A Tight Gas Sand Reservoir Characterization Approach in Delineating Different Benches across Lower Cotton Valley Rocks

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ABSTRACT

The lower Cotton Valley–upper Bossier tight gas sand benches in North Louisiana offer significant challenges in identifying the best section to drill a horizontal well or for vertical reservoir stimulation. These rocks are typically characterized by low resistivity pay and varying pore throat size. Determining correct saturation and a reasonable permeability estimation in these rocks has always been a challenge. A wireline logging suite comprised of gamma spectral elemental, nuclear magnetic resonance (NMR), and dielectric tools were deployed to acquire data for characterizing reservoir properties such as a quantitative mineral volumetric, varying Archie's cementation exponent used for water saturation estimation, permeability based on pore size distribution, etc. Water saturation model based on standard resistivity tool response cannot account for a true water saturation estimation in these type of laminated sand-shale reservoirs because of poor vertical resolution of the standard resistivity tool. An advanced resistivity tool which can resolve the resistivity measurement into vertical and horizontal component to have a better estimate of resistivity of the sand was not part of the logging tool string. Instead, a computational approach from the standard resistivity tool data in developing a laminated sand-shale analysis model was used to compute water saturation at an enhanced vertical resolution. Understanding vertical hydraulic fracture height growth, which may connect productive zones, is important in the lower Cotton Valley which has multiple target sections. A dipole sonic tool was added to the logging suite to provide measurements of rock mechanical properties for a reservoir stimulation model. A complete petrophysical and rock mechanical model was built using "TightGasXpert™" workflow, which integrates the enhanced saturation model with the pore size variation dependent permeability and 3D rock mechanical properties so as to take into account the frequent layering nature of the rocks and help in identifying the key parameters in delineating the best target section. This workflow offers a very robust methodology in characterizing low resistivity, frequently interbedded tight shale-sand formation.

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Stratigraphic Position and General Characteristics.

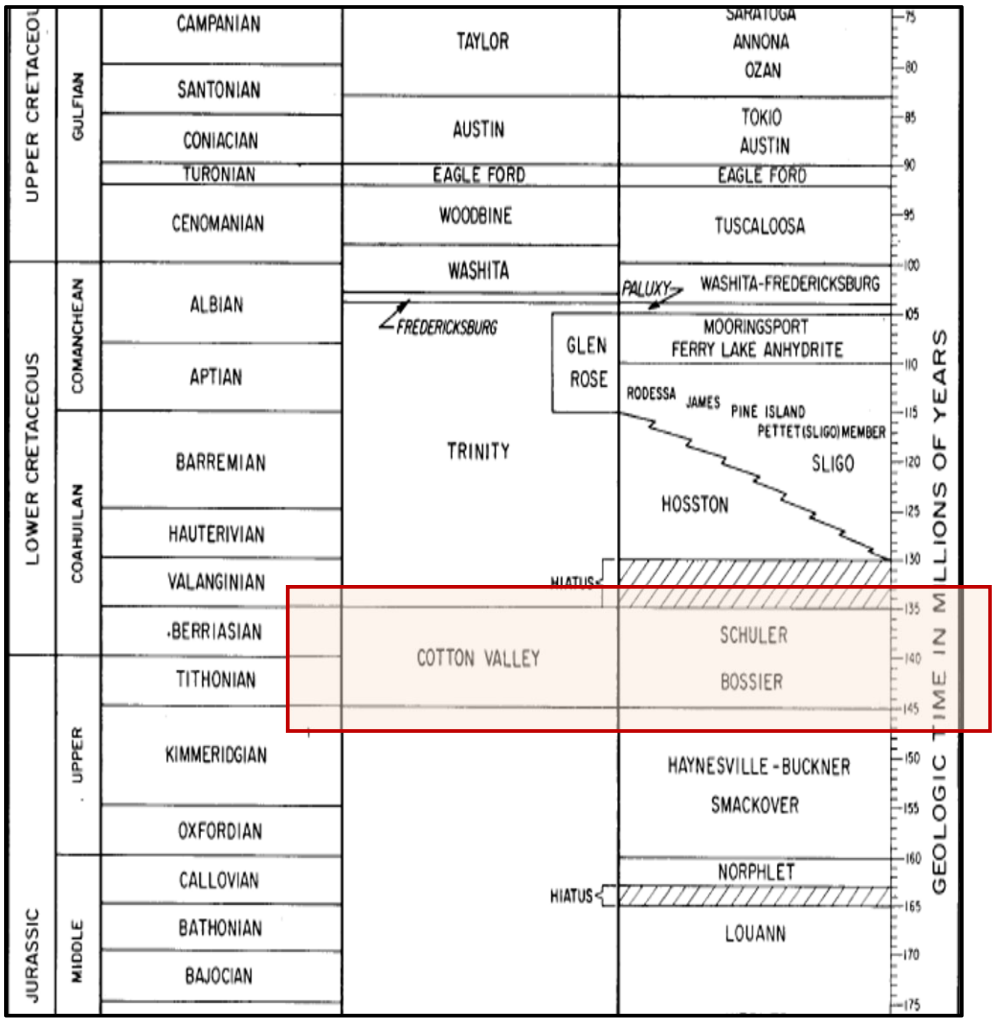


Figure 2. Stratigraphic column showing the position of Cotton Valley Group. The pinks and the reds referred in this paper belongs to upper section of the Bossier Formation. (Courtesy "Shreveport Geological Society")

Some characteristics:

- Upper Jurassic Lower Cretaceous in age
- Predominantly, Sand Shale inter bedding
- The Lower Cotton Valley has relatively higher clay content as compared to Upper Cotton Valley rocks.
- Low resistivity pay
- Varying pore size; predominantly small pores.

