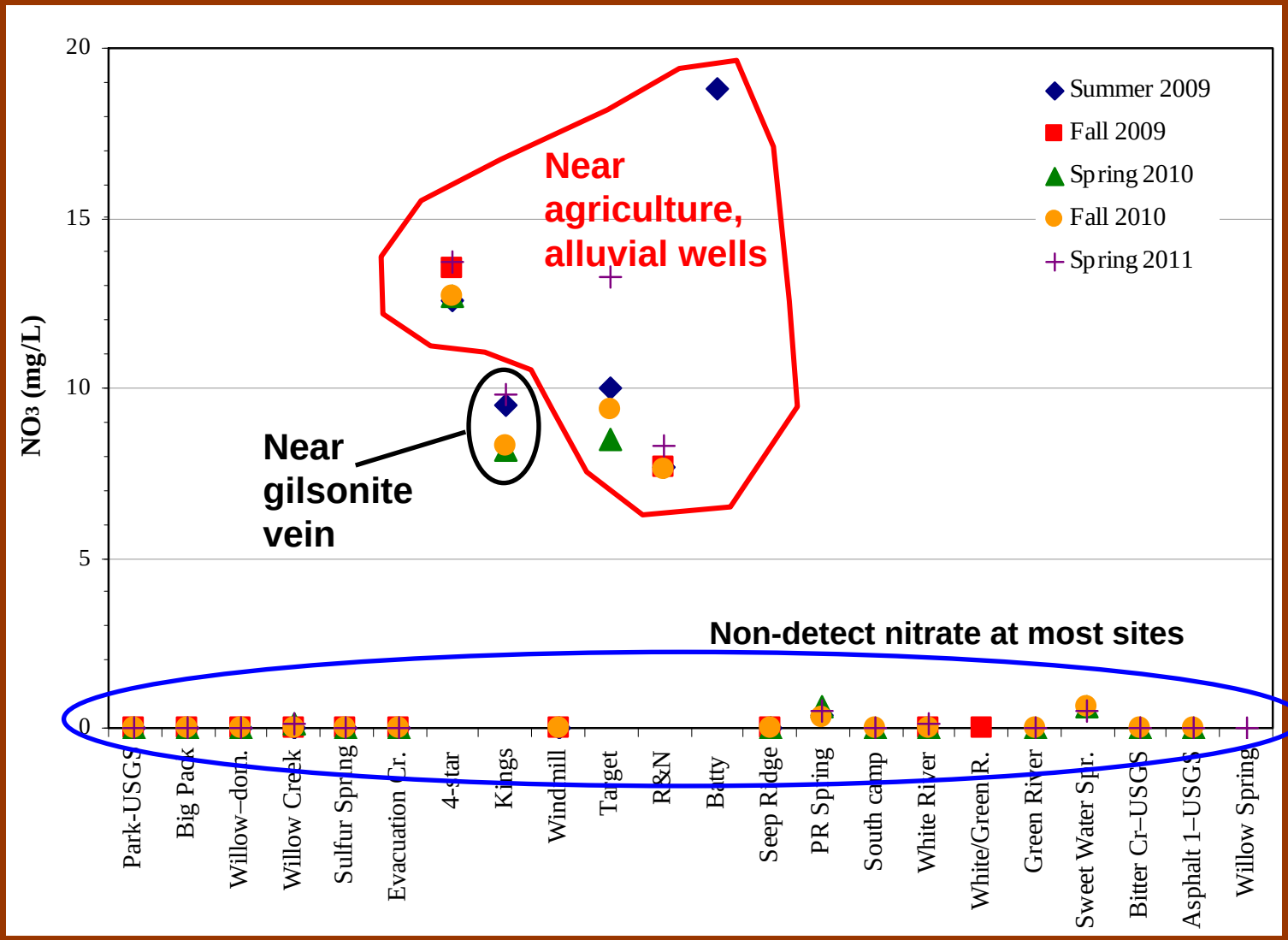



Explanation
well
spring
stream
Total Disolved Solids
0 - 5.0 mg/L
5.1 - 10.0 mg/L
10.1 - 20.0 mg/L
River
Roads
Water Body
BLM UT
(oil shale lease area)
UINTAH BASIN BOUNDARY
Location Map
UGS Autumn 2010
Nitrate
in the Uinta Basin
Leota
12.7
9.4
7.63
0.09
0.62
8.26
Kings well
0.56
0.30
UINTAH COUNTY
White River
Green River
T3S
T4S
T7S
T8S
T9S
T10S
T11S
T12S
T13S
T14S
R15E
R17E
R18E
R19E
R20E
R21E
R22E
R23E
R24E
R25E
40°0'0"N
39°35'0"N
110°0'0"W
109°35'0"W
109°10'0"W
N

Bi-annual nitrate water chemistry for all sites – minimal variation



Bi-annual nitrate water chemistry for all sites – minimal variation



Conclusions:

- New baseline water chemistry database provides GIS-based information to help local planners and potential oil shale/oil sand developers preserve the quality of ground and surface water through careful land-use planning
- Minimal seasonal changes in water chemistry
- Highest TDS was 2832 mg/L from Evacuation Creek (flows along outcrop of Birds Nest aquifer)
- Most nitrate concentrations were below detection limits, except in agricultural areas to the north and Kings well
- Some samples had detectable VOCs, but all were below EPA maximum contaminant levels
- Most of the water, in terms of being potable, could be used as a source for drinking water if treated properly, with all having TDS concentrations below 3000 mg/L, the upper limit set by the Utah Water Quality Board as “drinking water quality”

Task 5:
Analysis of produced water from simulated in-situ oil shale extraction technologies

This research was performed by Dr. Milind Deo and Pankaj Tiwari (PhD student), Department of Chemical Engineering, University of Utah

UGS role – provide oil shale samples (core plugs) for all experiments

Research:

Simulate in-situ oil shale extraction in the laboratory to:

1) Determine the presence and species of dissolved organics in the water phase post-pyrolysis

2) Determine the affect the presence of water has on retorting and its products

Several experiments were performed:

1) Water-soaked pyrolysis on powdered and whole-rock samples

2) Hydrous pyrolysis experiments at different temperatures

3) Analysis of water-phase products from non-hydrous pyrolysis experiments

Simplified results:

