

Utilization of a Regional Water Chemistry Database to Improve Formation Evaluation and Reservoir Simulation in Low Permeability Reservoirs of Southwest Wyoming

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Presentation Outline

- Database Overview
- Field Study
 - Eastern Green River Basin
- Conclusions
 - High Quality Water Chemistry has Improved Formation Evaluation in the Field Study Area
 - SP Used to Determine Gas-Water Boundary
 - Gas-water Boundary Usually Found Near Base of Significant Almond Coals (a local source for gas?)
 - Sands are a Series of Discontinuous Lenses

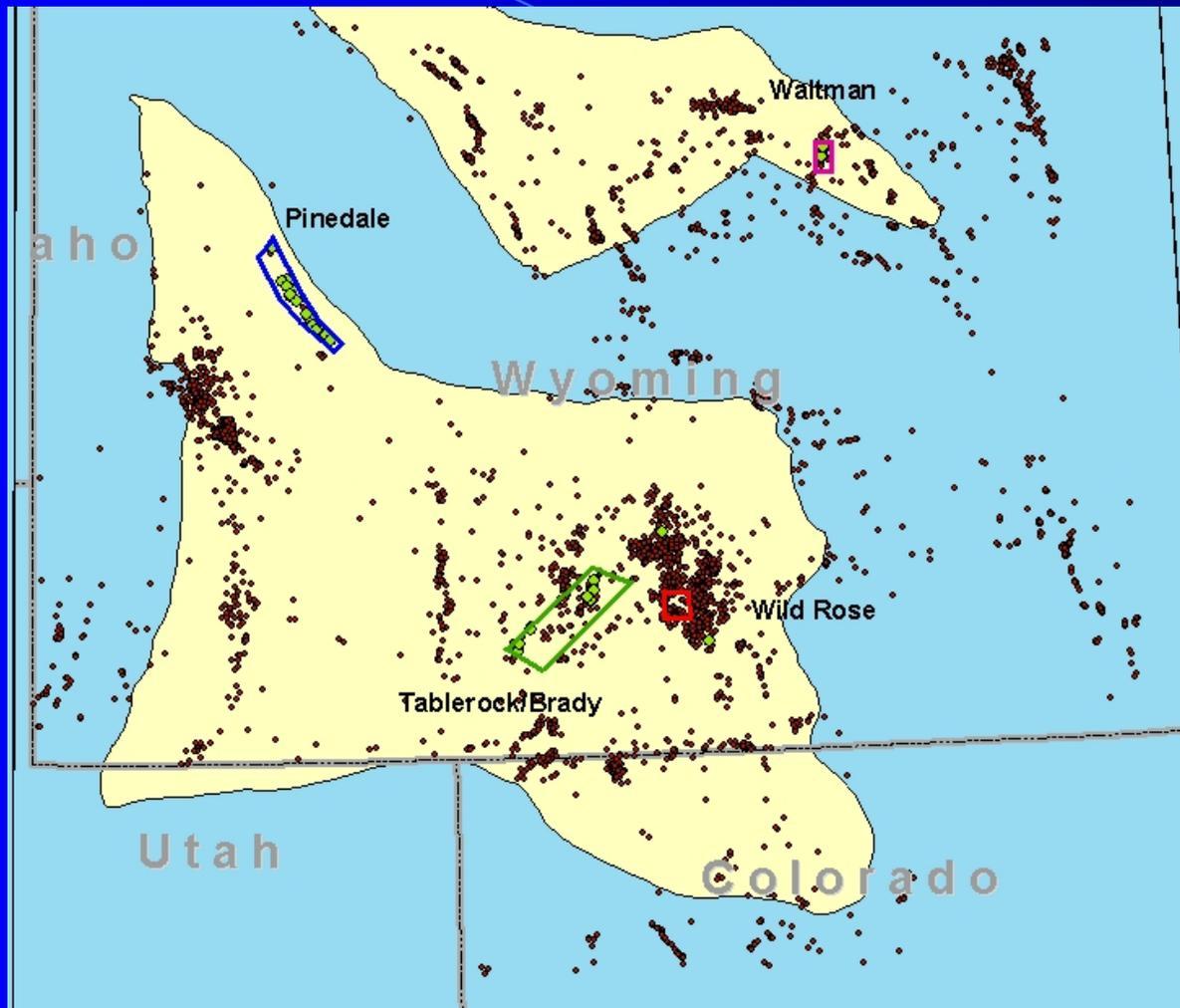


Database Overview

- **Historical Data**
 - 3200 Well Locations/GGRB and WRB
 - 8000 Chemical Analyses
- **Current Study**
 - 86 new samples with full analyses and isotopes
 - Waltman/Cave Gulch, Pinedale, Tablerock, Wamsutter
 - 7 component “Stiff” Analyses
 - Strontium, Oxygen Isotopes
- **Highly Accessible**
 - Quality Screened
 - Access/Excel Formats