Location:

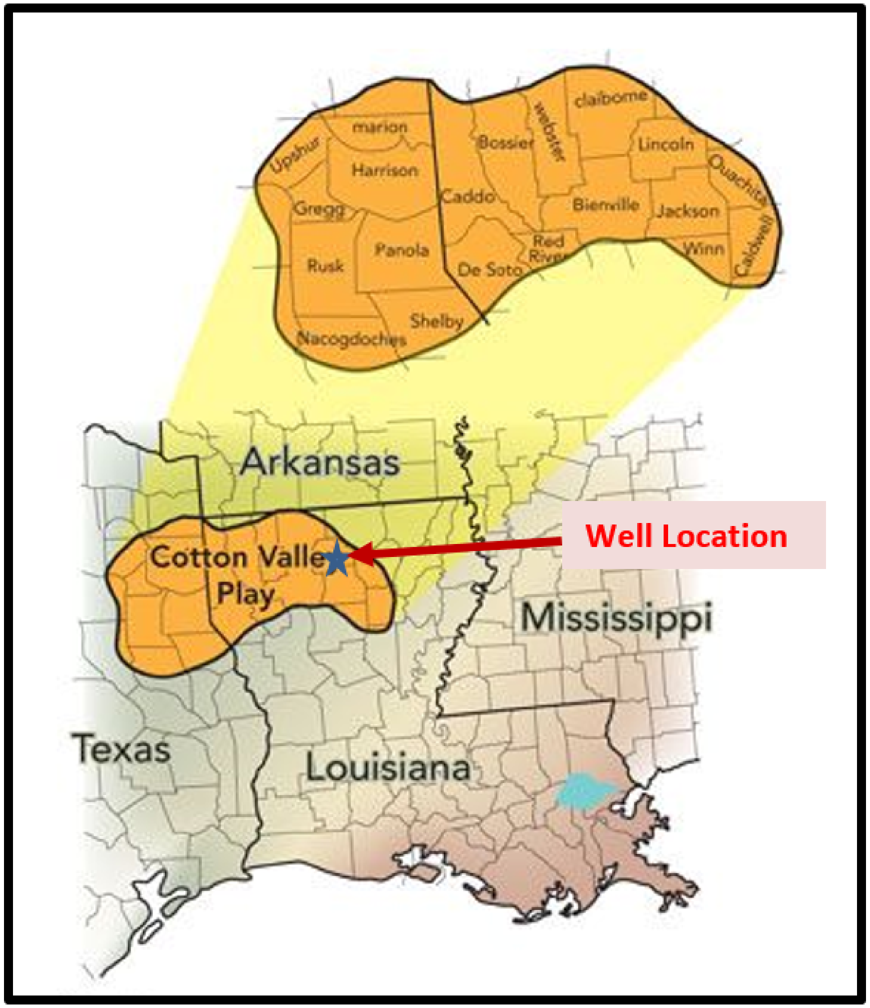


Figure 1. Geographical area of the past and current operations targeting the Cotton Valley formation. The blue star marks the well location in Lincoln Parish

- The Terryville field in Lincoln Parish was discovered in 1950s.
- Initially the cleaner upper Cotton Valley Sand packages were targeted.
- From the late 1970s and early 1980s operators started exploring the tight gas sands of Lower Cotton Valley.

Challenges:

OGIP under estimation	• Low resistivity pay • Frequent shale lamination
Bound fluid vs Free fluid	• Pore size variation
Permeability estimation	• Porosity and permeability transformation.
Delineation of the best target section	• Integration of Petrophysical – rock mechanical properties and production potential.

Tight Gas Sand Evaluation

- Mineralogy and fluid volumes –Probabilistic error minimization solving model.
- Bound Water and Free Fluid – NMR technology
- Laminated Sand – Shale Analysis- Multi Component Induction Tool
- Variable cementation exponent for Sw calculation
- Mechanical Properties- 2D and 3D
- Texture Perm- Using NMR distribution
- Net Pay - Frac Stage Discrimination
- Productivity - Frac Production Prediction

Tech Requirements:

Gamma Spectroscopy

NMR T1-T2 logging

Vertical and horizontal resistivity measurement

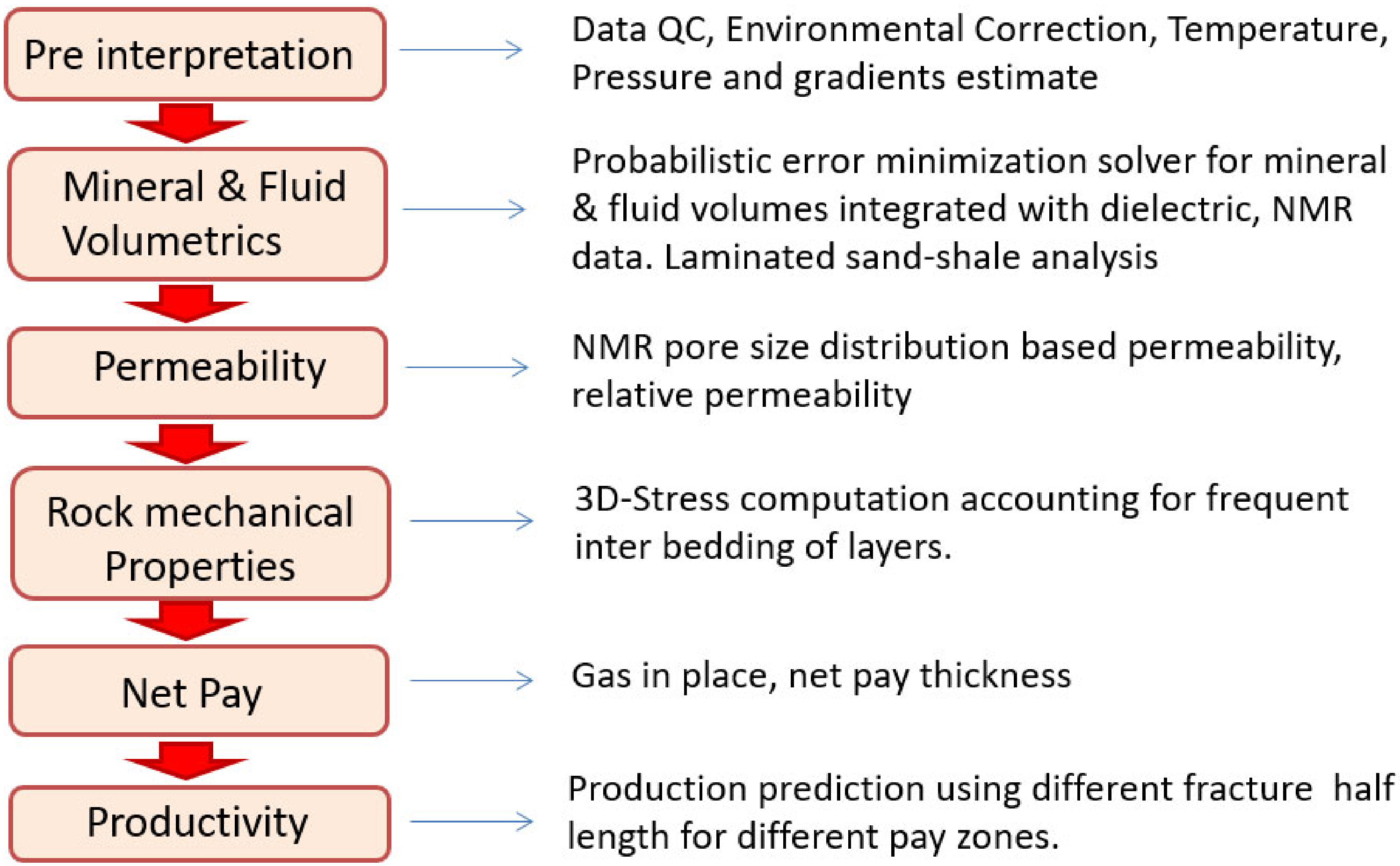
Dielectric Tool for variable "m" determination

Oriented WaveSonic® with Stoneley Slowness

Minifrac using wireline pressure and formation fluid sample tool.