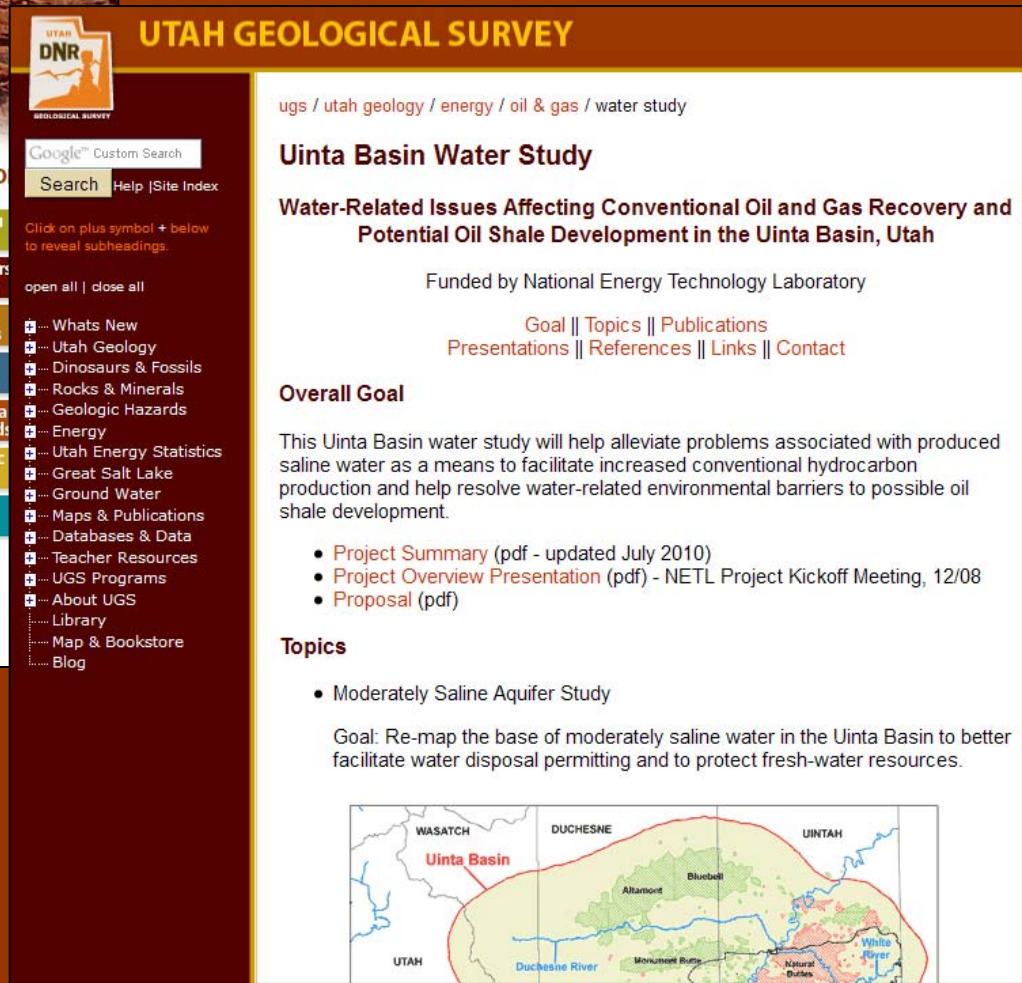
1) Very little water is released during retorting of Utah oil shale, thus reducing the potential for large volumes of water needing disposal during commercial-scale in-situ retorting