Database Coverage



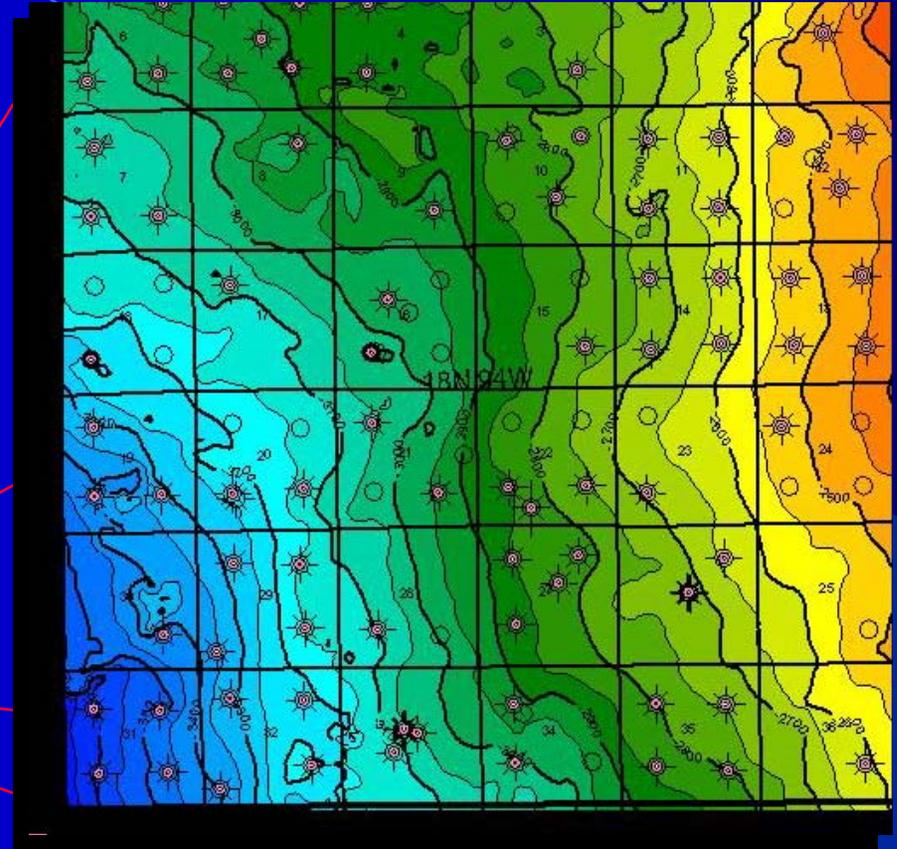
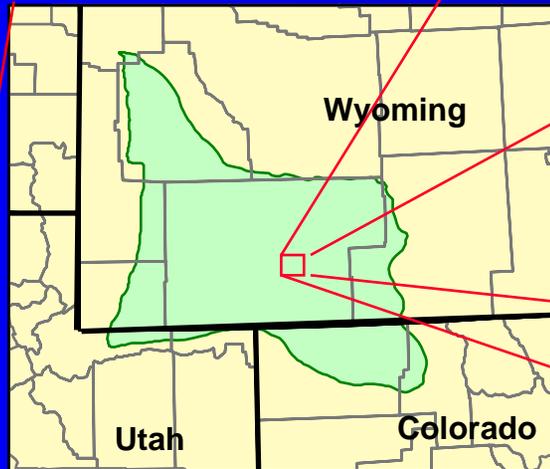
Water Database Value

- Catalogue of Water Resistivity (RW)
 - Improved Formation Evaluation
 - Critical for delineating gas from fresh water
- Provide Source Point for Water Chemistry Ideas and Technology
 - Areas of Diagenetic Porosity Enhancement
 - Potential Flow Paths
 - Hydrologic Compartments
- Basin Modeling Data
- Database facilitates organization, mapping and analysis of large amounts of water chemistry data



Eastern Green River Basin Field Study

Greater Green River Basin



Eastern Green River Basin Field Study

Operator Issue: How to minimize water while capturing additional resources?

- Long-lived historical production area
- 88 wells
- 40 BCF Cumulative Production
- Water production problems
- Available data
 - Well logs, core, 3D seismic, production data
 - Water chemistry data

Technical Strategy: Improve formation evaluation, simulate reservoir to understand bulk permeability/water production.

