A Petrophysical Method to Evaluate Irregularly Gas Saturated Tight Sands Which Have Variable Matrix Properties and Uncertain Water Salinities

Presented to 2010 AAPG International Conference and Exhibition, Calgary, Canada

Michael Holmes

Antony Holmes

Dominic Holmes

September 15, 2010

Outline

- Statement of Problem
- Shaley Formation Resistivity Analysis
- Gas Effects on Density and Neutron Logs
- Gas Saturation from Porosity Logs Assuming Different Matrix Properties
- Comparisons of Different Gas Saturation Calculations
- Examples from Piceance Basin, Colorado
- Conclusions

Statement of Problem

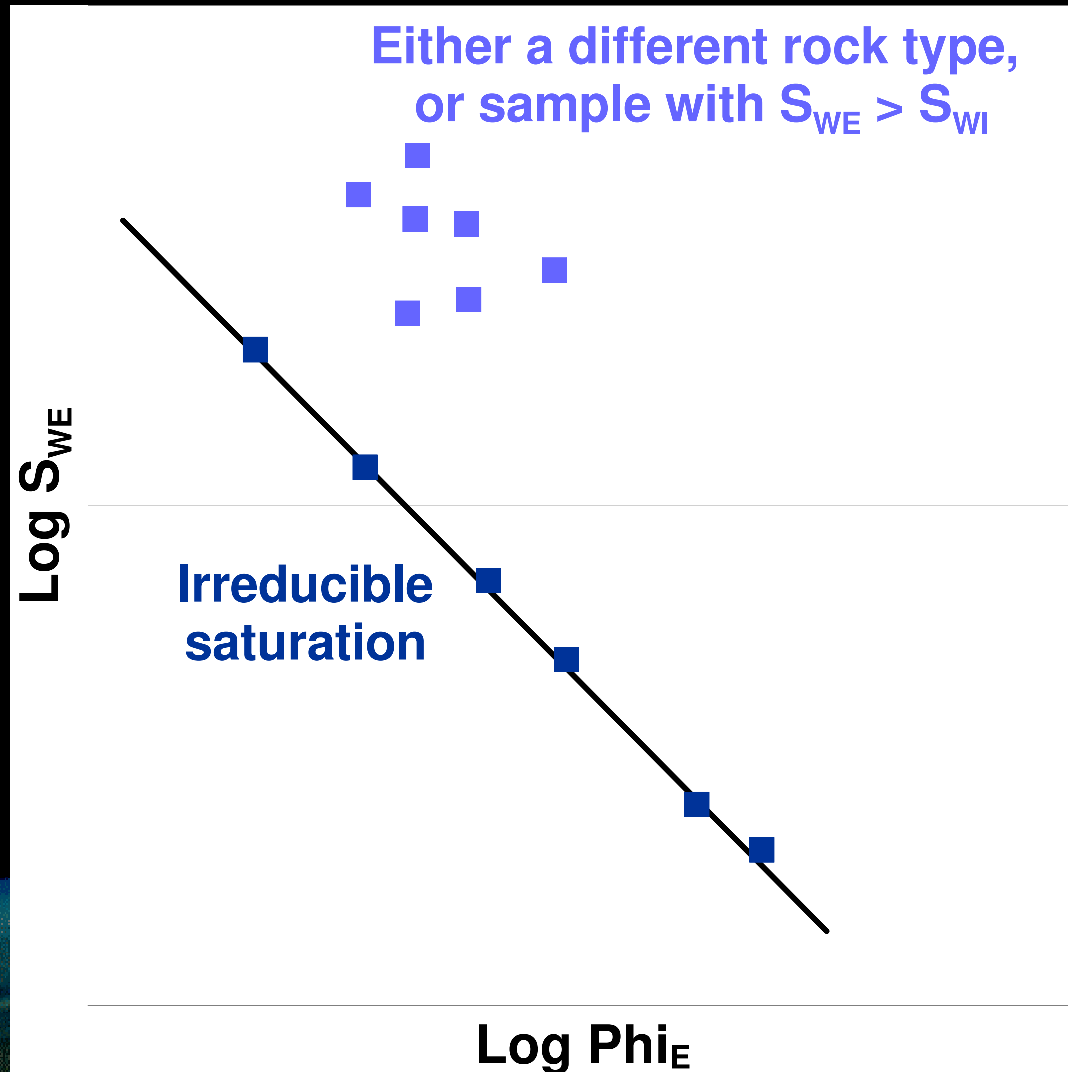
- Rocky Mountain tight gas sands may be only partially gas saturated
- Water salinities can vary; high resistivity indicates either gas saturation or fresh water wet sands
- Matrix properties are frequently variable
- This combination of properties makes standard petrophysical calculations sometimes unreliable

Shaley Formation Resistivity Analysis

- Standard analysis consists of calculations of shale volume, porosity, and water saturation
- Application of density/neutron cross plot porosity largely overcomes influences of variable grain density and fluid saturation on porosity calculation
- Often, there is no information available with respect to water salinity, and reliance has to be placed on calculations from the SP log and/or porosity/resistivity cross plots to estimate water resistivity (R_W)

Shaley Formation Resistivity Analysis

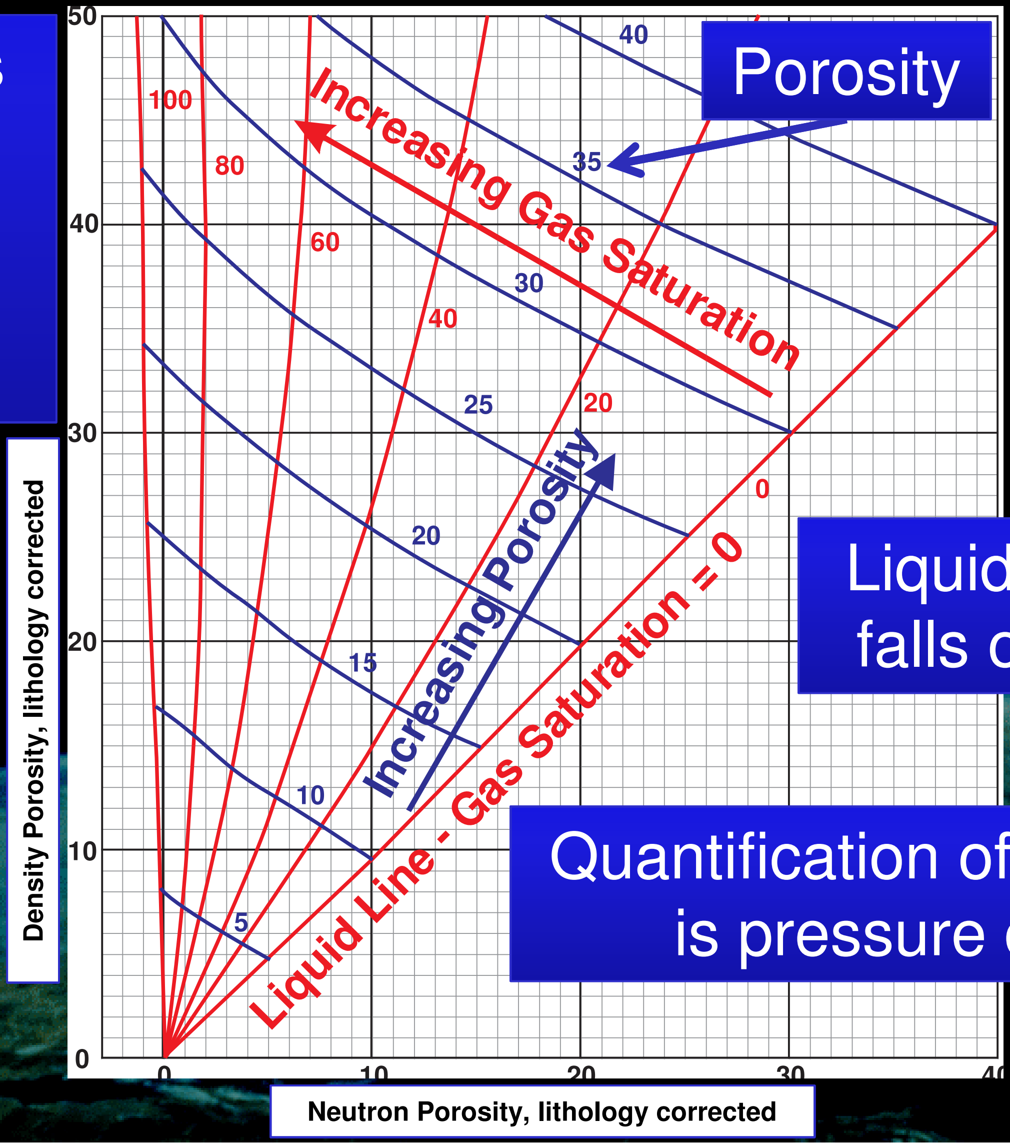
Comparisons between porosity and water saturation allow distinction between rocks at irreducible water saturation and rocks that might contain mobile water



Gas Effects on Density and Neutron Logs

Figure 1

Gas reduces neutron porosity and decreases bulk density



Liquid filled porosity falls on the 45° line

Quantification of gas saturation is pressure dependant

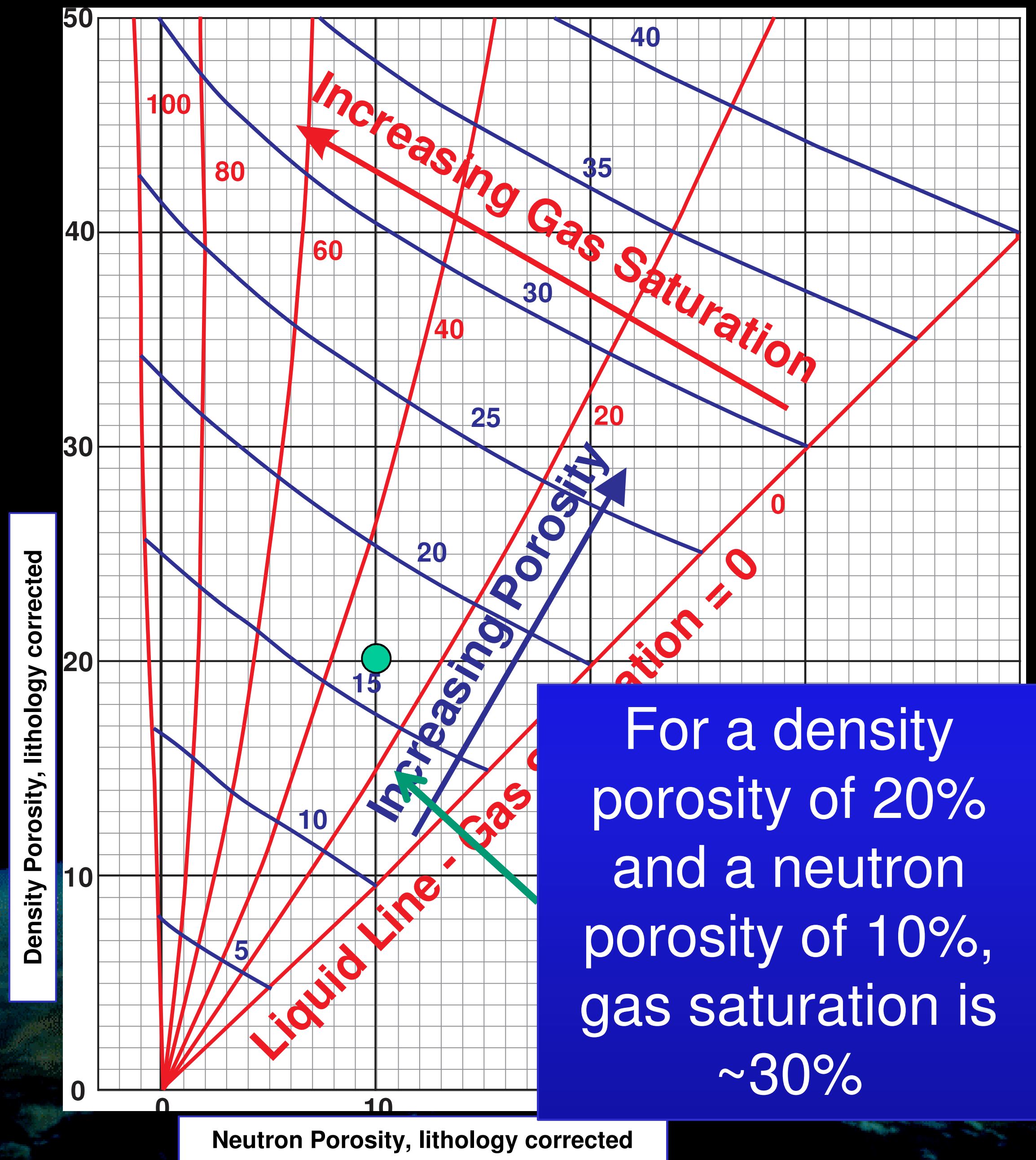
Gas Saturation from Porosity Logs Assuming Different Matrix Properties