2) Water produced in the laboratory experiments contained only very low to non-detectable amounts of organic components, reducing the likelihood of severe aquifer contamination

Task 6:
Technology Transfer

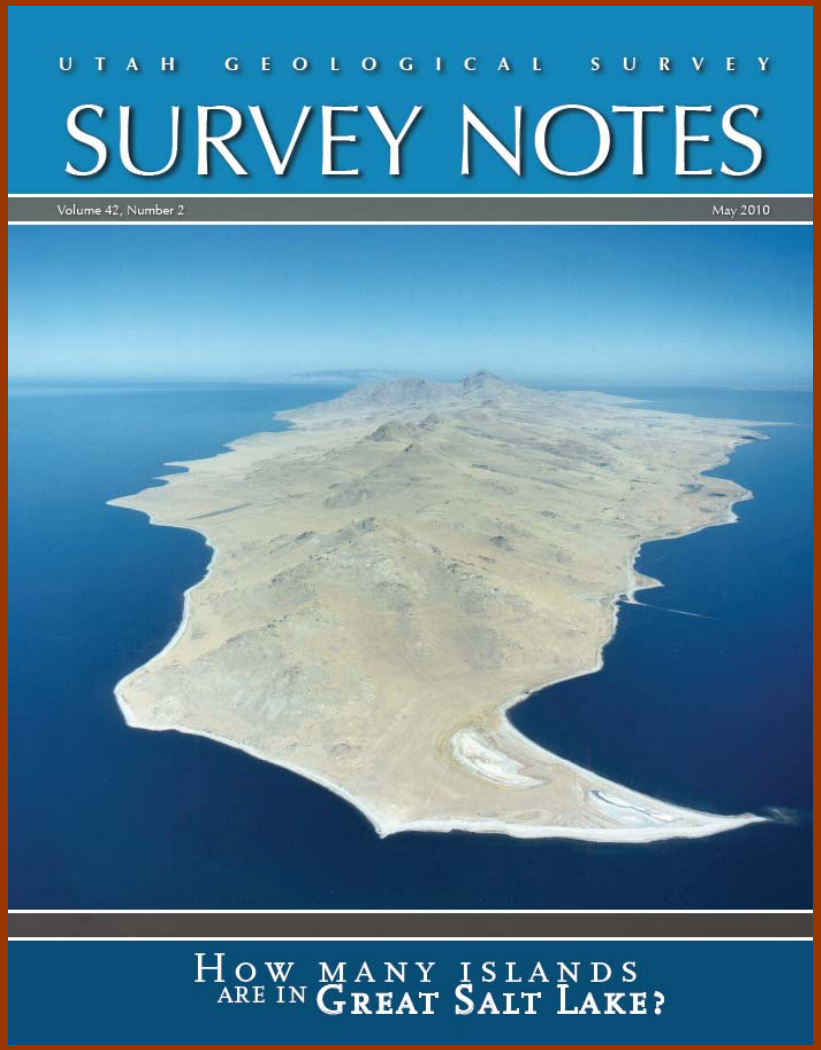
Project website:

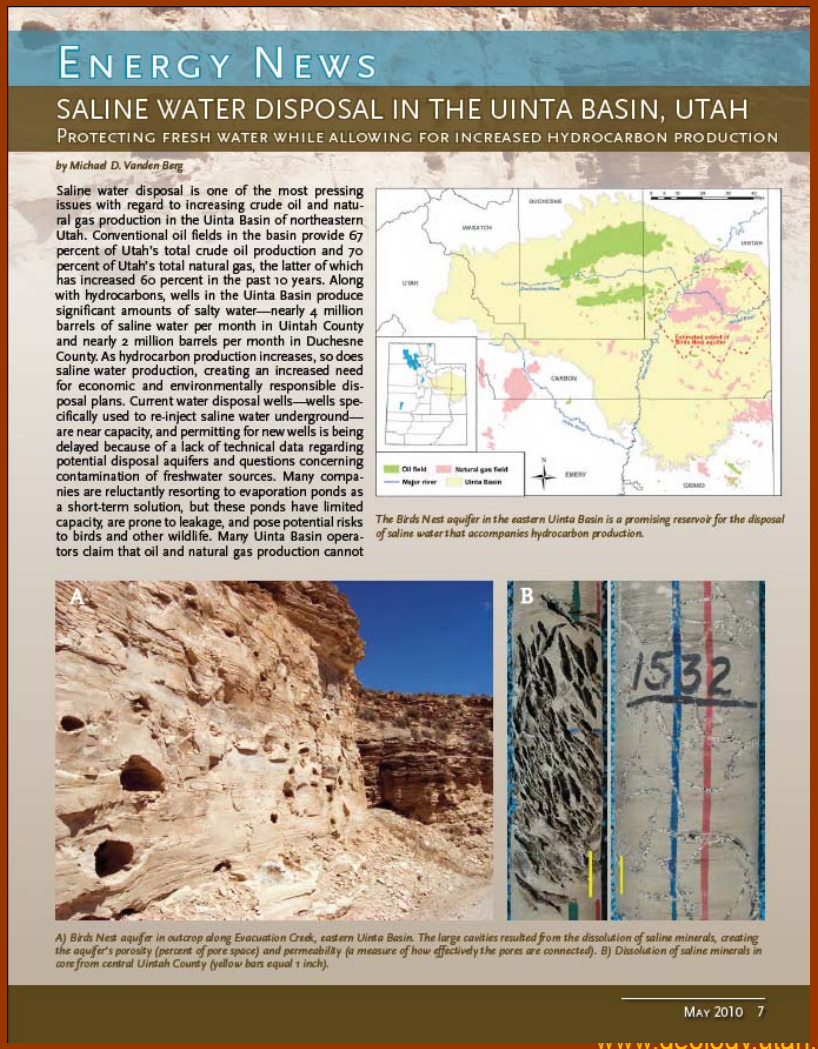
geology.utah.gov/emp/UBwater_study



Article in *Survey Notes*

UGS newsletter, published 3 times a year, distributed to over 5000 people





National and regional conferences (13 presentations)

Anderson, P., Vanden Berg, M., Carney, S., Morgan, C., and Heuscher, S., 2012. "Mapping Potentially Useable Strata for Underground Water Disposal, Uinta Basin, Utah." *2012 AAPG-RMS Annual meeting*, Grand Junction, CO, September 9-12, 2012.