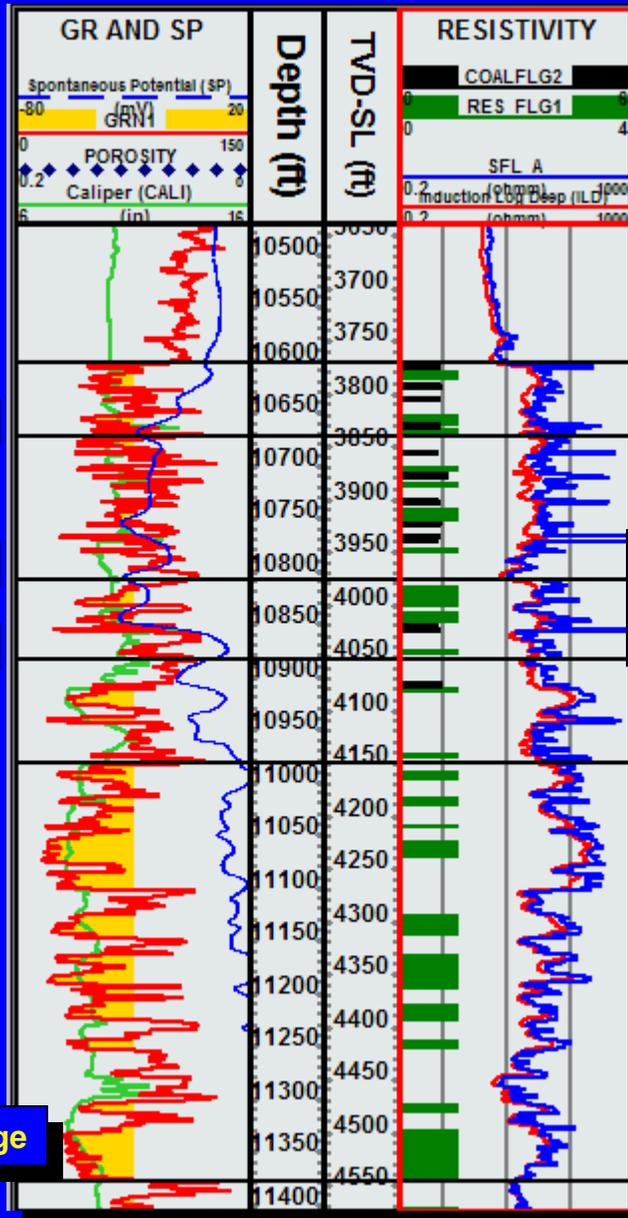


Work Flow

- Build Stratigraphic Correlation Framework
- Interpret 3D Seismic for Structure
- Perform Base Petrophysical Study for Reservoir Characterization
 - Emphasized Produced Water Chemistry for High Quality Formation Water Resistivity (R_w)
- Assembled 23 Unit Dual Permeability Reservoir Model
 - Discrete Fracture Network Permeability Grid
 - Constrained by Geomechanical Simulation of Basement Faulting
 - Matrix Porosity and Permeability From Petrophysics
- Production History Match/Forward Simulation



