

Optimizing Shale Reservoir Characterization with Spectroscopy Evaluation While Drilling*

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Abstract

The unparalleled growth of unconventional shale plays has greatly changed the practice of petrophysics; from the analytical workflows to the laboratory analysis techniques to the tools utilized for logging. Data, such as kerogen volume, total organic carbon (TOC), and clay mineralogy, has proven to be reservoir characteristics fundamental to the shale oil and gas reservoir petrophysical analysis. Typically, this data is derived in the laboratory on vertical well cuttings and core samples with Pyrolysis, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Fluorescence (XRF), X-ray diffraction (XRD). These vertical well data points are then extrapolated through the horizontal well section and typically only correlated with total gamma ray. This methodology makes the assumption of mostly homogeneity in the shale reservoir and negligibly accounts for heterogeneity with total gamma ray, which is normally measured by a standard Measurement While Drilling (MWD) gamma ray sonde sensor.

The Spectral Gamma Ray Logging While Drilling (LWD) tool measures the Potassium (K), Uranium (U), and Thorium (Th) concentrations of the formation along the vertical and horizontal wellbore and provides this data in real-time while drilling. When calibrated to the laboratory data points of the vertical offset or pilot well, the Uranium content provides a reliable TOC and Kerogen volume, which not only provides the heterogeneity reservoir characteristics for an accurate unconventional petrophysical analysis, but can also be used to place the wellbore in the reservoir “sweet-spot.” Potassium and Thorium concentrations historically have been used for qualitative mineral clay typing based on the Th/K ratio. By identifying clay minerals from cuttings with FTIR, XRF, and XRD, the Th/K ratio is calibrated to a specific formation or litho-facies to provide accurate clay mineral identification. This calibration is then used to qualitatively identify clay minerals in horizontal wells, which can be done while drilling with a LWD Spectral Gamma Ray tool. Additionally, variations of Thorium and Potassium

spectroscopy measurements can aid in the well bore placement by identifying facies markers that the total gamma ray measurement cannot resolve.

The real time while drilling acquisition of Uranium, Potassium, and Thorium concentrations calibrated to geochemistry measurements from cuttings provides an unconventional petrophysical analysis and enhances the horizontal well placement.

Selected References

- Blakey, R., North American Paleogeographic Maps: Middle Devonian 385 Ma. Website accessed February 22, 2017, https://www.google.com/?gws_rd=ssl#q=blakey+paleogeography+north+america; <http://jan.ucc.nau.edu/rcb7/namD385.jpg>.
- Chou, M., and D.R. Dickerson, 1979, Pyrolysis of eastern gas shale-- Effects of temperature and atmosphere on the production of light hydrocarbons: Proceedings of the Third Eastern Gas Shales Symposium (October 3), p. 211-223.