or DFIT™ Stress Calibration

Interpretation Flow Chart



Water Saturation comparisons

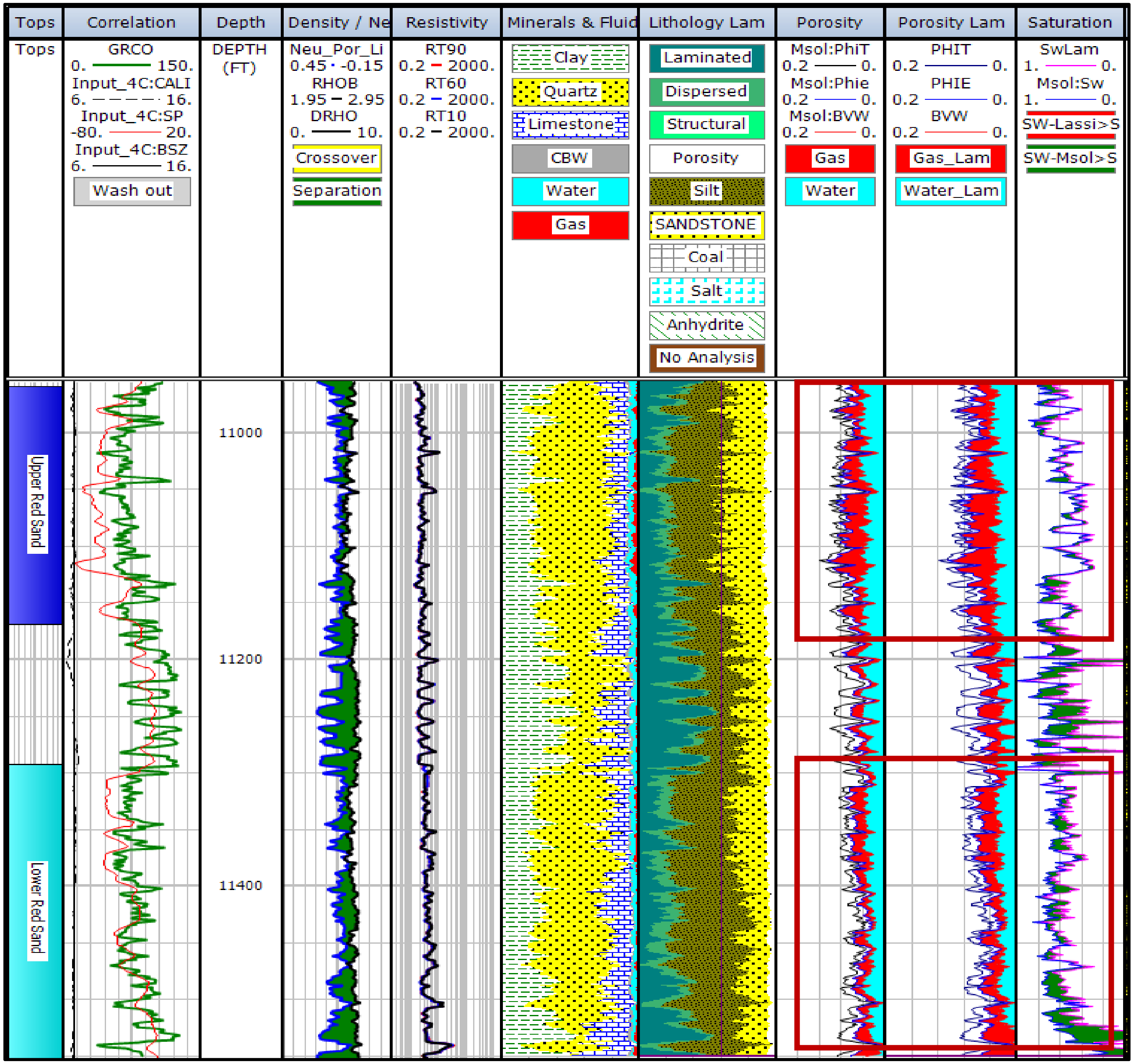


Figure 3. Sw comparison between laminated sand shale model and standard probabilistic error minimization mineral and fluid volume model.

- Overall the Laminated Sand shale model computed lesser water saturation across both the sections.
- The laminated Sand Shale model computed avg. 10.5% less water saturation as compared to the standard saturation model in the Upper Red Section.
- The laminated Sand Shale model computed avg. 22.5% less water saturation as compared to the standard saturation model across the Lower Red section.

Variable cementation exponent "m"