Type Log



ALMD

ALMD_SH1

ALMD_SH2

ALMD_SH3

ERCS

Allen Ridge

Environments of Deposition

Regional Water Chemistry Data

Upper Almond
Marine to Marginal Marine

TDS Range 1,700 to 50,000 ppm
Average 19,000 ppm

Middle/Lower Almond
Marginal Marine to Coastal Plain

TDS Range 7,000 to 18,000 ppm
Average 13,000

Ericson
Coastal Plain/Fluvial

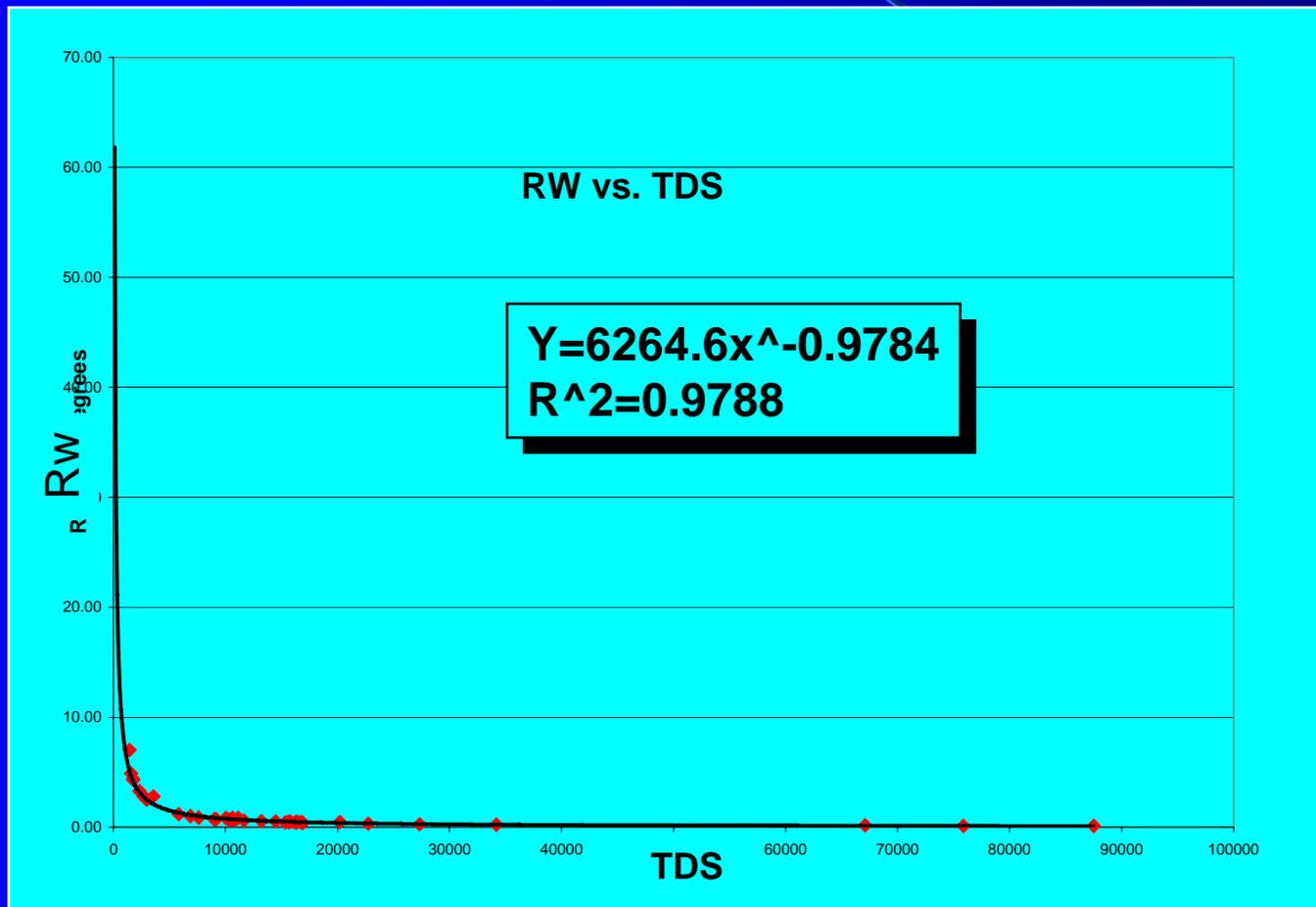


Water Resistivity (R_w) and Petrophysics

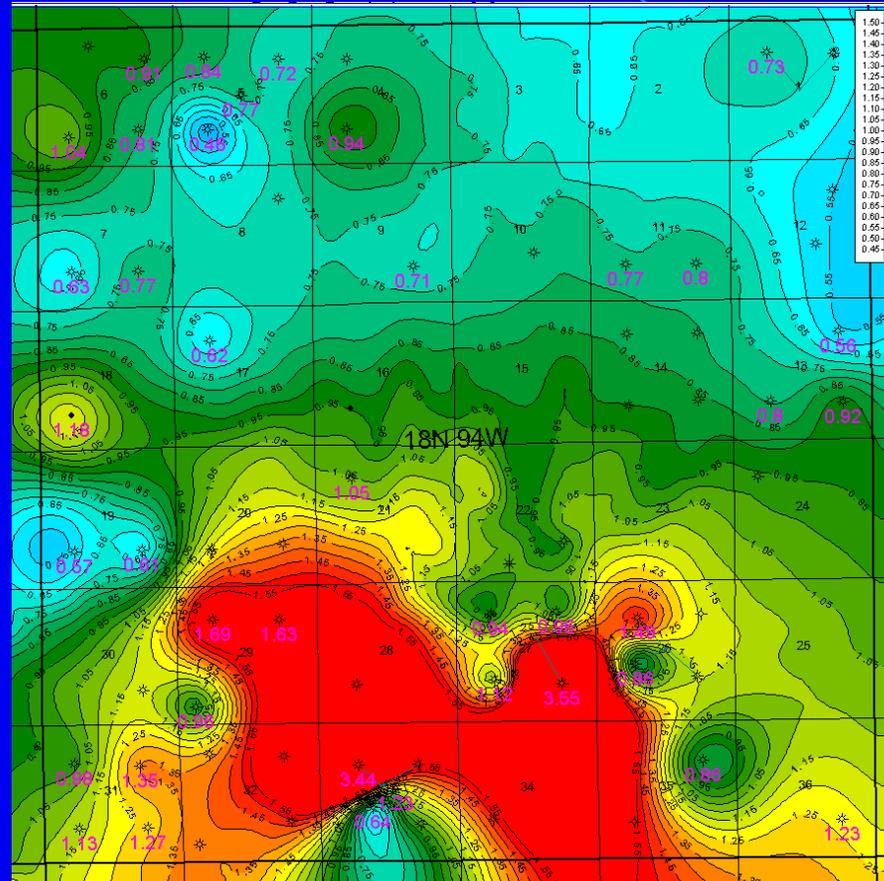
- **Evaluated Regional Almond R_w Trends**
 - Variable R_w influenced by Depositional Environments
- **9 Township Focused Area**
 - Vertical and Horizontal Variation
 - Established R_w -Total Dissolved Solids (TDS) Relationship
- **Established R_w by Zones for Saturation Calculations**
 - Aquifer water is so fresh (<5000 ppm NaCl) that it is difficult to distinguish from gas invaded by a fresh water filtrate
 - Porous and permeable Ericson has high resistivity, although it only produces water
 - Used water chemistry, fluids and logs in Upper and Middle Almond to calibrate R_w in gas zone, and the Ericson to calibrate R_w in the aquifer