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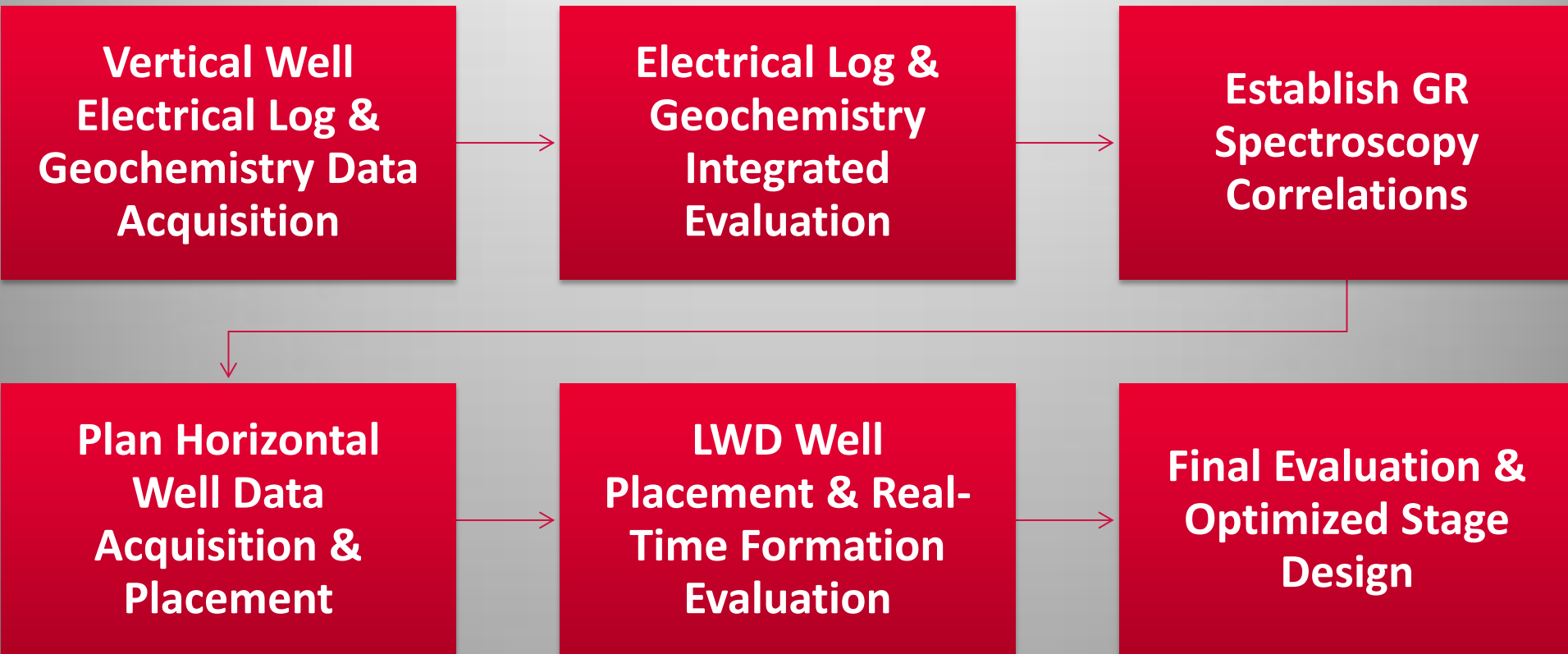
Outline

- Objective
- Workflow
- New Albany Shale
- Data Acquisition
- Vertical Well Evaluation
- Horizontal Well Execution
- Results
- Summary

Objective

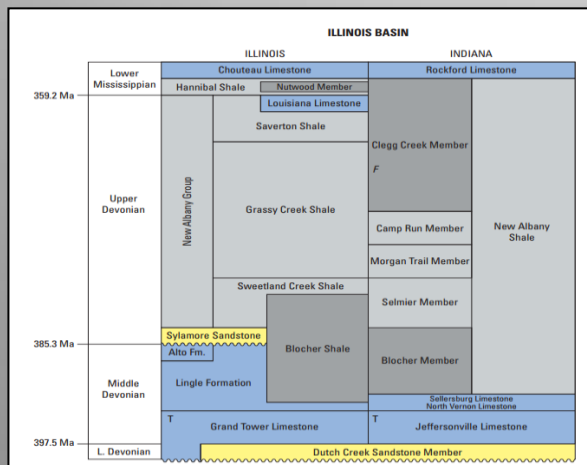
- Improve Reservoir Characterization of Horizontal Wells using Spectral Gamma Ray vs. Total Gamma Ray.
 - TOC
 - Clay Volume
 - Clay Typing
 - Fracability Indicator
- Establish Geochemistry and Well Log Correlations from Vertical offset wells.