Vanden Berg, M., Carney, S., Morgan, C., 2012. "Geologic Characterization of the Birds Nest Aquifer in the Uinta Basin, Utah: Assessing the Aquifer's Potential as a Significant Saline Water Disposal Zone." *2012 AAPG Annual meeting*, Long Beach, CA, April 22-25, 2012.

Anderson, P., Vanden Berg, M., Carney, S., Morgan, C., 2012. "Mapping Potentially Useable Strata for Underground Water Disposal, Uinta Basin, Utah." *2012 AAPG Annual meeting*, Long Beach, CA, April 22-25, 2012.

Vanden Berg, M., Carney, S., Morgan, C., Lehle, D., 2011. "Stratigraphic Characterization of the Birds Nest Aquifer in the Uinta Basin, Utah: Updated Research Regarding the Aquifer's Potential as a Significant Saline Water Disposal Zone." *2011 AAPG-RMS meeting*, Cheyenne, WY, June 26-29, 2011.

Wallace, J., 2011. "Analysis of Seasonal Water-Quality Data in the Uinta Basin, Eastern Utah." *2011 GSA-RMS meeting*, Logan, UT, May 18-20, 2011.

Vanden Berg, M., Anderson, P., Morgan, C., Carney, S., 2011. "New Insights Regarding Aquifers in the Uinta Basin, Utah: Implications for Saline Water Disposal." *2011 AAPG Annual meeting*, Houston, TX, April 11-13, 2011.

Vanden Berg, M., 2010. "Saline Water Disposal into the Birds Nest Aquifer in the Uinta Basin, Utah: Updated Research on the Implications for Oil Shale Development." *30th Oil Shale Symposium*, Colorado School of Mines, Golden, CO, October 18-20, 2010.

Vanden Berg, M. Carney, S., Morgan, C., Laine, M., 2010. "Stratigraphic Characterization of the Birds Nest Aquifer in the Uinta Basin, Utah: Implications for Saline Water Disposal from Natural Gas Production." *2010 AAPG-RMS meeting*, Durango, CO, June 13-16, 2010.

Vanden Berg, M., 2010. "Understanding the Aquifers in the Uinta Basin, Utah: A Key to Solving the Basin's Saline Water Disposal Problem." *2010 AAPG Annual Meeting*, New Orleans, LA, April 11-14, 2010.

Vanden Berg, M., 2009. "Saline Water Disposal into the Birds Nest Aquifer in Uintah County, Utah: Implications for Potential Oil Shale Development." *29th Oil Shale Symposium*, Colorado School of Mines, Golden, CO, October 19-21, 2009.

Vanden Berg, M., 2009. "Understanding the Birds Nest Aquifer in Uintah County, Utah: A Potential Source for Large-Scale Saline Water Disposal." *Water/Energy Sustainability Symposium*, GWPC, Salt Lake City, UT, September 13-17, 2009.

Vanden Berg, M., Carney, S., Anderson, P., Morgan, C., Laine, M., 2009. "Saline water disposal in the Uinta Basin, Utah: The single most pressing issue with regard to increasing petroleum production and protecting freshwater aquifers." *2009 AAPG Annual Meeting*, Denver, CO, June 7-10, 2009.

Lehle, D., Vanden Berg, M., 2009. "Comparing the depositional characteristics of the oil-shale-rich Mahogany and R-6 zones of the Uinta and Piceance Creek Basins." *2009 GSA-RMS meeting*, Orem, UT, May 11-13, 2009.