TDS/Rw Cross-Plot 68 degrees F 9 Township Area



AVERAGE PRODUCED WATER RESISTIVITY



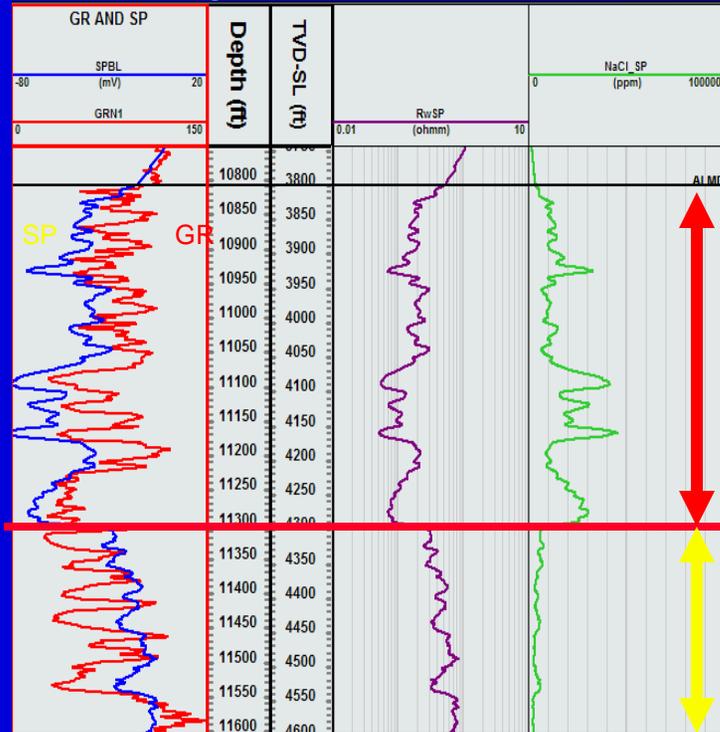
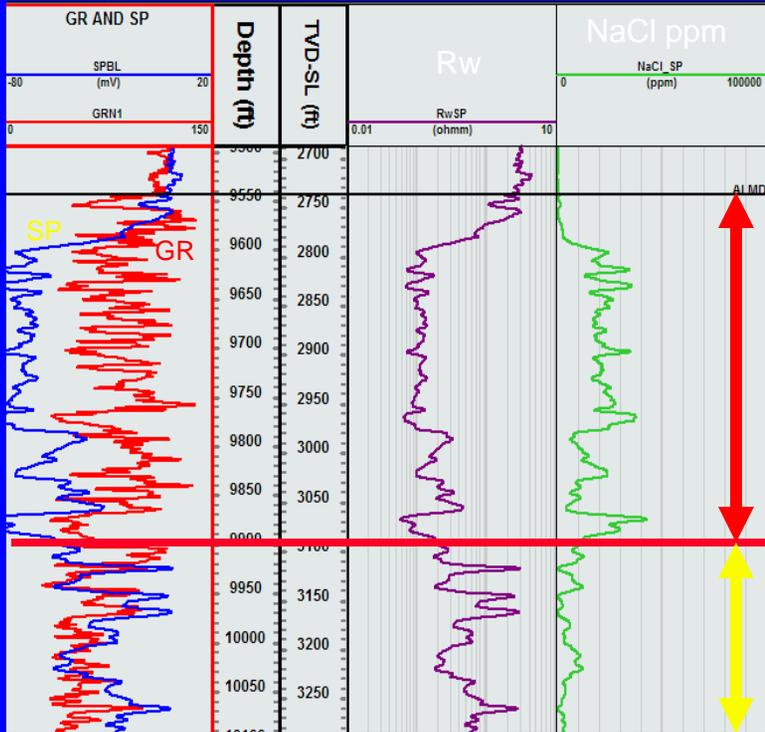
Red Shades indicate High Rw, Blue indicate Low Rw (@ 68 F)



SP-Rw

Mungo Federal 1-14

Champlin 221C



Medium salinity water in gas zone

SP Change (Gas-Water Boundary)

Low salinity water in aquifer

Despite difficulties, SP to Rw calculations show a dramatic shift in formation water salinity in the upper (more saline) and lower (fresher) parts of the formation.