Workflow

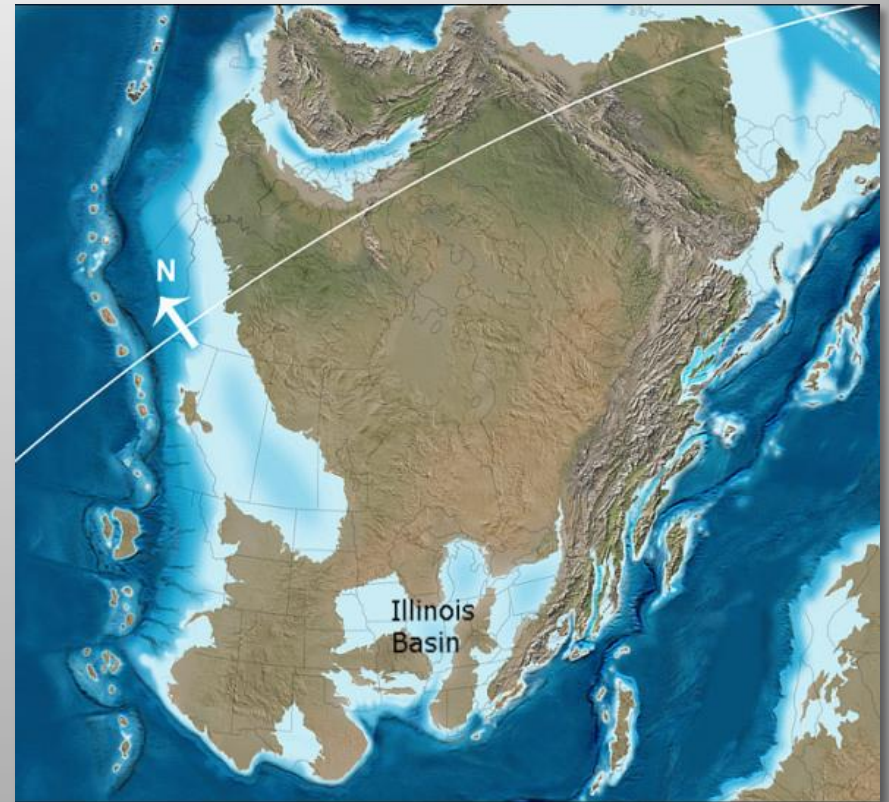


New Albany Shale

- Illinois Basin (Indiana, Illinois, Kentucky)
- Upper Devonian
- Quartz-Dominant Organic Shale
- TOC: 5-17%*
- Type II Kerogen: 8-16% *
- Heavily Fractured



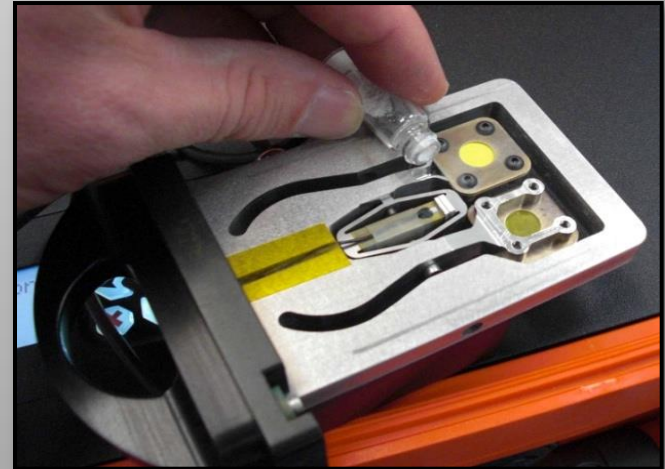
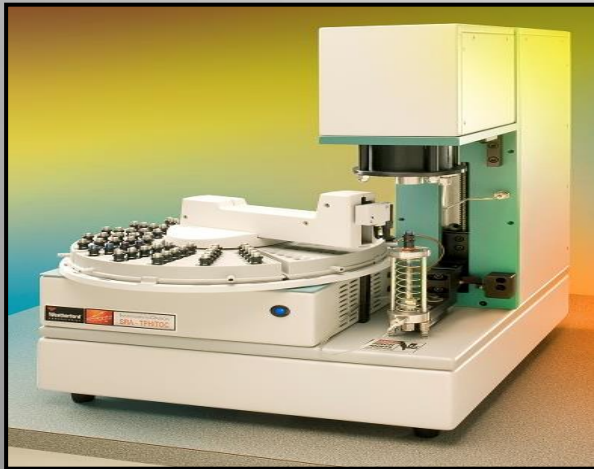
USGS 2011