National and regional conferences (13 presentations)

Anderson, P., Vanden Berg, M., Carney, S., Morgan, C., and Heuscher, S., 2012. "Mapping Potentially Useable Strata for Underground

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Vanden Shale

Vanden Water

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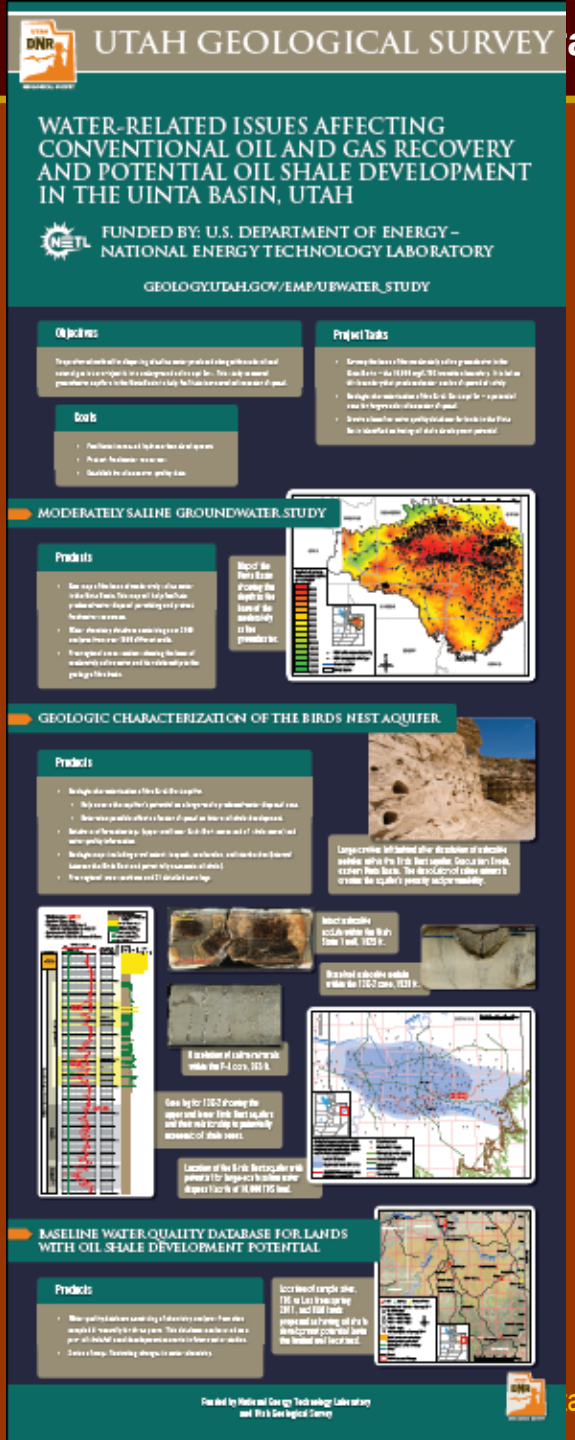
Lehle, L., Vanden Berg, M., 2009. "Comparing the depositional characteristics of the oil shale rich Mahogany and R-8 zones of the Uinta and Piceance Creek Basins." *2009 GSA-RMS meeting*, Orem, UT, May 11-13, 2009.

Exhibit booth at AAPG



Quarterly reports, annual review meetings, etc.

Quarterly reports emailed to ~80 interested individuals from private and public sectors