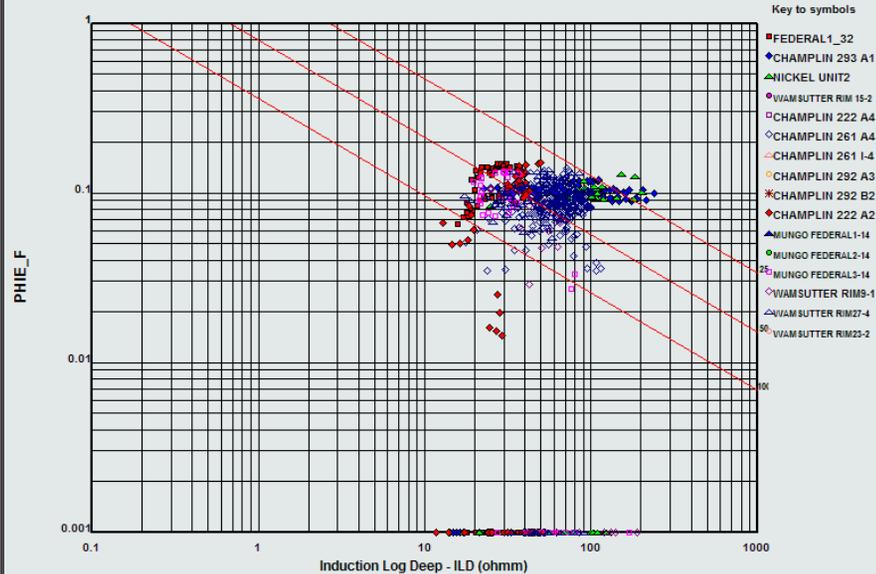


Pickett Plot Gas Zone & Aquifer

16 well crossplot. Well collection used: OpenholeLogs-Rt

Constraints: VCLSTB (0.00-0.10)

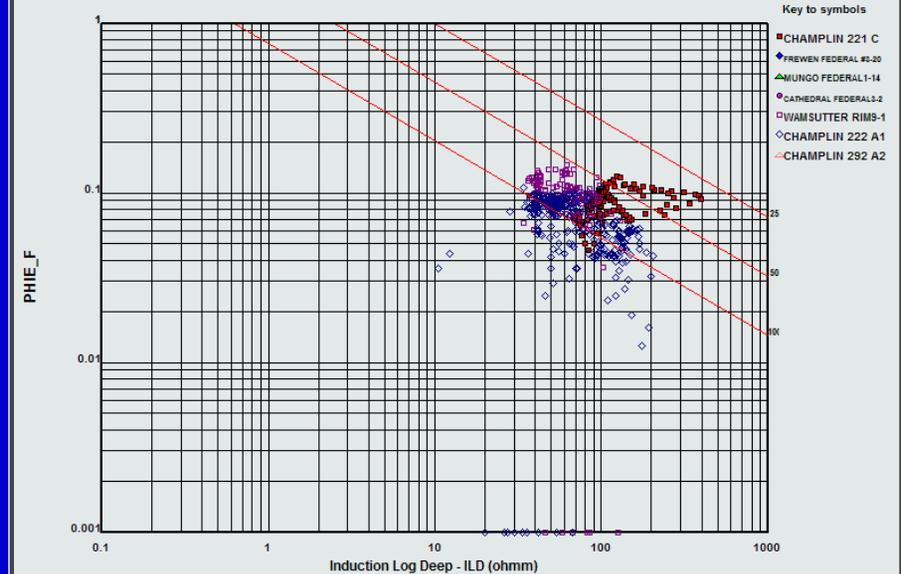
Resistivity-Porosity Crossplot - Pickett Plot



7 well crossplot. Well collection used: Unnamed Collection

Constraints: VCLSTB (0.00-0.10)