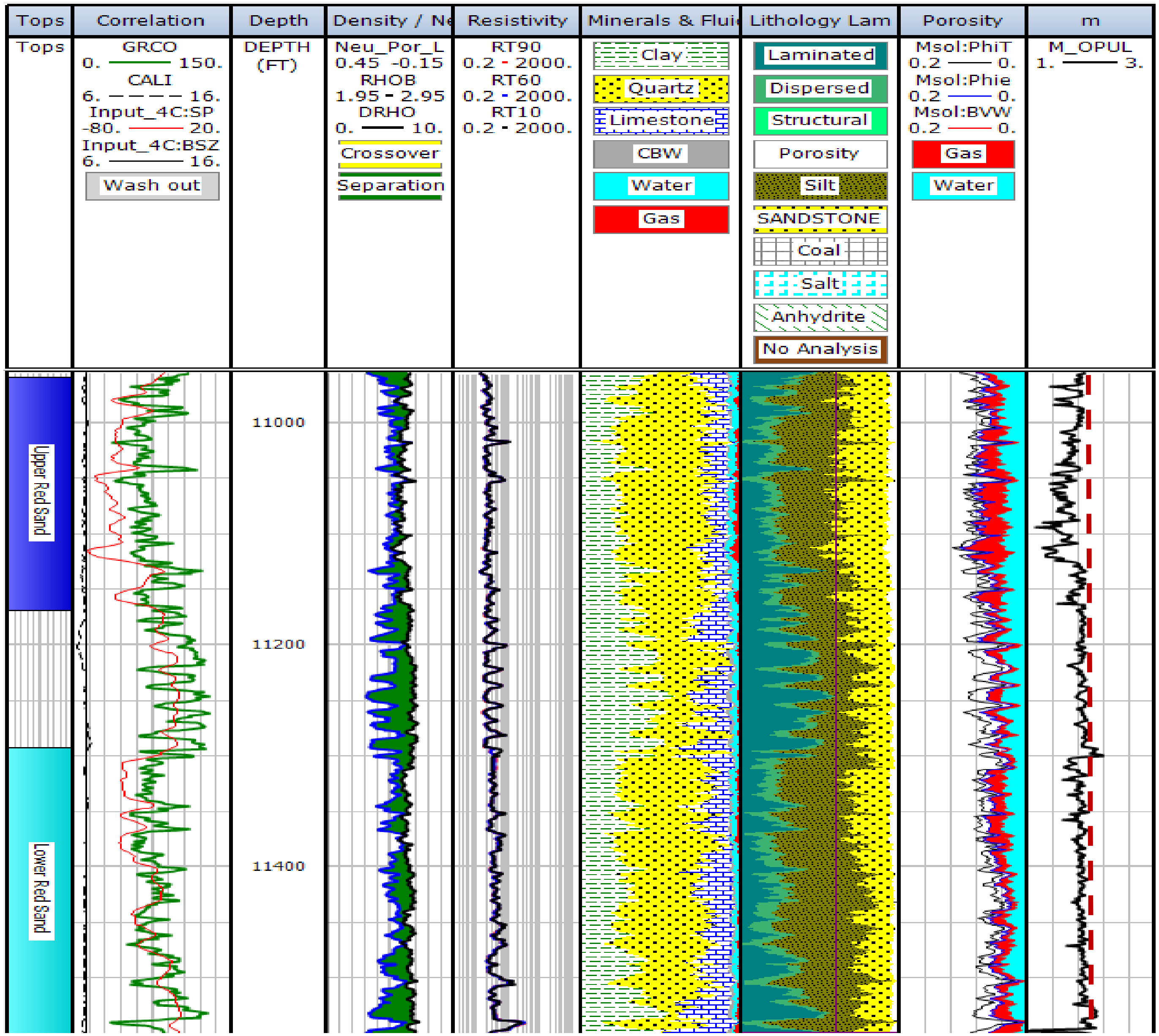
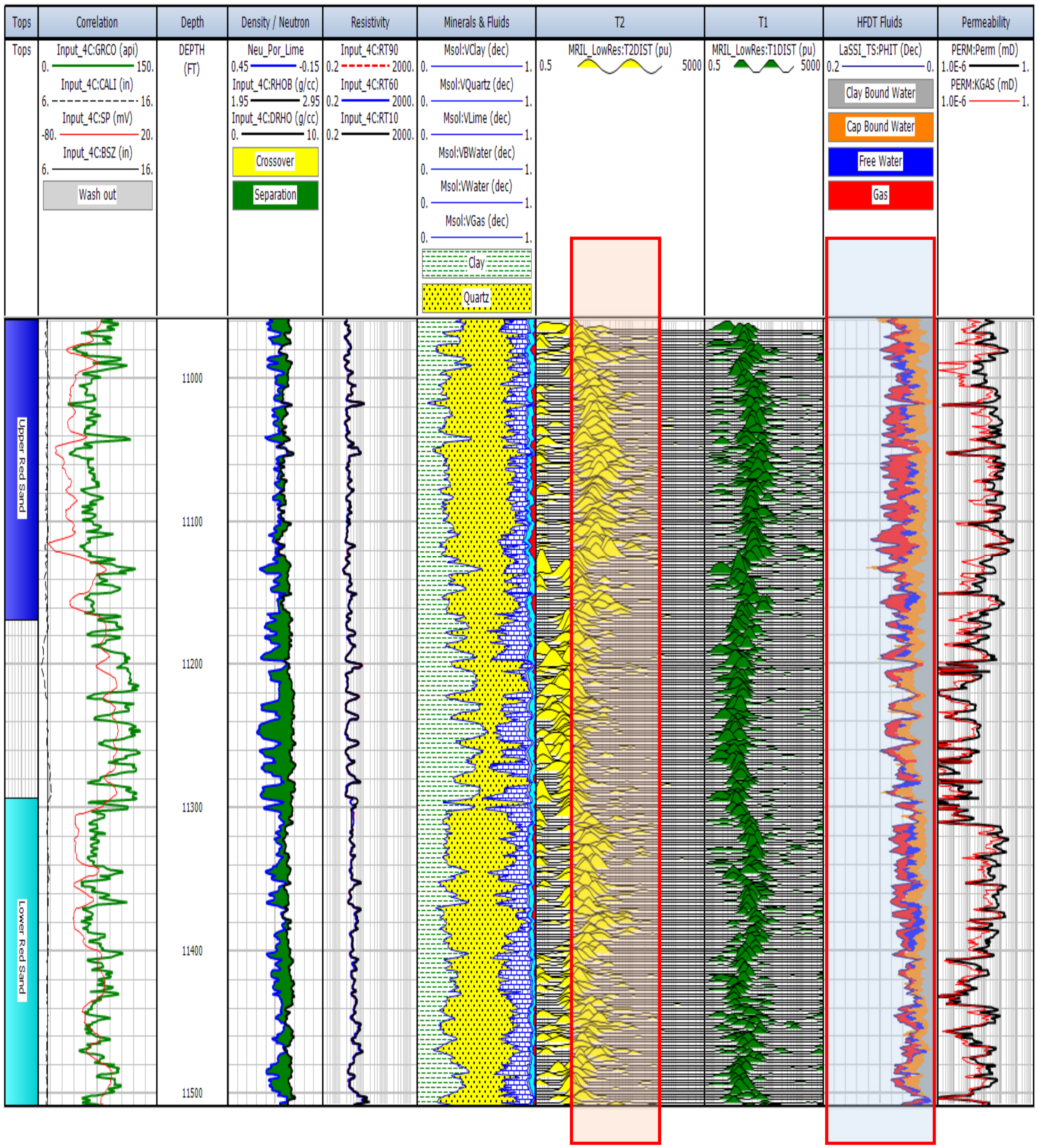
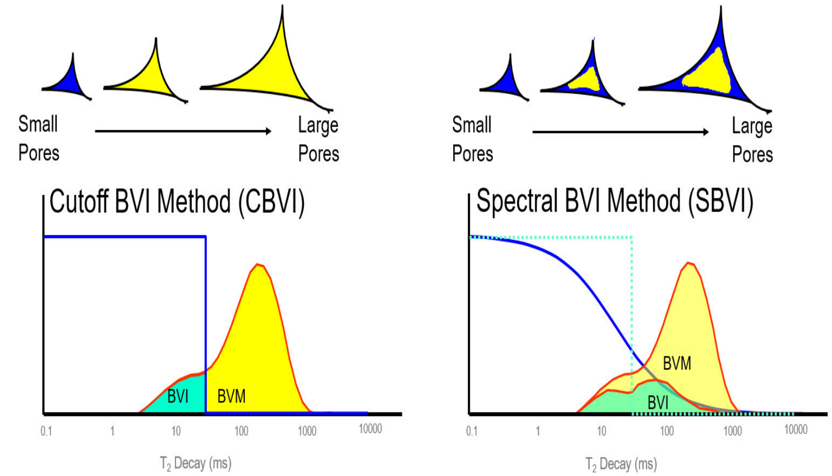