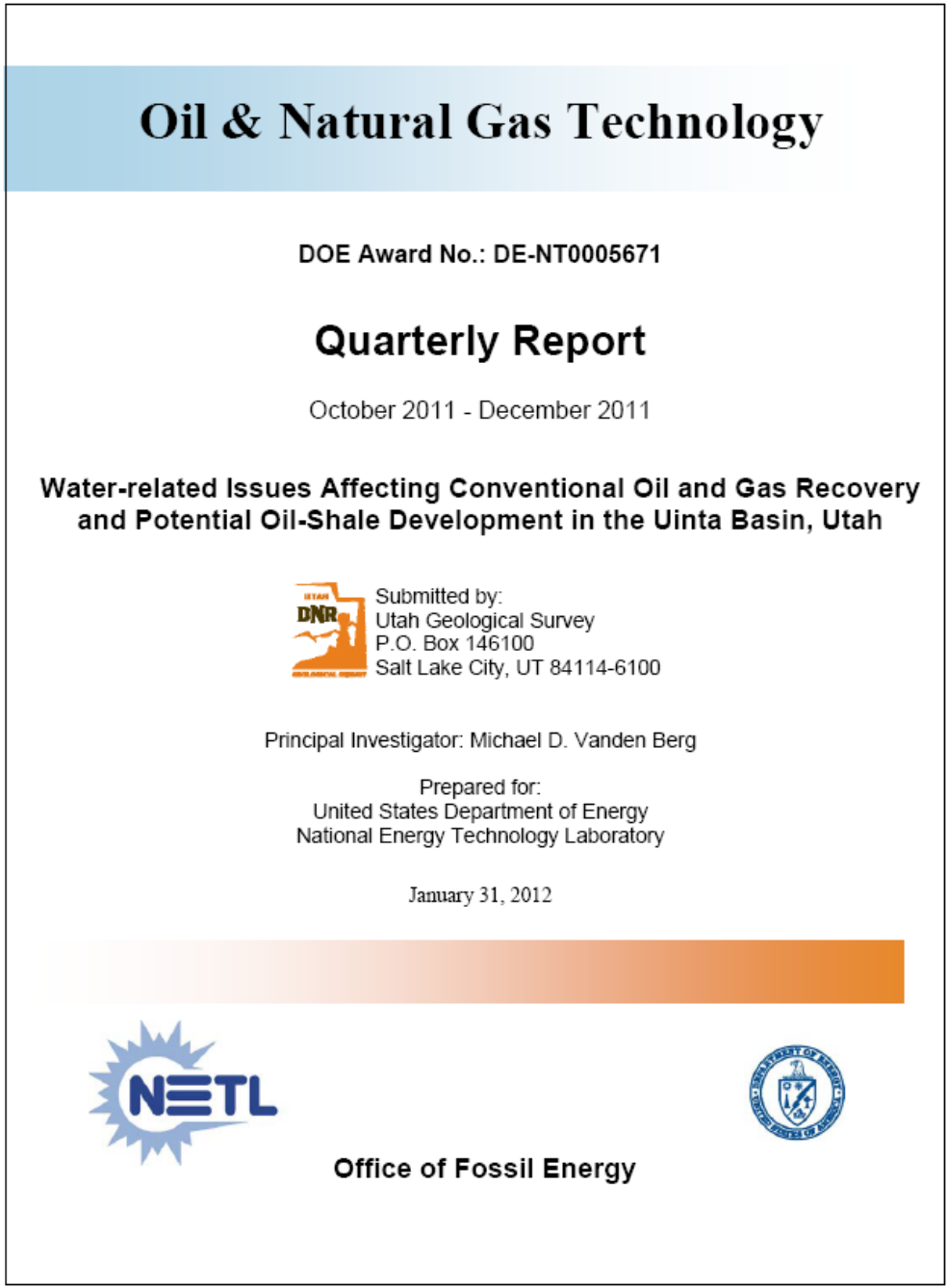
October 2009 – Year 1 review meeting

- Vernal, UT
- 16 participants

January 2011 – Year 2 review meeting

- Vernal, UT
- 33 participants

Final results will be presented at AAPG national meeting – April 2012



Oil & Natural Gas Technology

DOE Award No.: DE-NT0005671

Quarterly Report

October 2011 - December 2011

Water-related Issues Affecting Conventional Oil and Gas Recovery and Potential Oil-Shale Development in the Uinta Basin, Utah

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NETL

Office of Fossil Energy

Fieldtrips – Discussed project at Birds Nest outcrop along Evacuation Creek

- May 2009 – University of Utah Uinta Basin field trip
- October 2010 – 30th Oil Shale Symposium
- November 2010 – UGS board field trip
- May 2011 – University of Utah Unconventional Fuels Conference
- October 2011 – 31st Oil Shale Symposium

Is it really over…….

……. any more questions

Hazards of doing fieldwork in the Uinta Basin