Resistivity-Porosity Crossplot - Pickett Plot



Gas Zone

Upper & Middle Almond
Vclay<10%

$a=1.0$, $n=2.00$, $m=1.74$

$R_w=0.17$ @ 200F

NaCl=13,000 ppm

Water

Lower Almond & Ericson
Vclay<10%

$a=1.0$, $n=2.00$, $m=1.74$

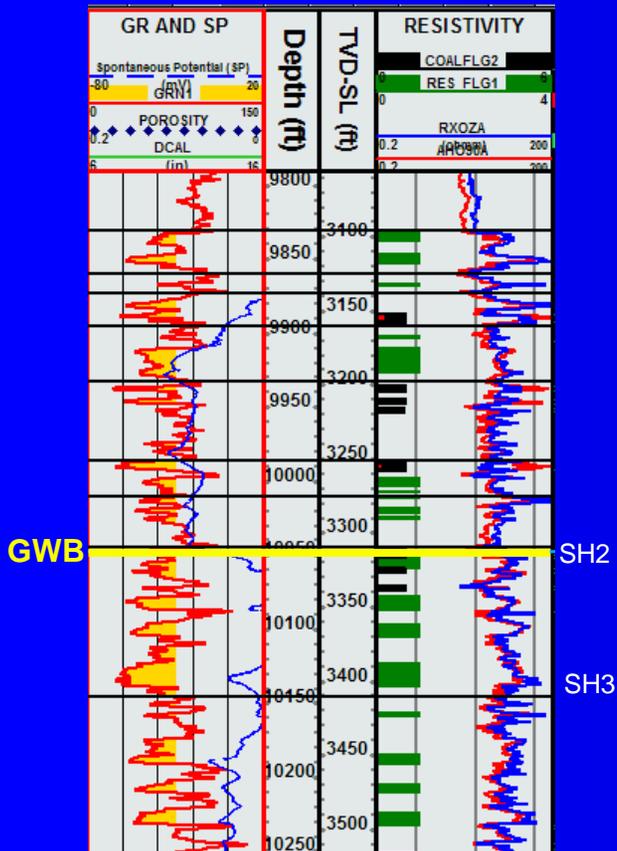
$R_w=0.63$ @ 200F

NaCl=3,500 ppm

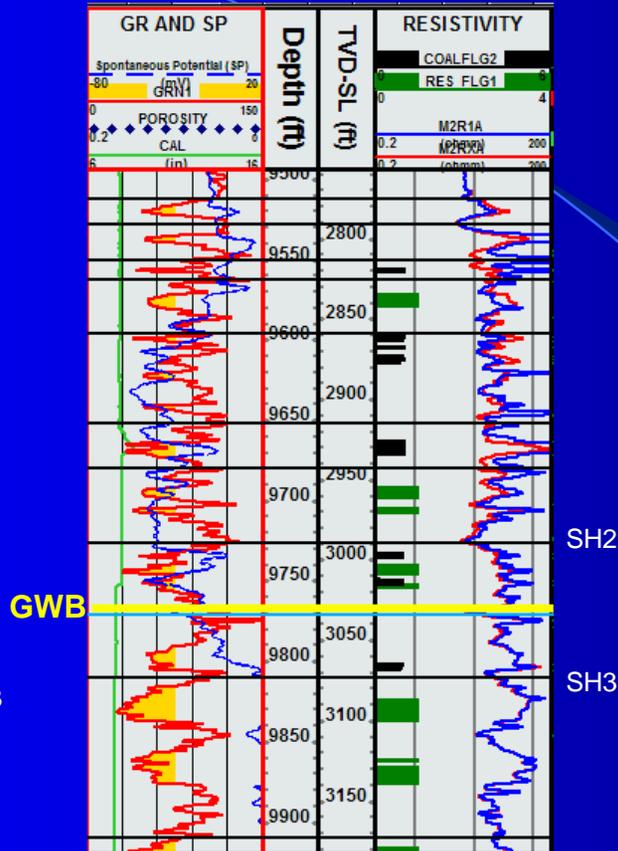


Gas-Water Boundary & Coal & Wells

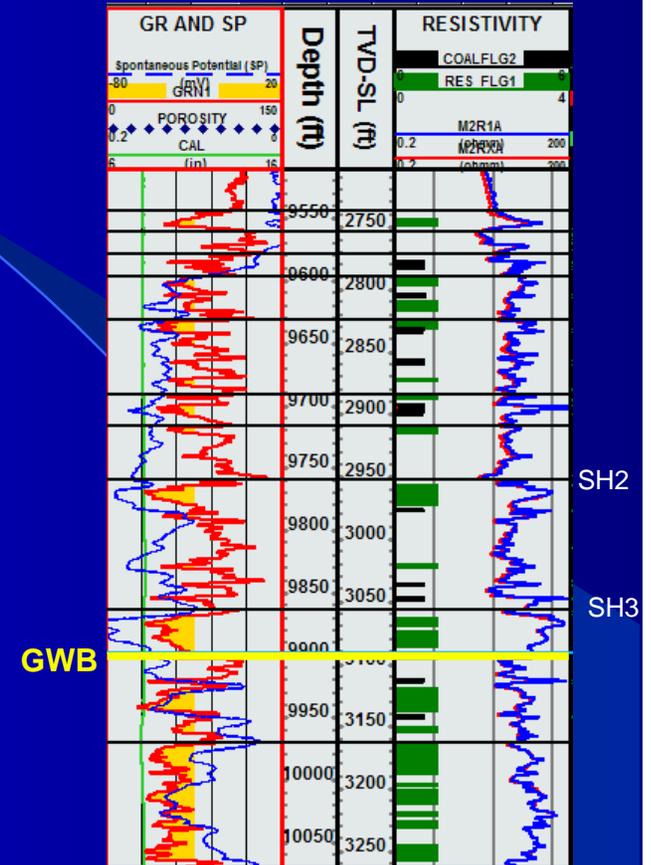
Wamsutter Rim 17-1



Cathedral Federal 3-2



Mungo Federal 1-14



Gas-Water Boundary is picked based on SP and/or Resistivity curves.

Generally near Almd_SH2 and Almd_SH3 picks in this township.

Usually appears near first significant appearance of coals, which is a presumed local gas source.