Figure 4. Variable cementation exponent "m".

- Dielectric computed variable "m" is less than 2 in most part across both the upper and the lower Red sections.
- The avg. computed "m" value across the upper Red is 1.77
- The avg. computed "m" value across the lower Red is 1.89.

NMR application





- A spectral BVI method was used to determine bound and free fluid

- Permeability was computed using T2 distribution

Figure 5. NMR pore size distribution, free and bound fluid.

Average Petrophysical Parameters

Benches	Top Depth feet	Bottom Depth feet	Net Pay feet	Avg Por %	Avg Sw %	OGIP mscf/acre	Kgas md	Kgh md-ft
UR 1	10957	11040	80.75	6.36	58.71	23387	0.000849	0.068528
UR 2	11044	11164	119.5	6.79	47.30	51089	0.002787	0.333046
LR 1	11301	11400	98.5	5.14	54.22	25296	0.001505	0.148289
LR 2	11405	11530	123.25	4.09	53.21	22111	0.000467	0.057609

Table 1. Average petrophysical parameters across different benches.

- The Upper Red 2 (UR 2) section has the highest average porosity, lowest average water saturation and highest "gas permeability height".
- Local knowledge on reservoir stimulation model indicates hydraulic fracture initiated in the upper Red 2 section actually grows into the upper Red 1 section.