- Rocky Mountain Gas Sands have variable degrees of cementing materials. A reasonable range of grain densities is 2.65 gm/cc to 2.71 gm/cc. This is equivalent to a range of neutron matrix from sandstone to limestone.
- Three different lithologies are examined:

	Grain Density	Neutron Lithology
Increasing calculations of gas saturation ↓	2.65	Sandstone
	2.68	Calcareous Sandstone
	2.71	Limestone or heavily carbonate cemented sandstone

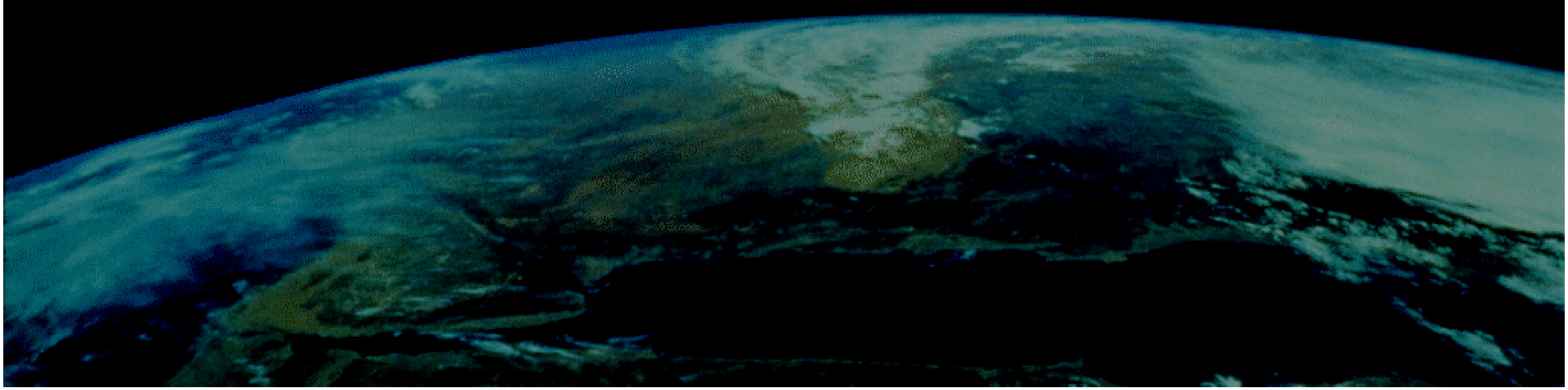
Gas Saturation from Porosity Logs Assuming Different Matrix Properties

- For each matrix combination, effective density and effective neutron porosities are used to calculate gas saturation
- It is assumed that the density and neutron logs both “see” the same degree of gas saturation in tight gas sands, which is reasonable, because there is little or no invasion by drilling mud



Comparisons of Different Gas Saturation Calculations

- By combining all sets of analysis, four independent calculations of gas saturation are available:
  - Gas saturation ($1–S_W$) from standard resistivity
  - Gas saturation from porosity logs, assuming 2.65 gm/cc
  - Gas saturation from porosity logs, assuming 2.68 gm/cc
  - Gas saturation from porosity logs, assuming 2.71 gm/cc

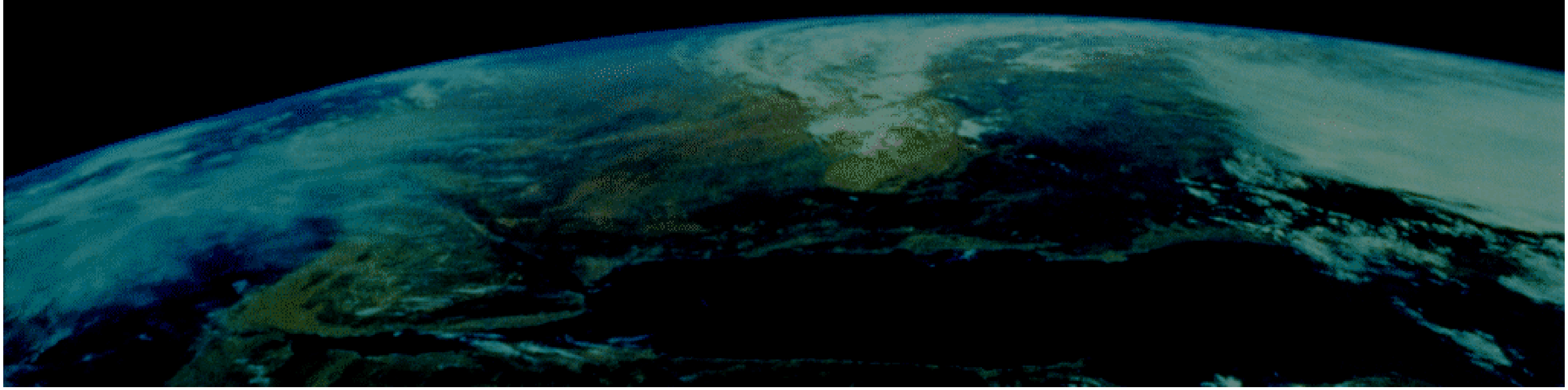


Comparisons of Different Gas Saturation Calculations

- Comparisons will give a methodology to
  - Estimate most likely grain density/lithology, which can be compared with core data, if available
  - Confirm or deny wet levels, as identified from resistivity analysis
  - Suggest which intervals may have lower than anticipated R_w
  - Suggest which intervals may have higher than anticipated R_w

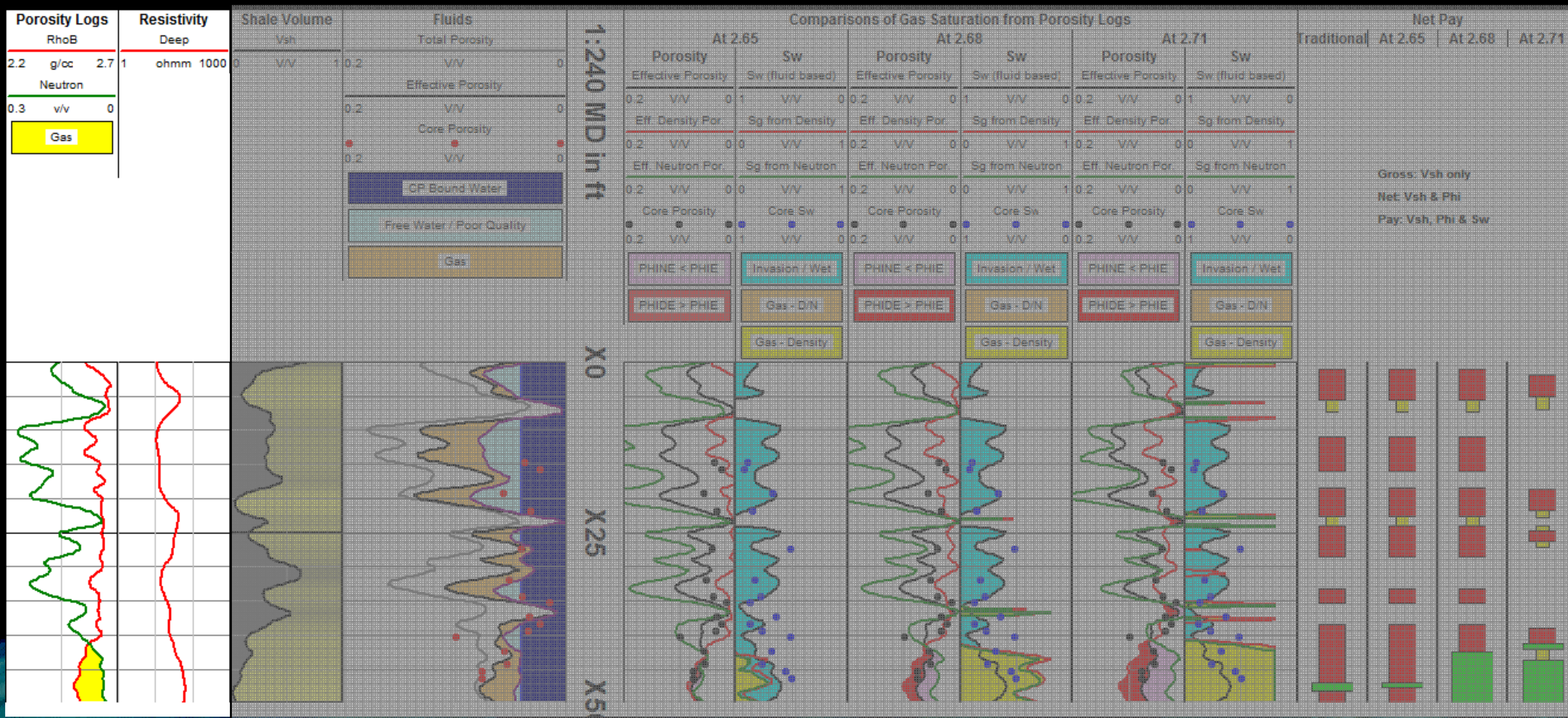
Template Description

- An example of data is shown, along with a description of the depth log tracks. This template was used in the three examples presented.