Ron Blakey, NAU Geology

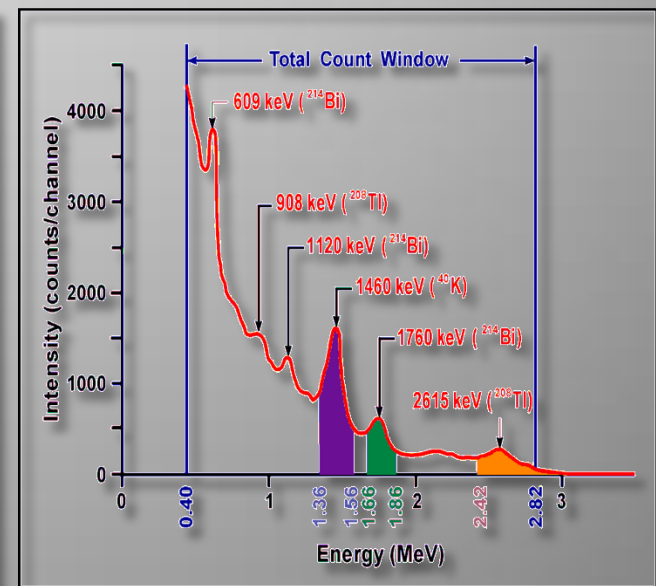
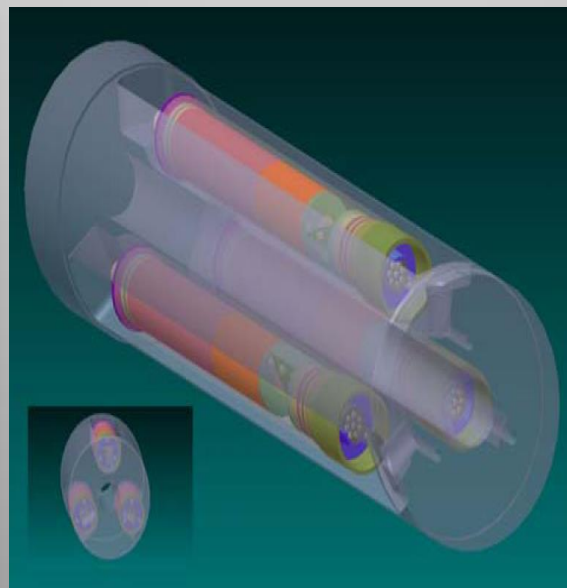
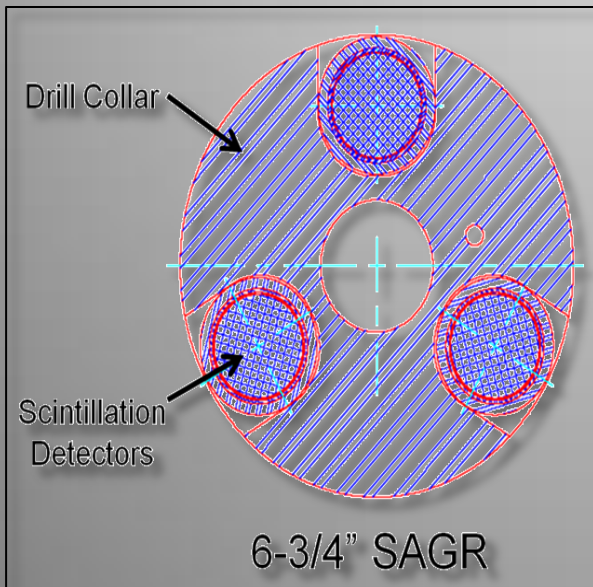
Vertical Well Data Acquisition