Rock Mechanical parameters

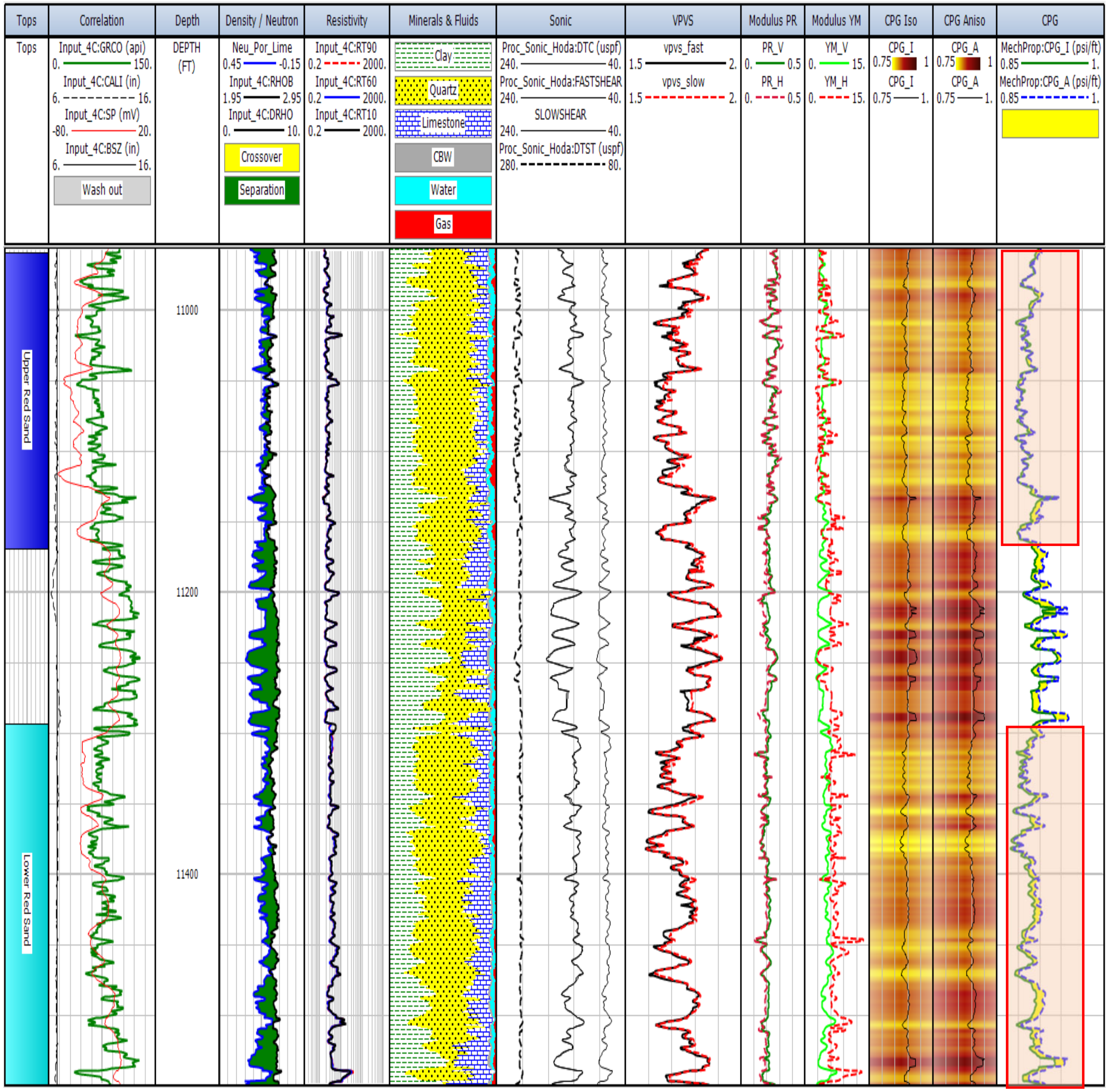
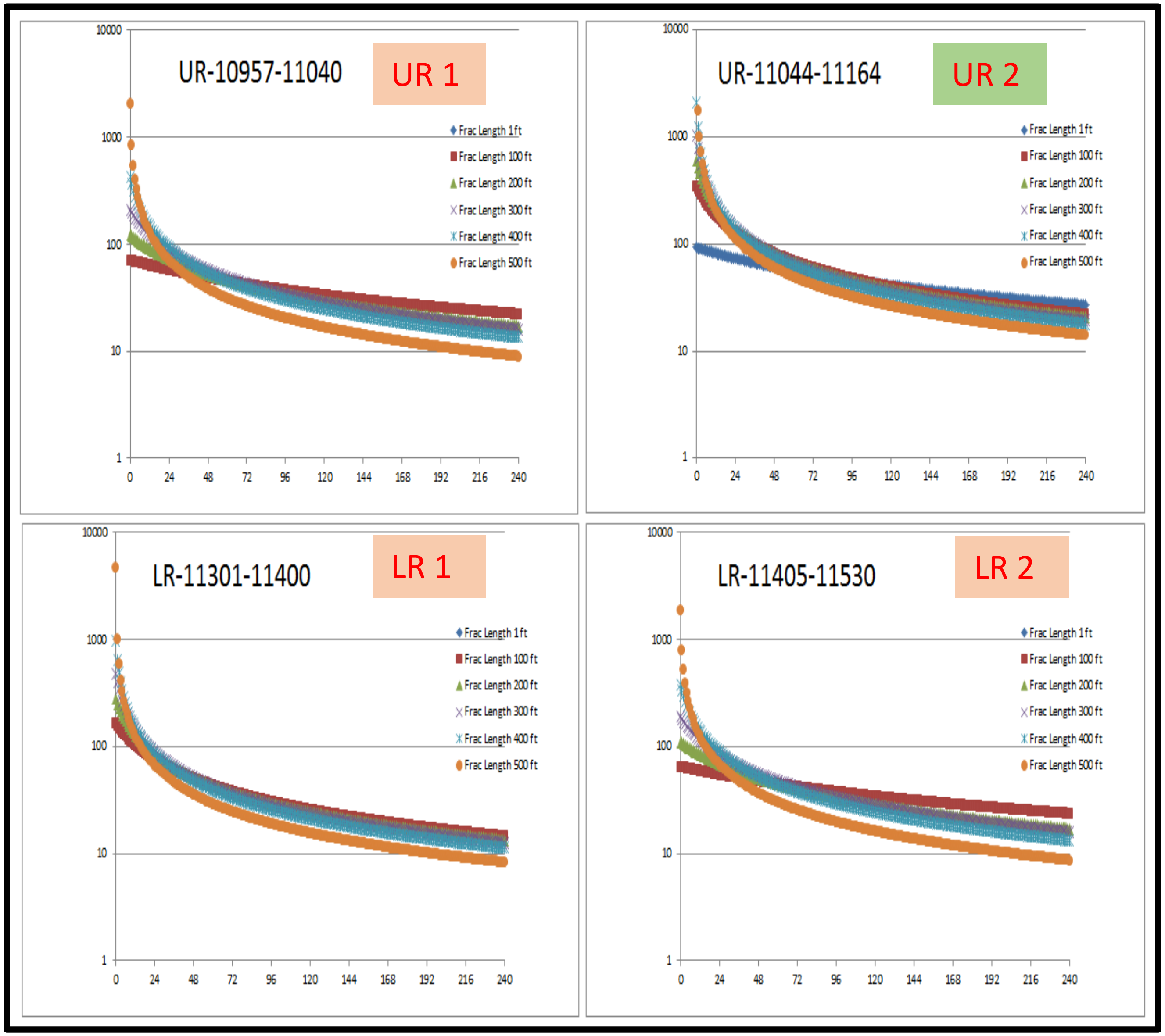


Figure 6. Rock mechanical properties across Upper and the Lower Red sections.