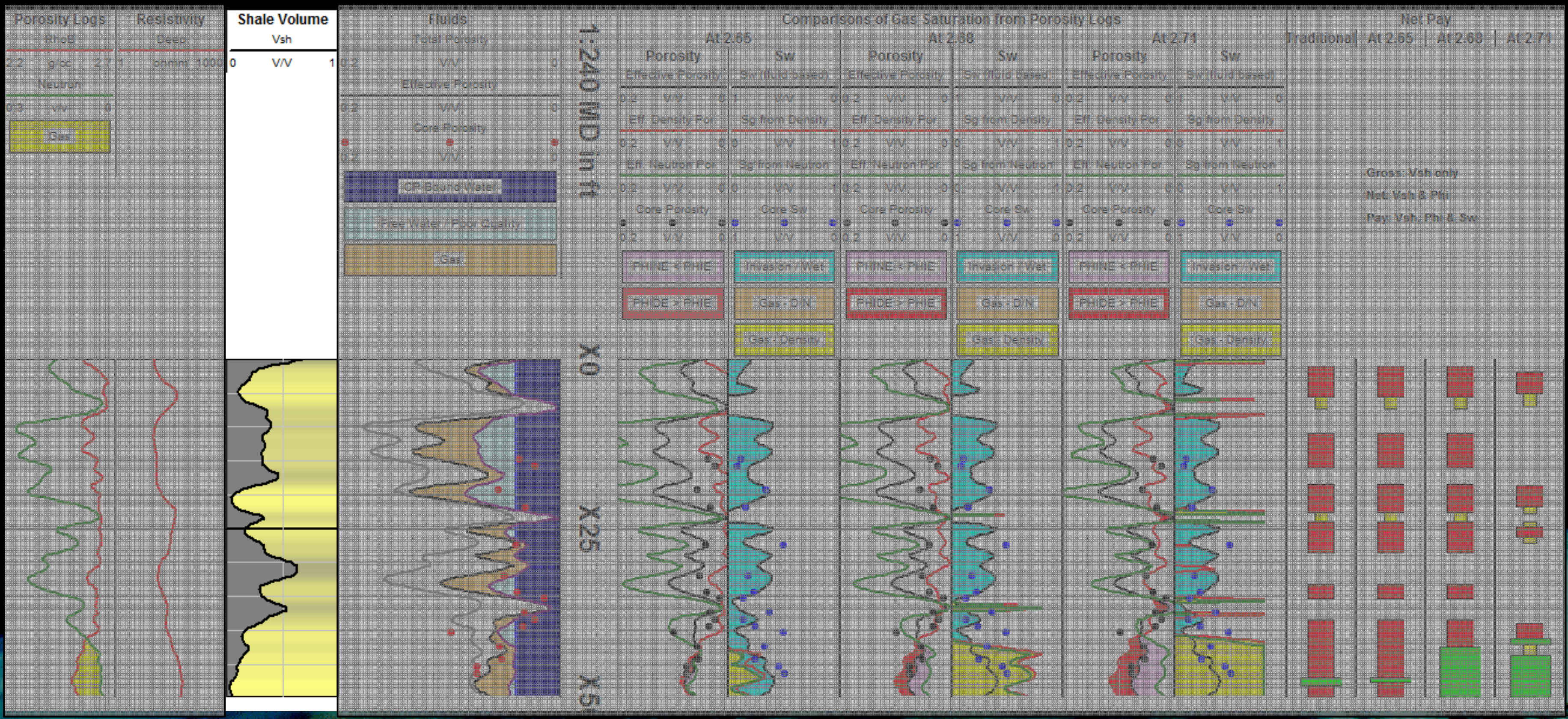
Template Description

Raw Data



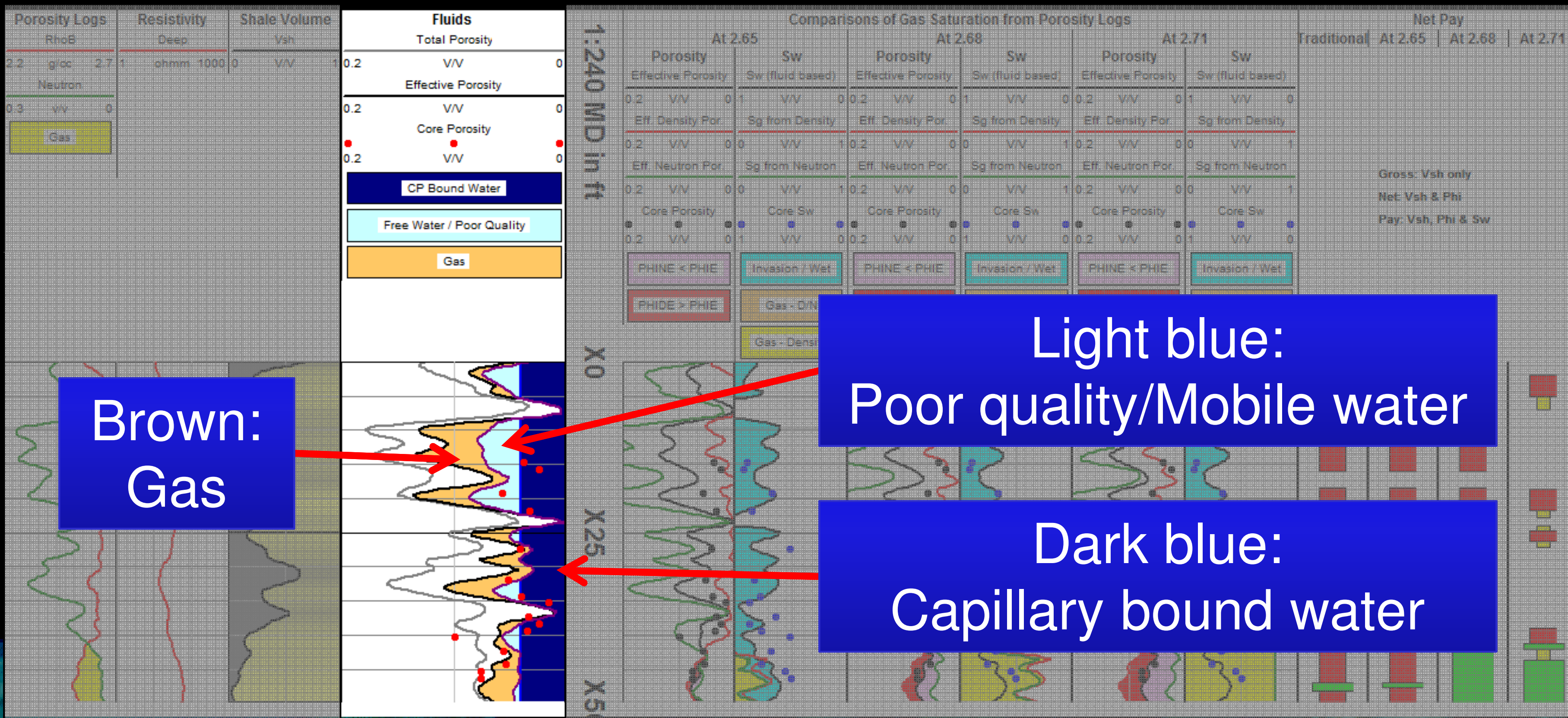
Template Description

Shale Volume



Template Description

Fluid Components from Standard Resistivity Analysis



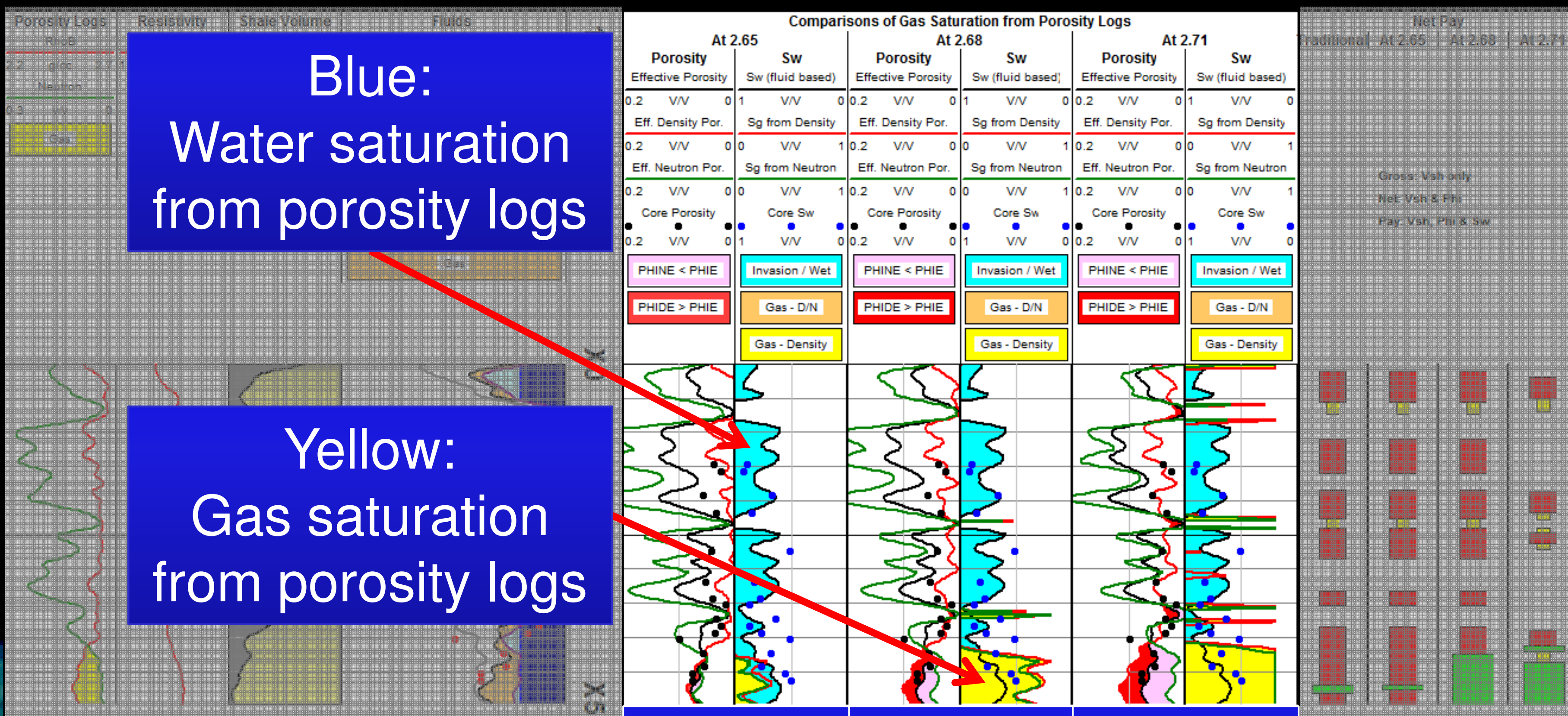
Brown: Gas

Light blue: Poor quality/Mobile water

Dark blue: Capillary bound water

Template Description

Gas Saturations from Porosity Log Analysis



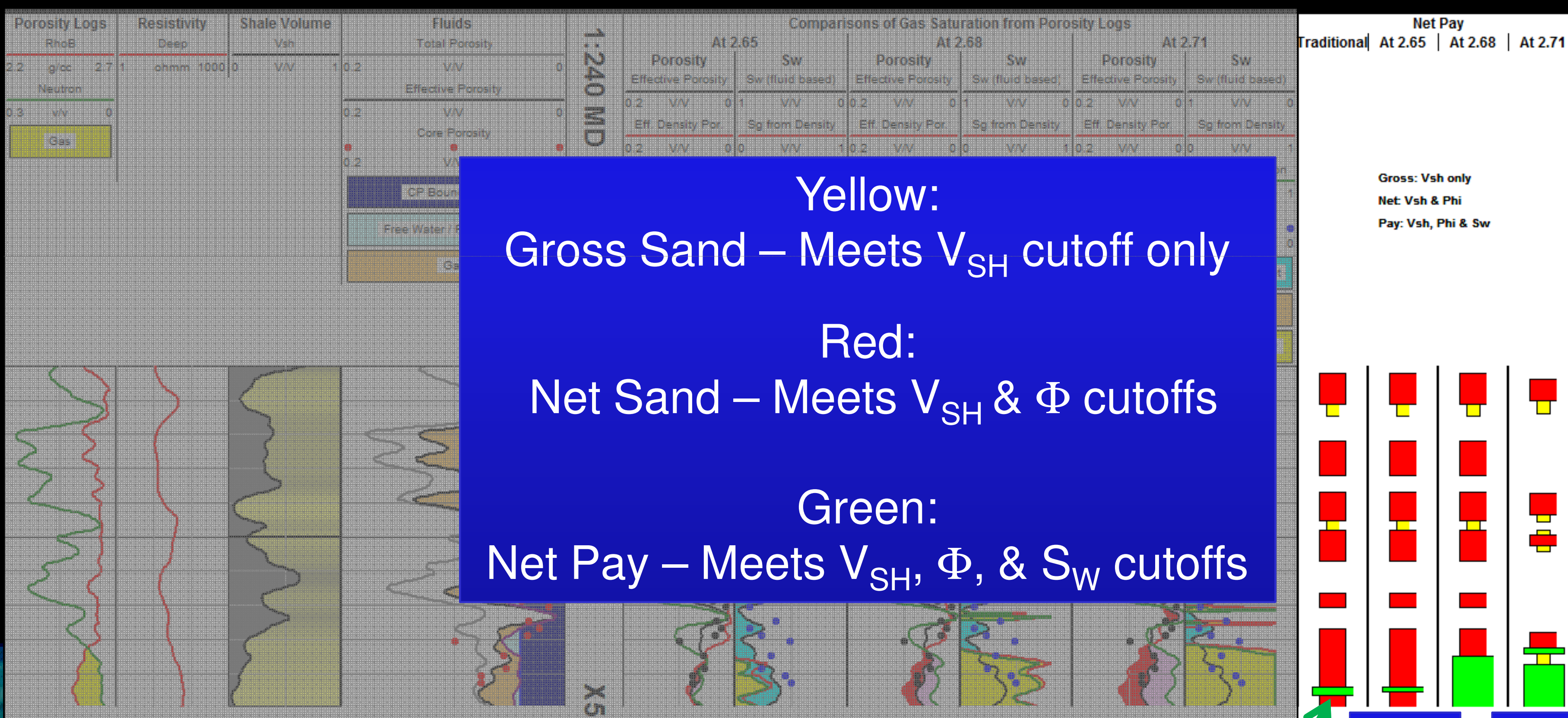
Blue:
Water saturation from porosity logs