- Electrical Logs
 - Quad-Combo, Spectral GR, Resistivity Micro-imager
- Geochemistry
 - XRD, Pyrolysis, GRI



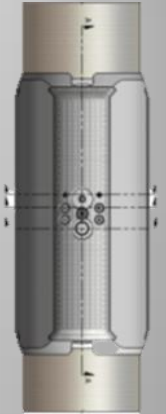
Horizontal Well LWD Data Acquisition

Spectral Azimuthal Gamma Ray

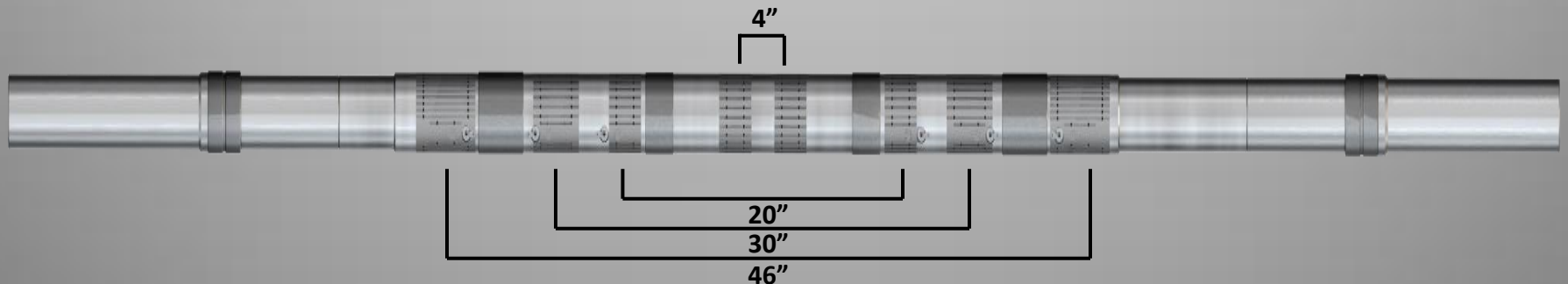


Horizontal Well LWD Data Acquisition

Electrical Micro-imager

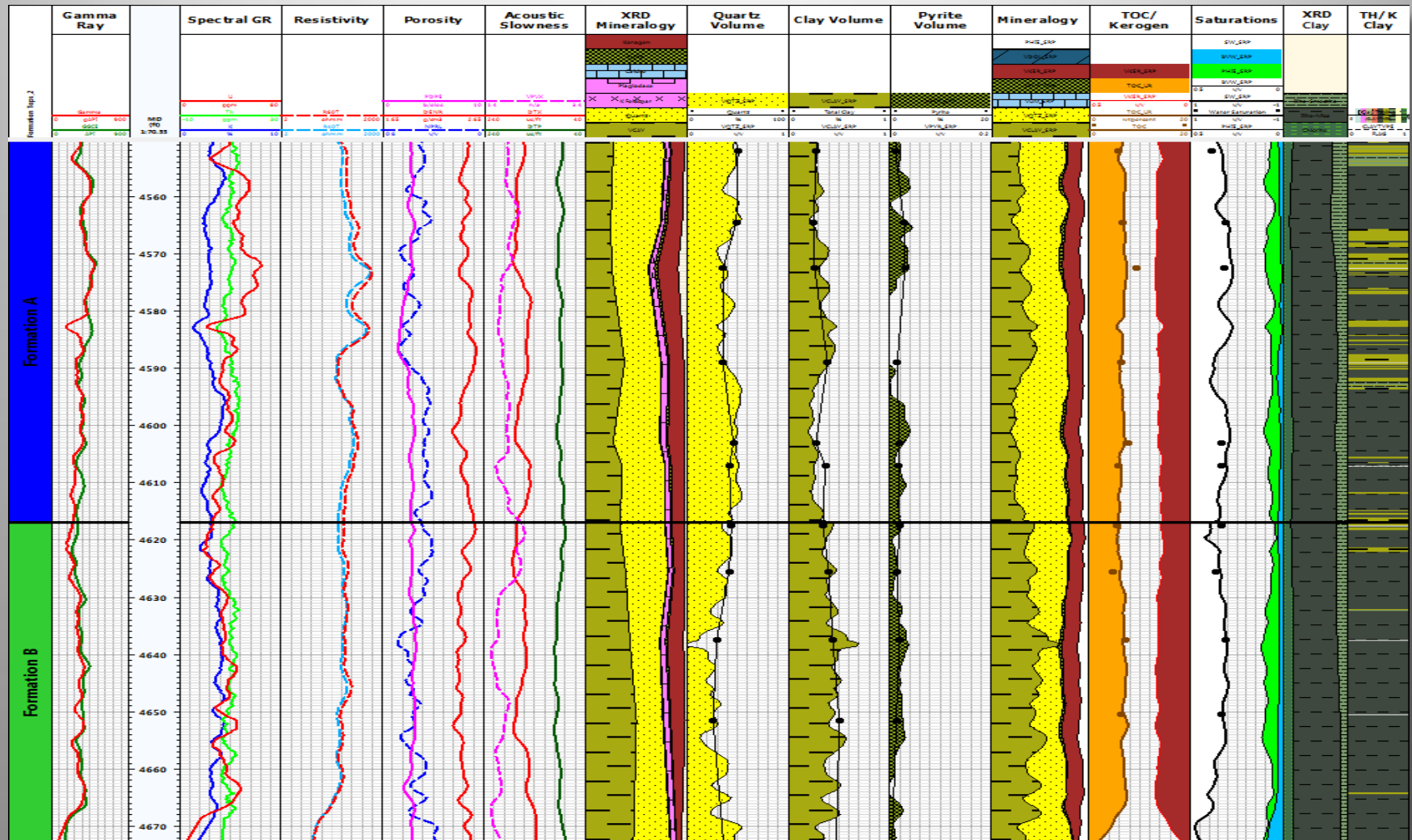


Propagation Resistivity