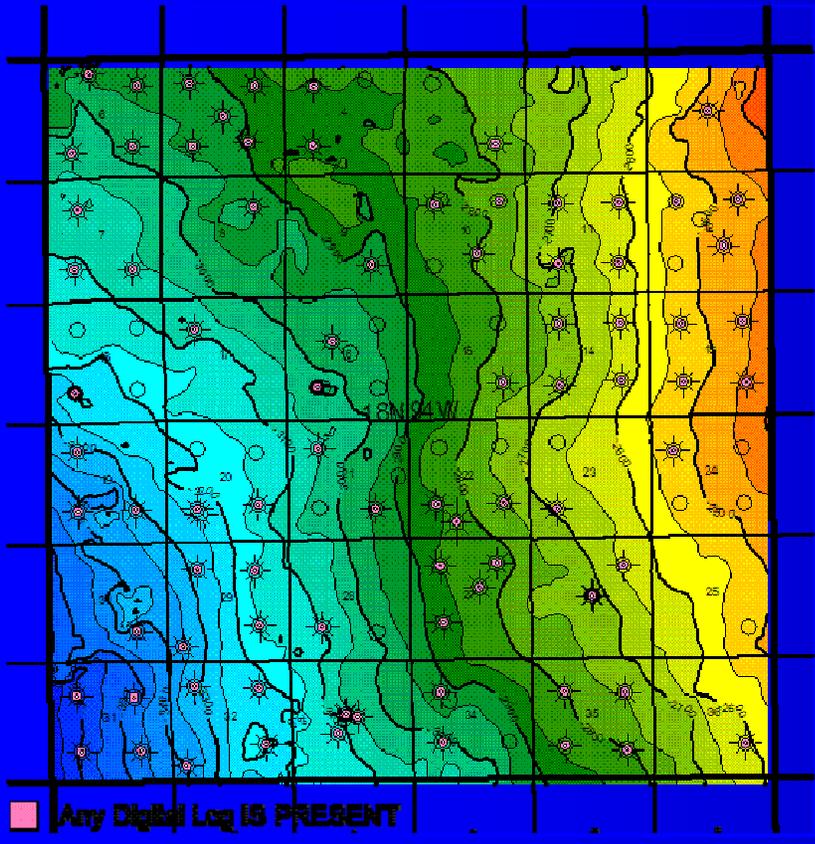
Follows dipping structure, but not rigorously; therefore, is a boundary between discontinuous gas-charged

& aquifer sands rather than an actual contact.

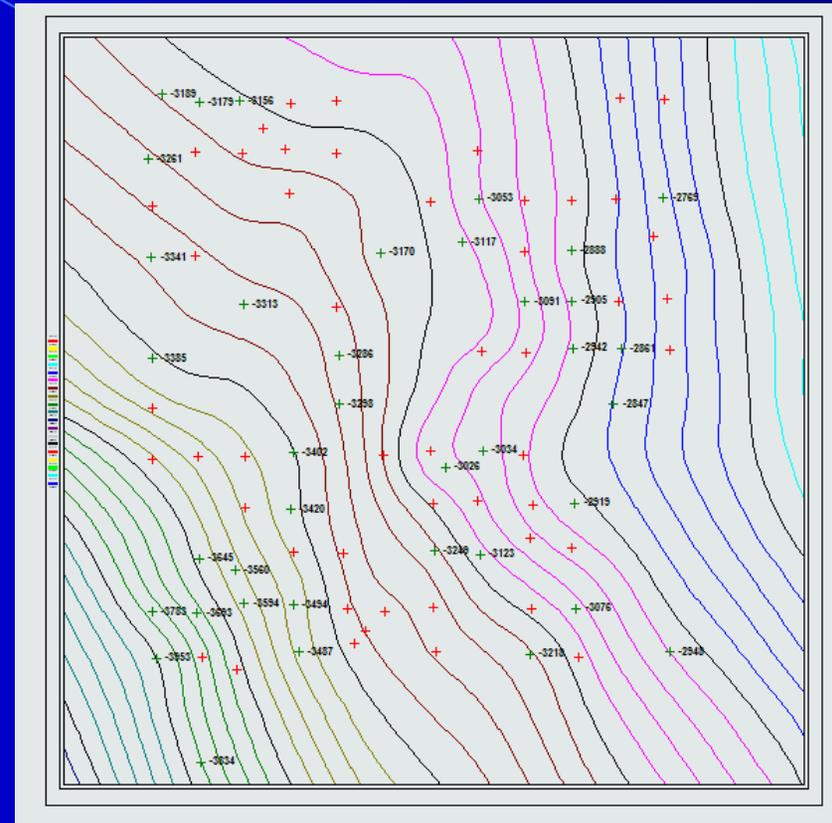


SP-GWC Structure Map

Structure Map on Top Almond



Structure Map on Gas-Water Boundary



Gas-Water Boundary follows dipping structure, but not rigorously; therefore, this is a boundary between discontinuous gas-charged & aquifer sands rather than an actual contact.



Testing Gas-Water Boundary Hypothesis

The depth of the gas-water boundary was compared to the initial fluid production in 41 wells as reported in the Wyoming Oil and Gas Commission website.

Initial Production tests above gas-water boundary (15 wells)

< 10 BWPD	17 tests
11-20 BWPD	3 tests
21-30 BWPD	2 tests

Initial Production tests below gas-water boundary (26 wells)

<25 BWPD	7 (4 not perf'd in permeable sand below GWB)
25-50 BWPD	2 tests
>50 BWPD	20 tests



Conclusions

- **High Quality Water Chemistry has Improved Formation Evaluation in the Field Study Area**
 - SP used to determine gas-water boundary
 - Supported by initial production data (75% agreement)
 - Useful for perforation and completion strategy
- **Gas-water Boundary Usually Found Near Base of Significant Almond Coals (a local source for gas?)**
- **Sands are a series of discontinuous lenses**