Yellow:
Gas saturation from porosity logs

Assuming 2.65 gm/cc grain density	Assuming 2.68 gm/cc grain density	Assuming 2.71 gm/cc grain density

Template Description

Net Pay



Yellow:
Gross Sand – Meets V_{SH} cutoff only

Red:
Net Sand – Meets V_{SH} & Φ cutoffs

Green:
Net Pay – Meets V_{SH}, Φ, & S_W cutoffs

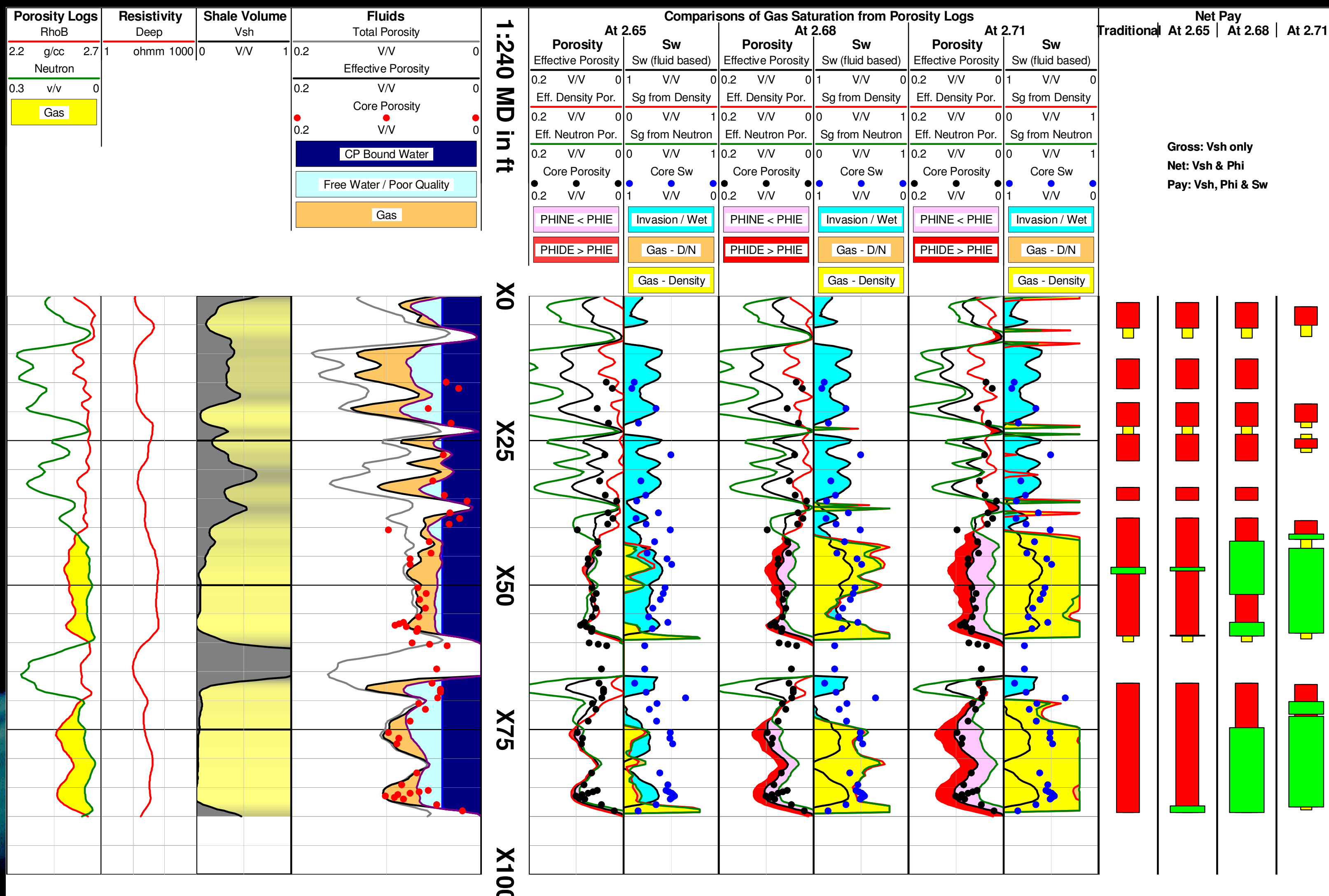
Standard resistivity analysis

2.65 gm/cc

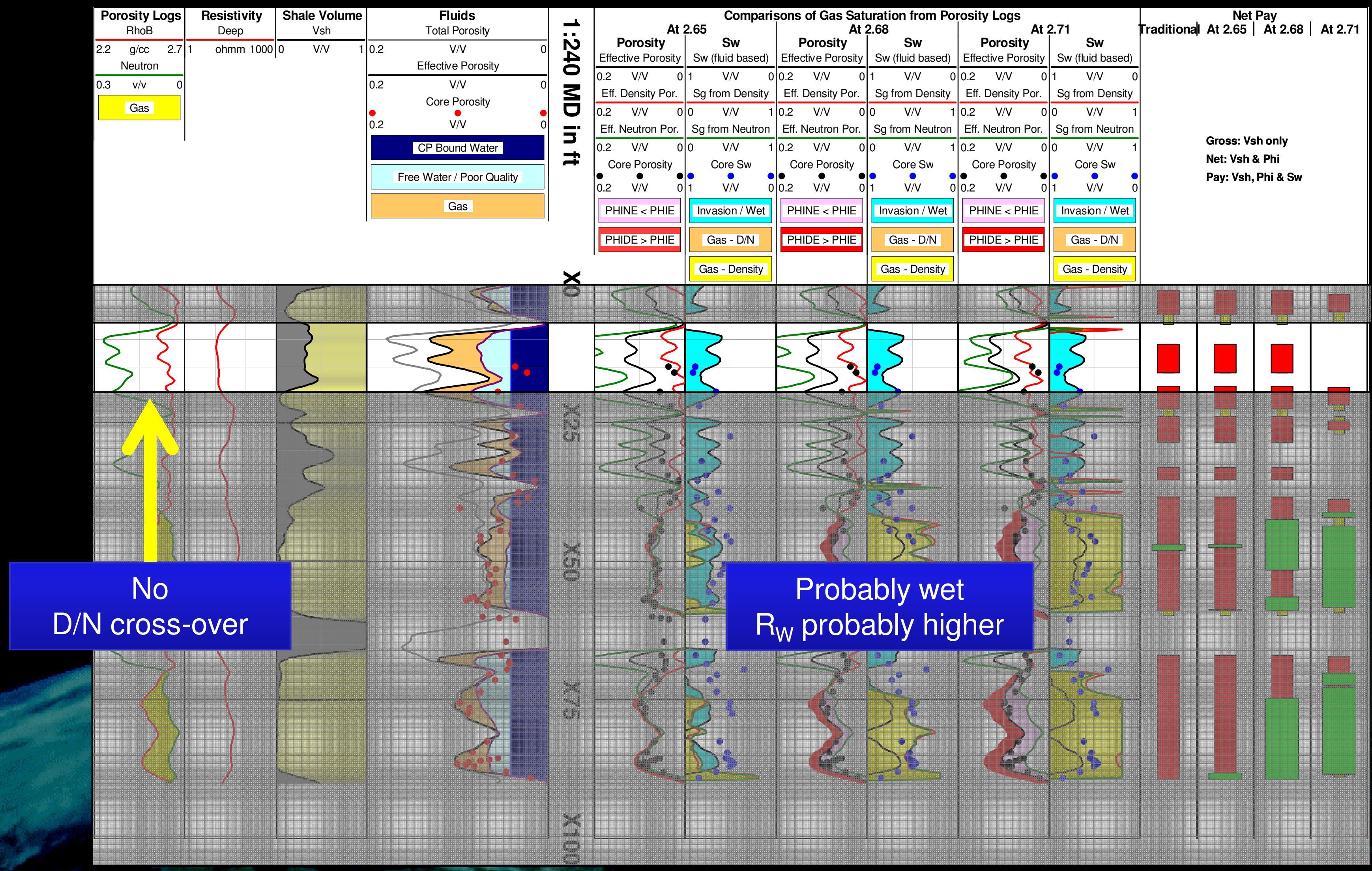
2.71 gm/cc

2.68 gm/cc

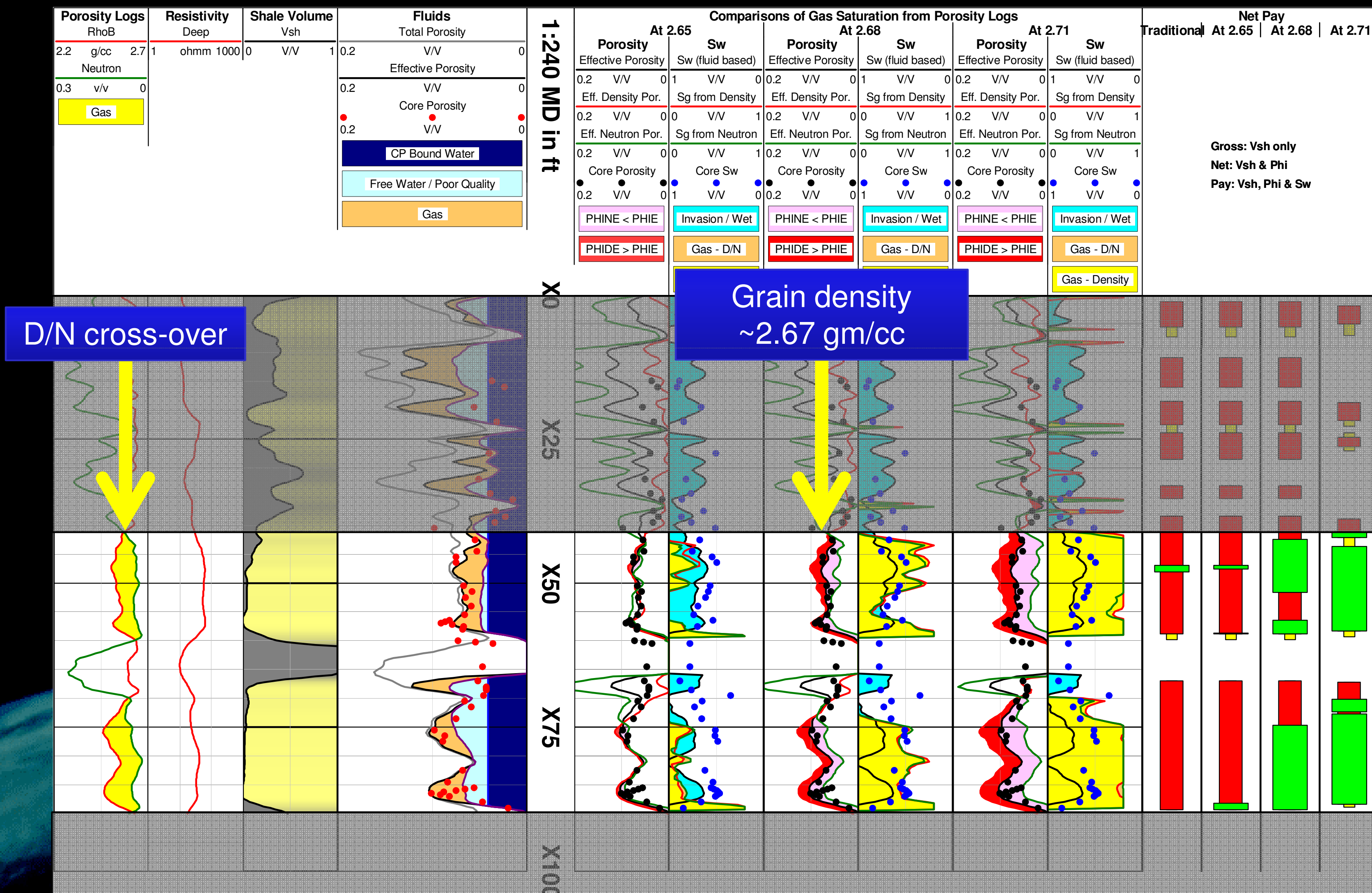