- A 3D rock mechanical model was used to compute petrophysical parameters using stoneley slowness and dipole sonic data.

- The Upper red section showing a lesser difference between the 2D and 3D model computed closure pressure gradients (shade yellow in the last track). This indicates the upper Red section to be relatively less heterogeneous rocks as compared to the lower Red section.

Production Prediction



- The Upper Red 2 (UR 2) predicts a higher initial production and better decline rate as compared to the other three sections.

Figure 7. production prediction for 240 months for different section for a single fracture.

Tight Gas Sand interpretation presentation

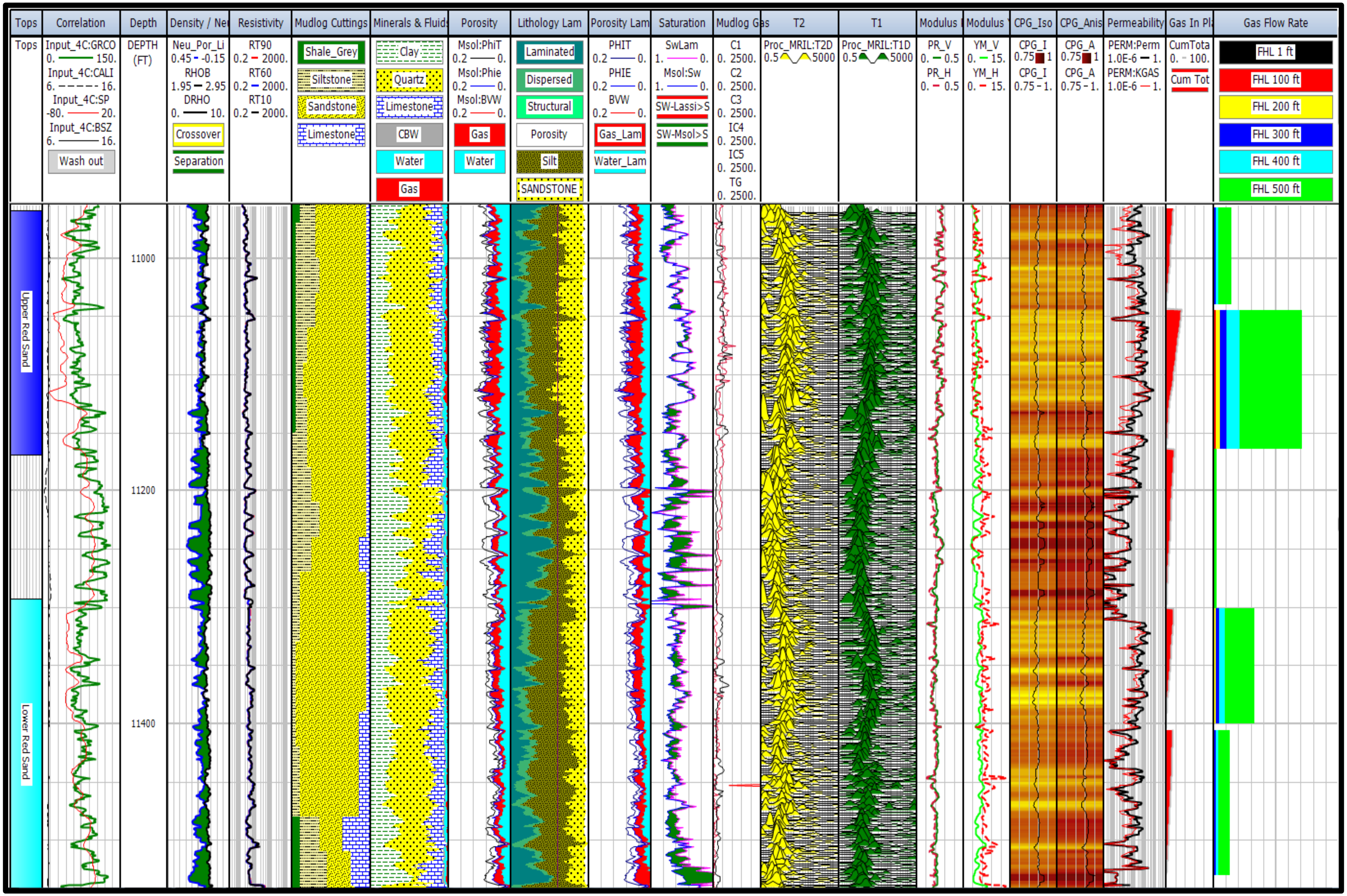


Figure 8. “TightGasXpert” presentation.

Conclusions:

- A comparative evaluation that includes understanding of reservoir storage, deliverability, productivity and a vertical stress profile determination is very important in delineating the stacked low resistivity lower Cotton Valley sand-shale laminated play.
- Conventional triple combo logging suite cannot adequately address all the challenges offered by low resistivity and variable pore size in the tight sand reservoirs.
- The "TightGasXpertTM" workflow which integrates petrophysical and rock mechanical properties along with production capacity for all the probable benches in a stacked play, helps in delineating the primary target.

Acknowledgements / Thank You / Questions

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