Example #1
Piceance Basin, MWX 1



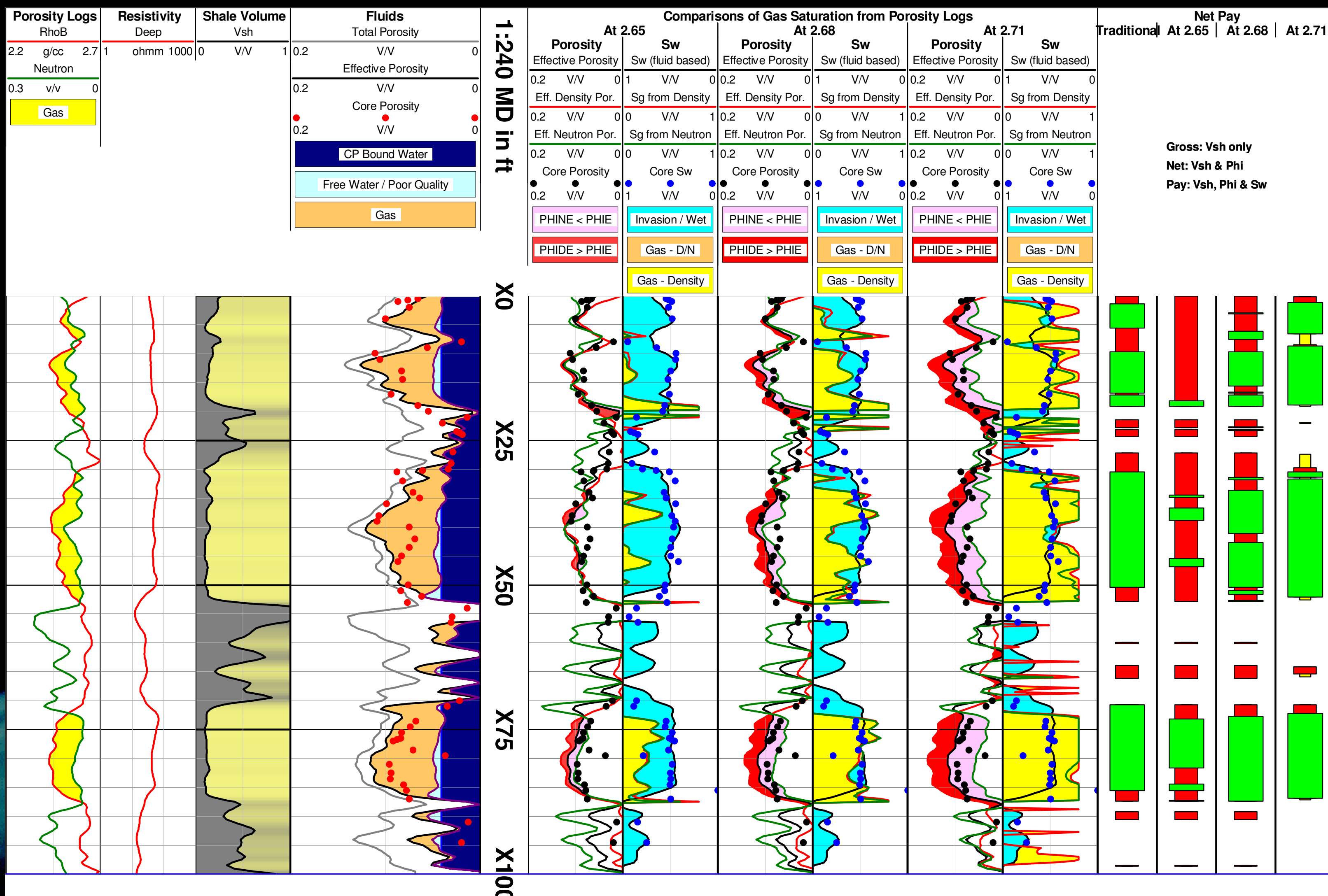
Example #1
Piceance Basin, MWX 1



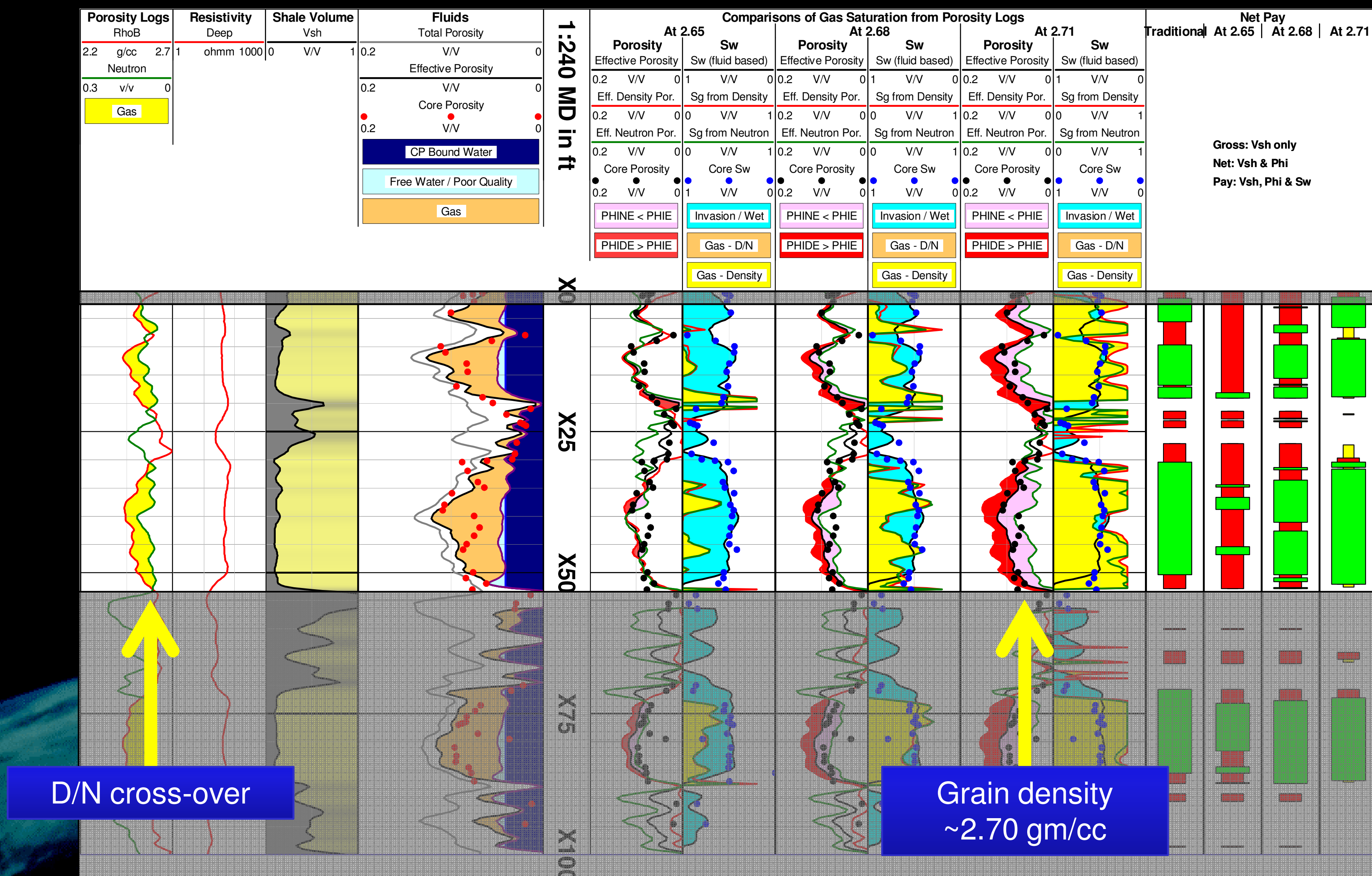
Example #1
Piceance Basin, MWX 1



Example #1
Piceance Basin, MWX 1



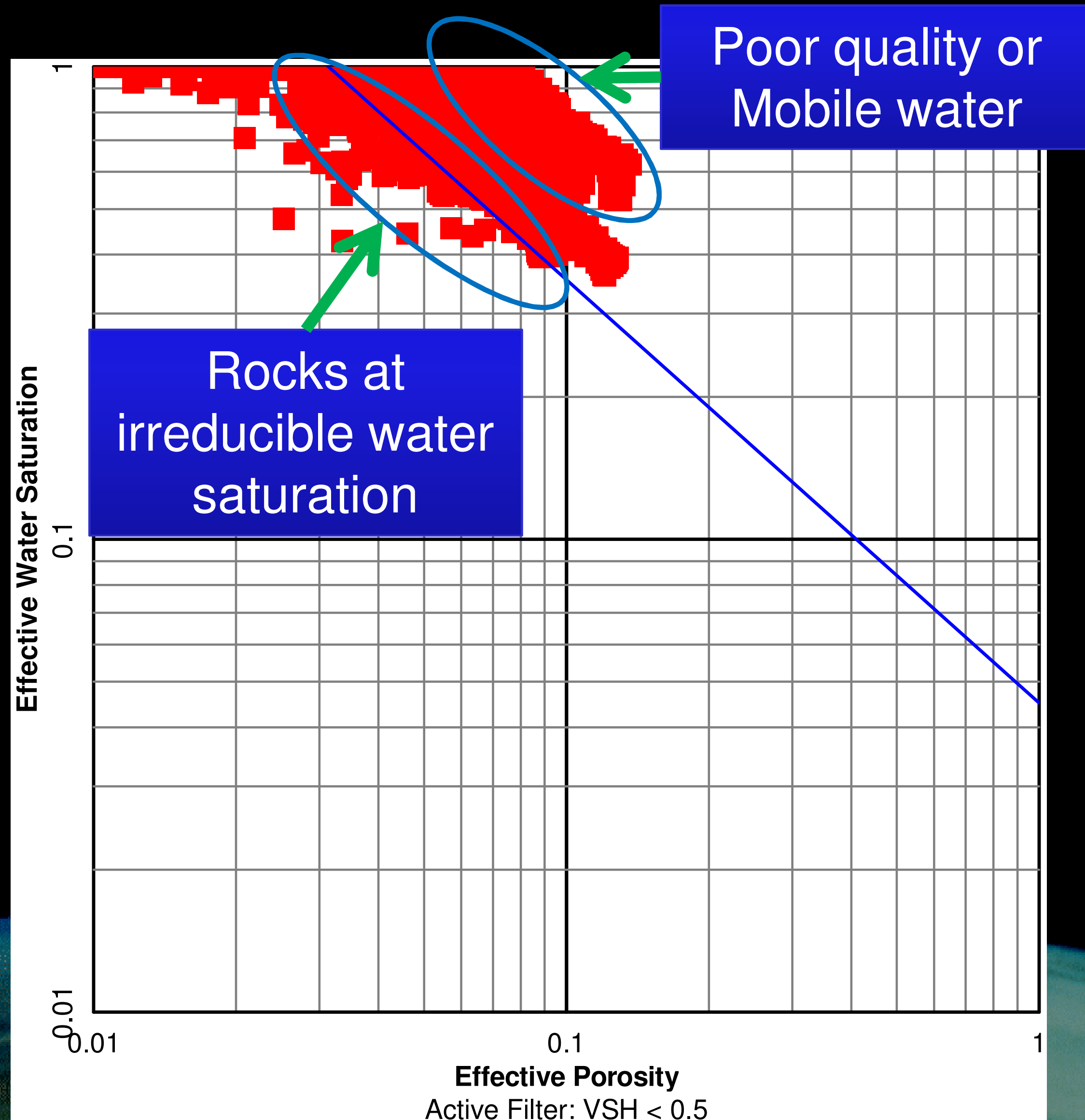
Example #1
Piceance Basin, MWX 1



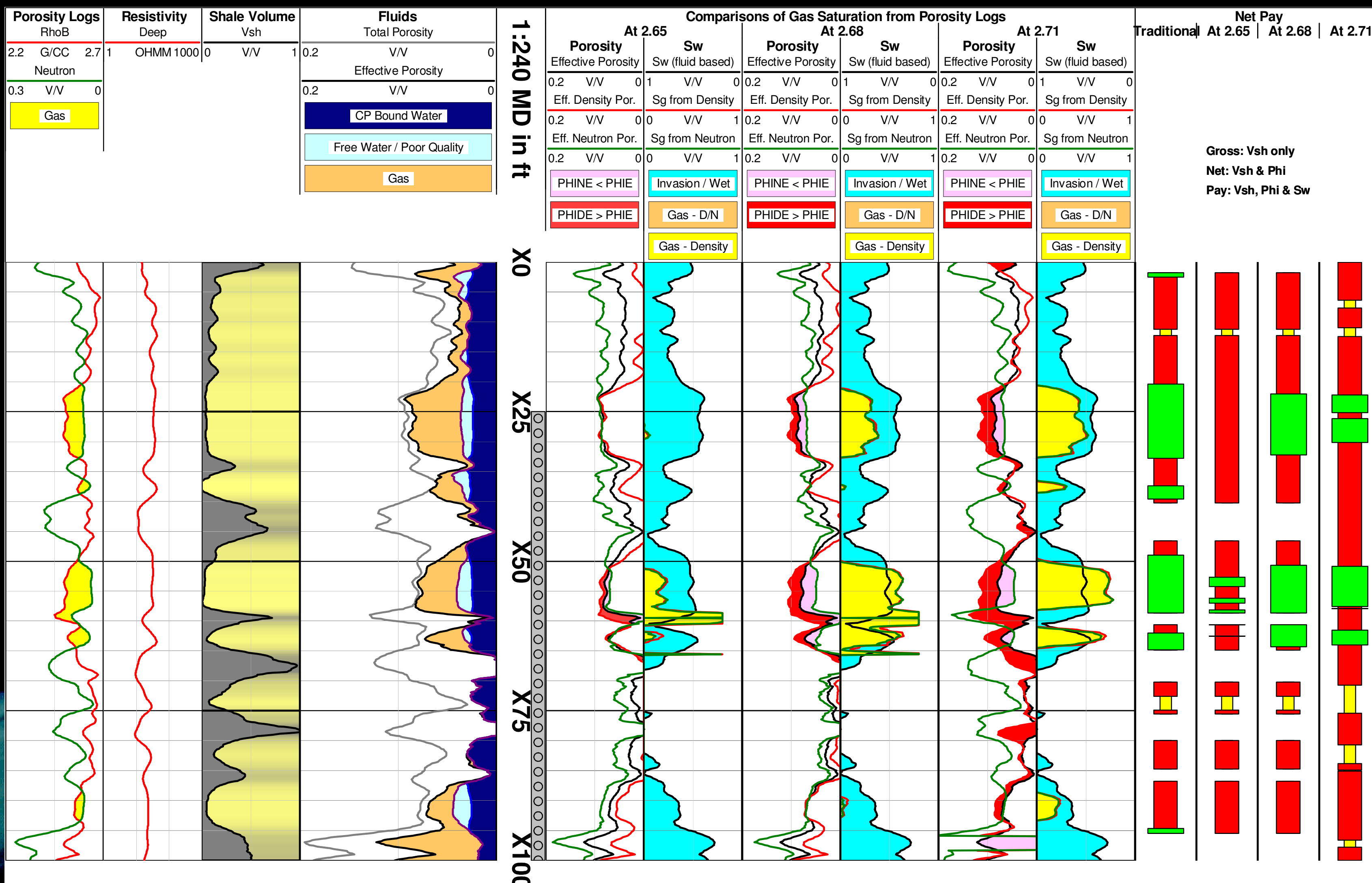
Example #1
Piceance Basin, MWX 1

Cross plot of effective porosity and effective water saturation.

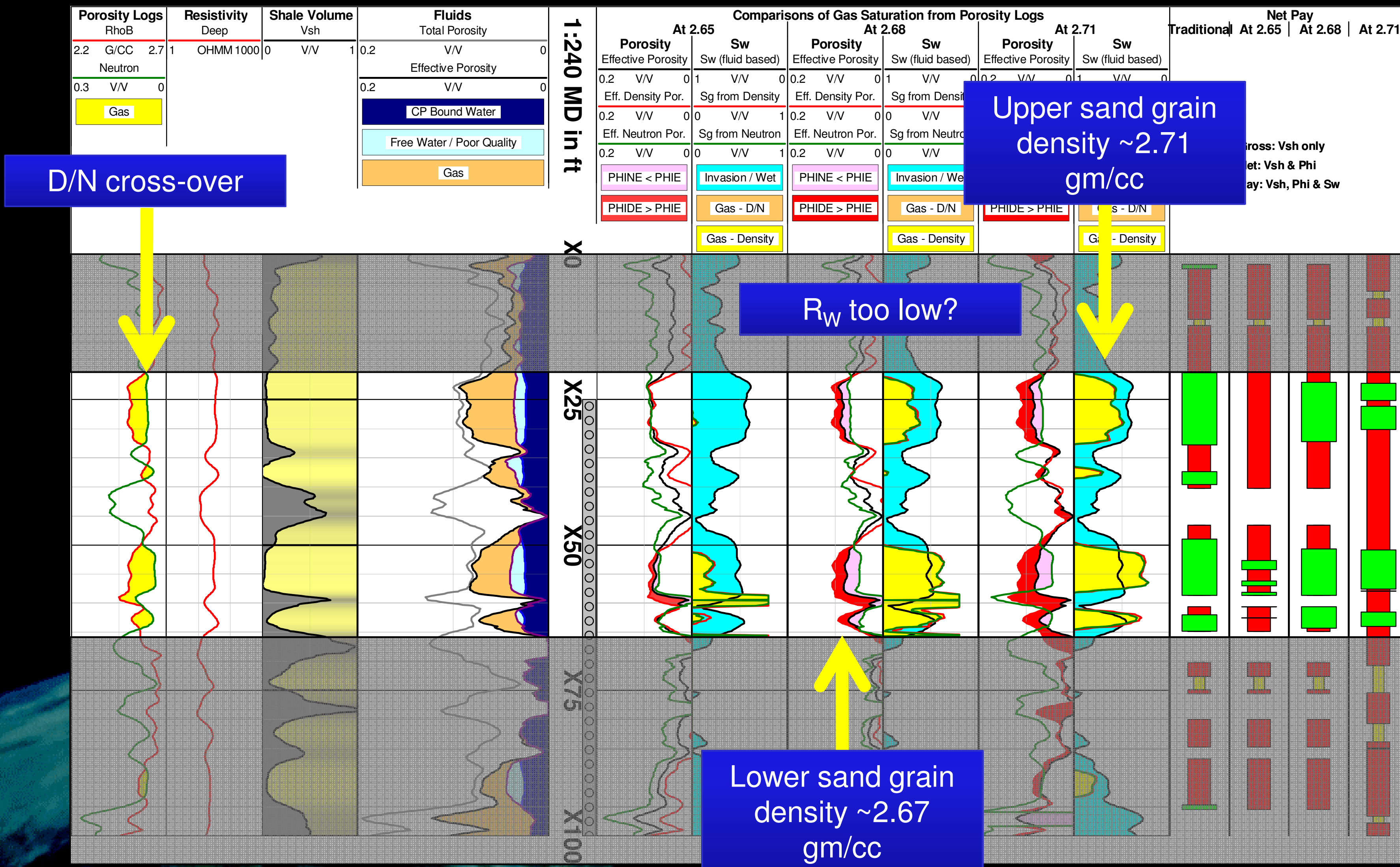
Interpretation involves choosing a straight line fit through the cloud of data towards the lower left. This established the irreducible water trend. Divergence from this trend (to the upper right) suggests either mobile water, or a different, poorer rock quality.



Example #2
Piceance Basin well with low water production
This well produces about 2 barrels of water per MMCFG



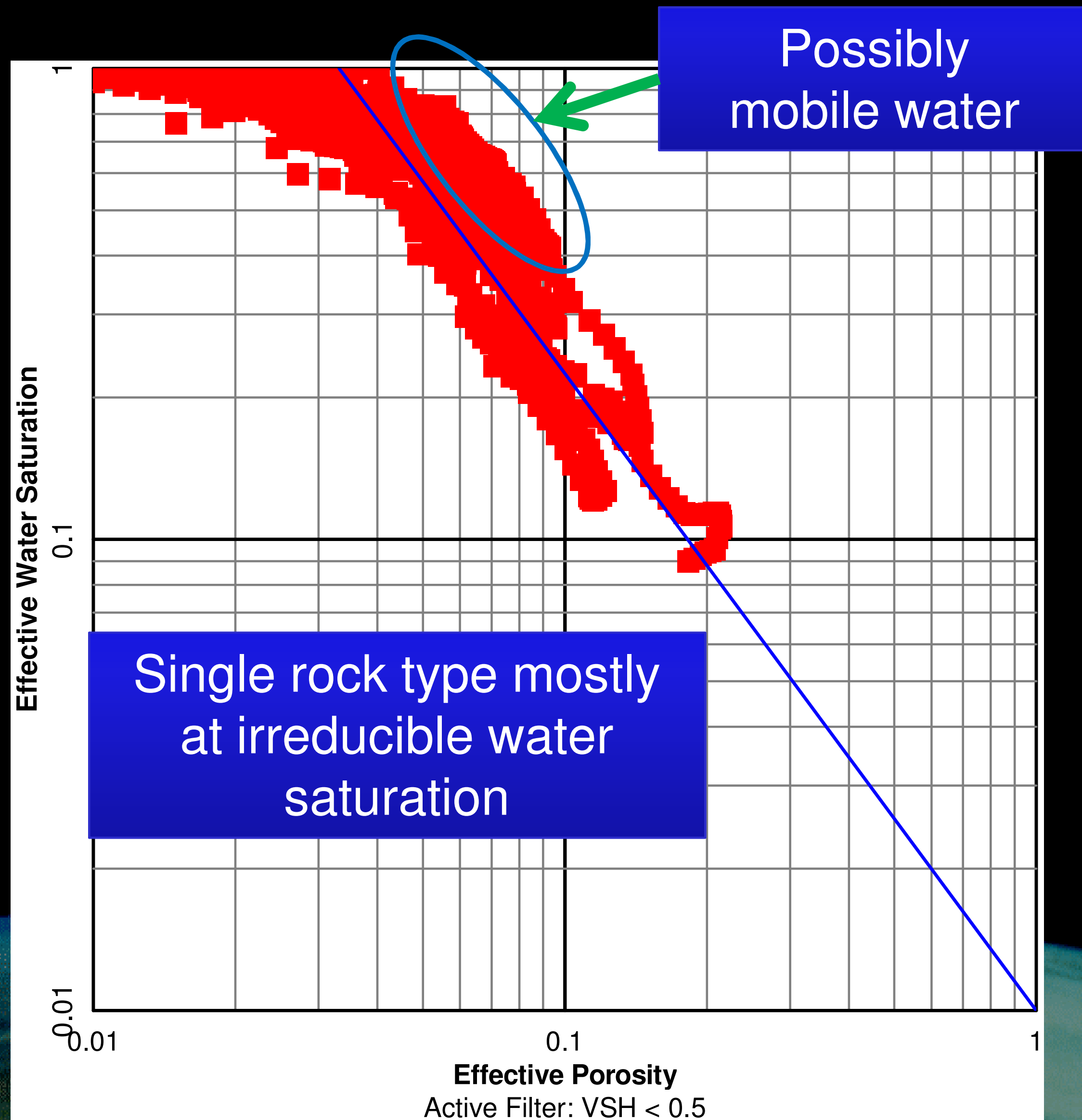
Example #2
Piceance Basin well with low water production
This well produces about 2 barrels of water per MMCFG



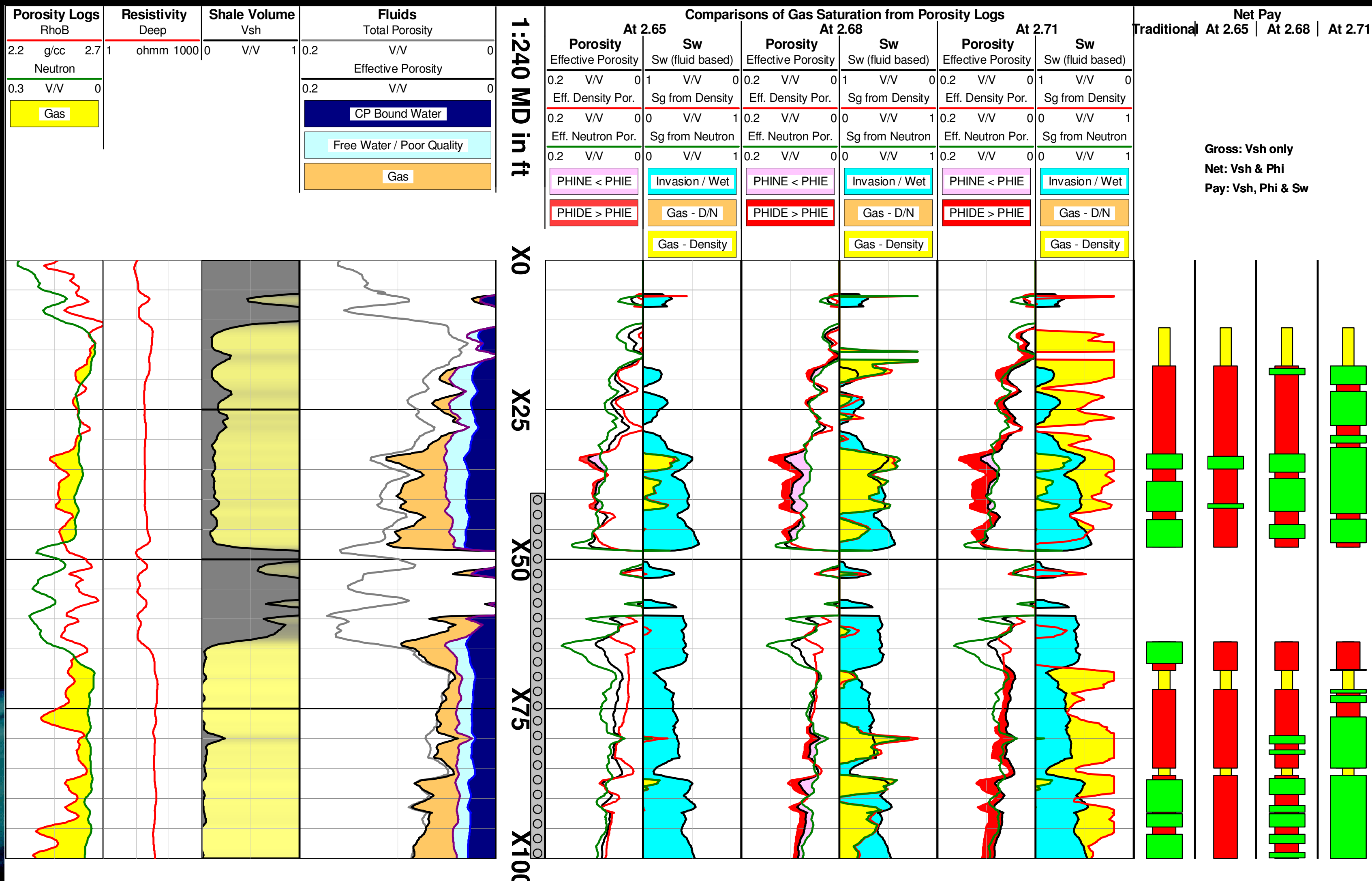
Example #2
Piceance Basin well with low water production

Cross plot of effective porosity and effective water saturation.

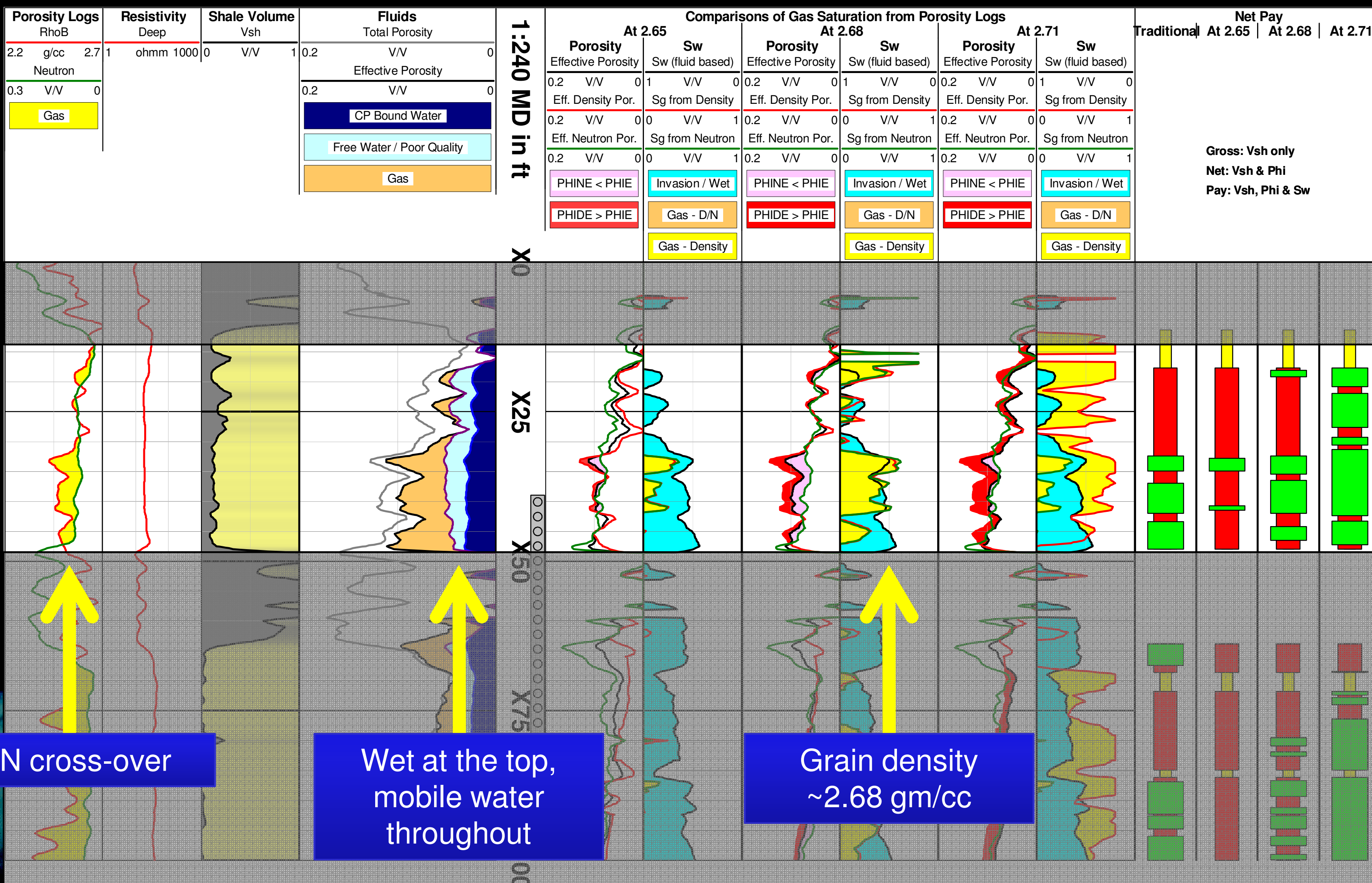
Interpretation involves choosing a straight line fit through the cloud of data towards the lower left. This established the irreducible water trend. Divergence from this trend (to the upper right) suggests either mobile water, or a different, poorer rock quality.



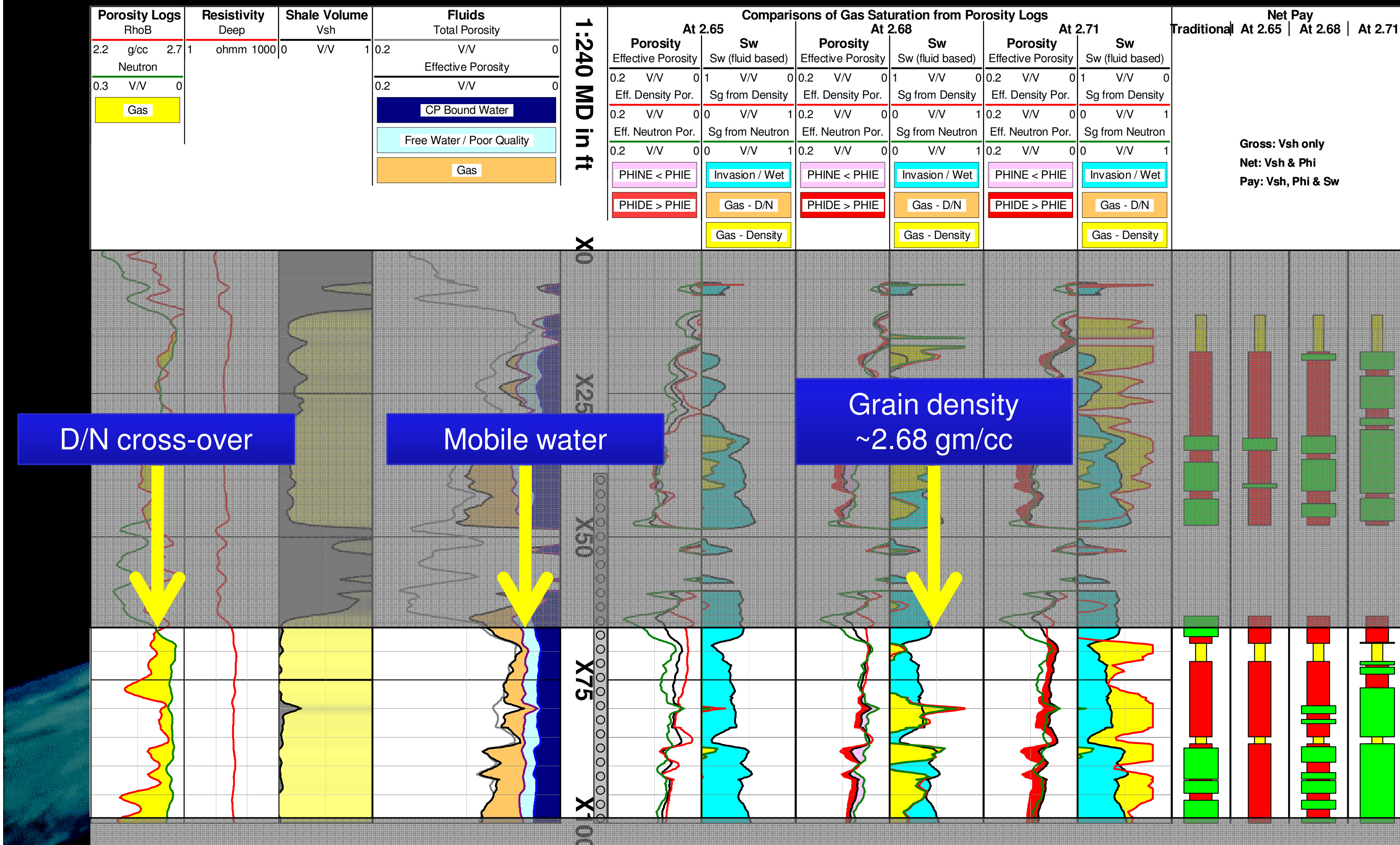
Example #3
Piceance Basin well with high water production
This well produces 60-80 barrels of water per MMCFG



Example #3
Piceance Basin well with high water production
This well produces 60-80 barrels of water per MMCFG



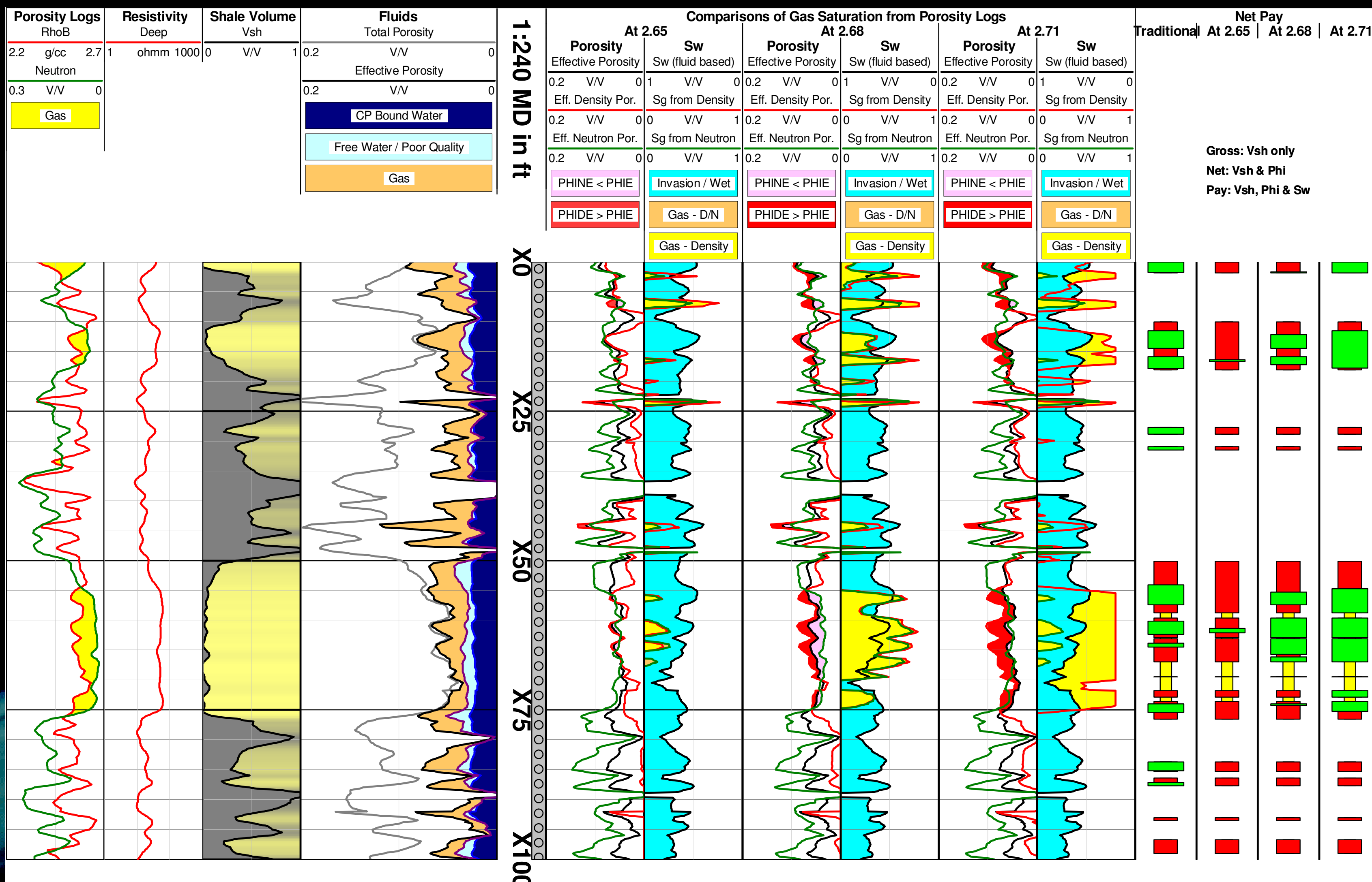
Example #3
Piceance Basin well with high water production
This well produces 60-80 barrels of water per MMCFG



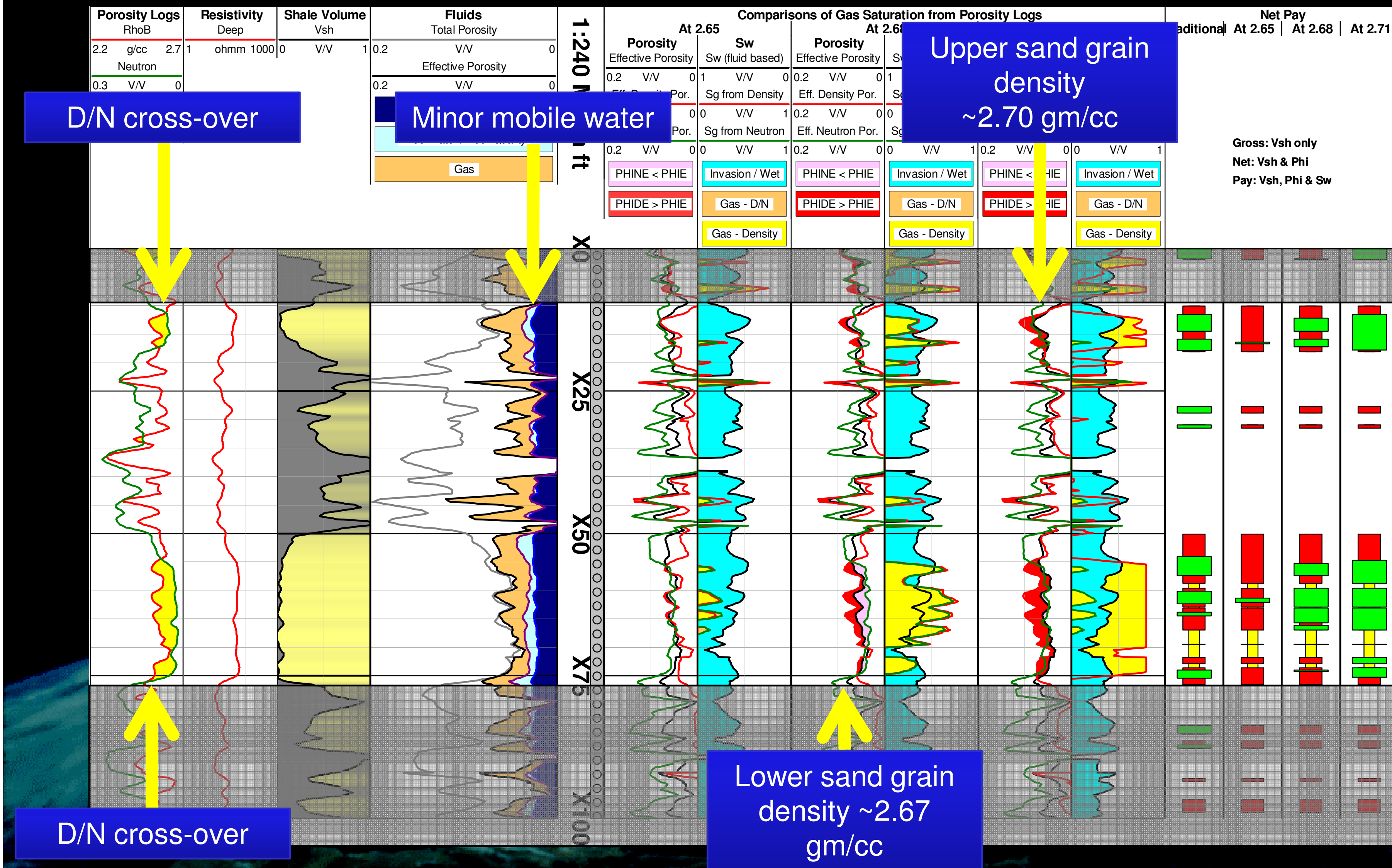
Example #3

Piceance Basin well with high water production

This well produces 60-80 barrels of water per MMCFG



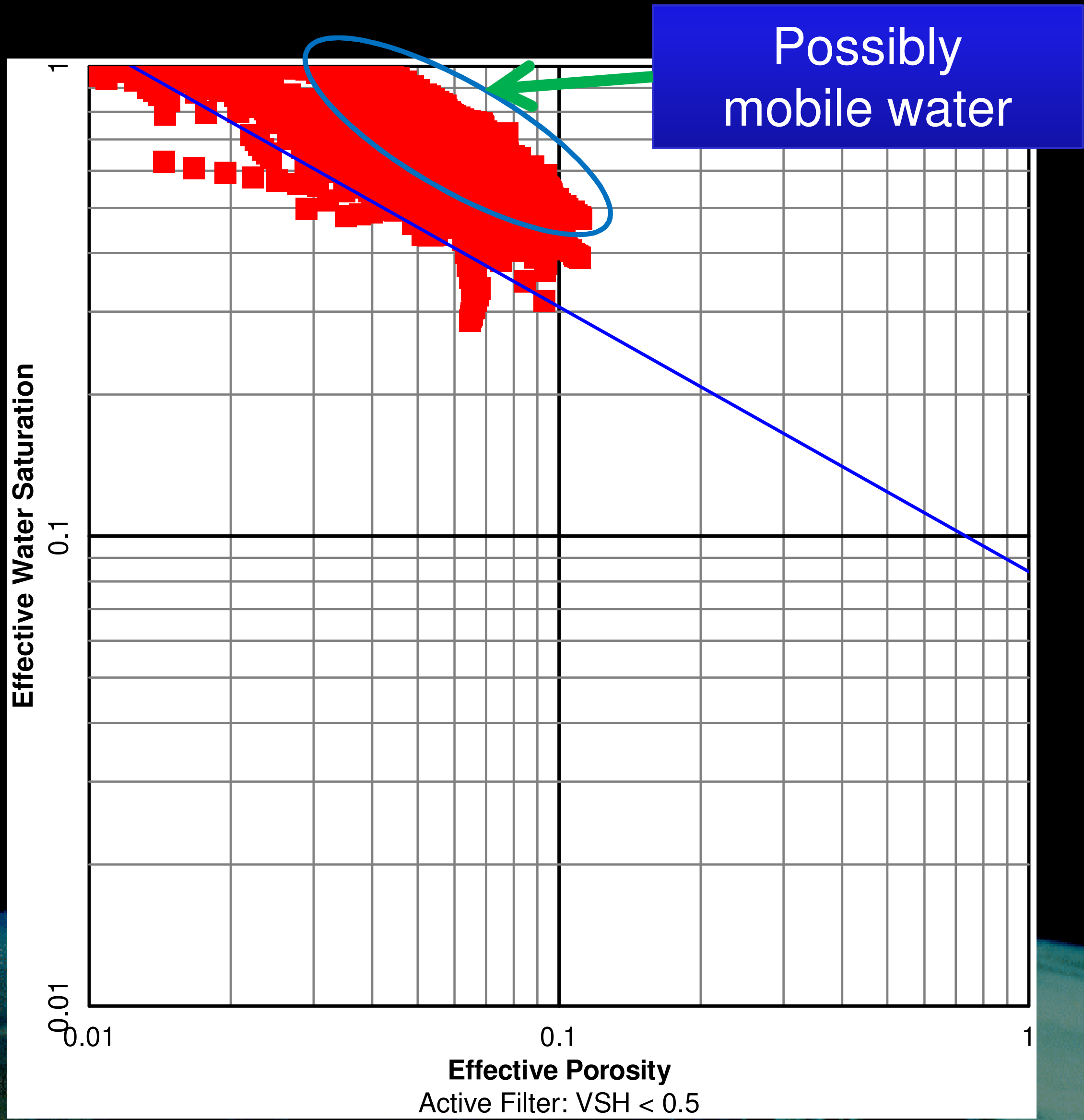
Example #3
Piceance Basin well with high water production
This well produces 60-80 barrels of water per MMCFG



Example #3
Piceance Basin well with high water production

Cross plot of effective porosity and effective water saturation.

Interpretation involves choosing a straight line fit through the cloud of data towards the lower left. This established the irreducible water trend. Divergence from this trend (to the upper right) suggests either mobile water, or a different, poorer rock quality.



Conclusions

- A technique is described to enhance petrophysical analysis of tight gas sands when grain density and water resistivity (R_W) are both variable.
- Standard resistivity – based gas saturation is compared with porosity – derived gas saturation assuming three different matrix lithologies:
  - Sandstone: 2.65 gm/cc
  - Cemented Sandstone: 2.68 gm/cc
  - Heavily Cemented Sandstone: 2.71 gm/cc

Conclusions

- When the four sets of calculations are compared, it is possible to:
  - Verify accuracy of R_W
  - Speculate presence of fresh water wet sands
- Availability of core data to define matrix properties enhance significantly confidence that can be placed on the interpretations
- The technique can be linked to analysis of porosity/water saturation relations, to identify which sands might contain mobile water

The End

www.DigitalFormation.com