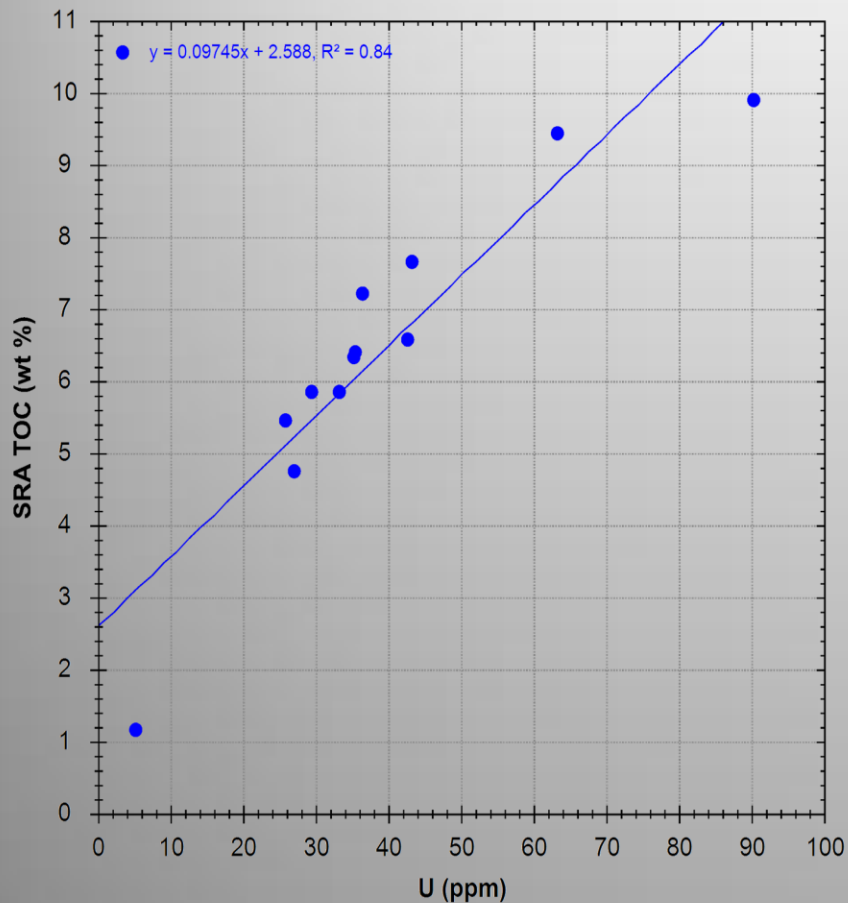
Vertical Well Analysis

Vertical Well Data Integration

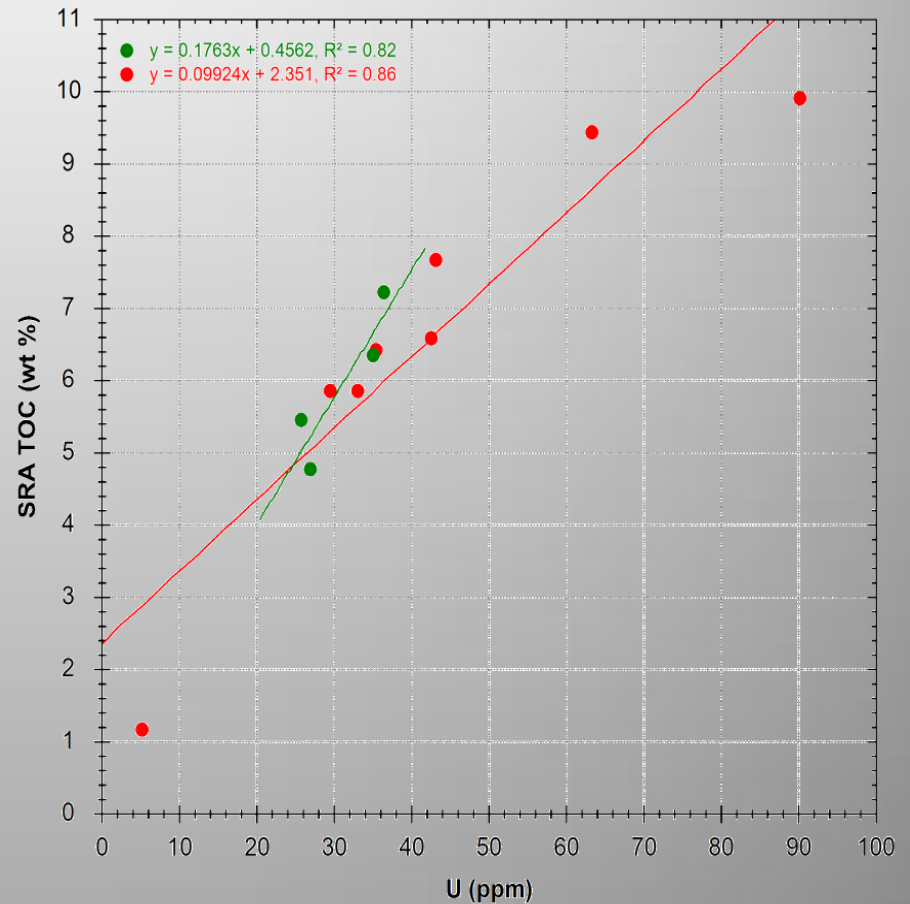


TOC vs. Uranium Correlation

Total Zone of Interest



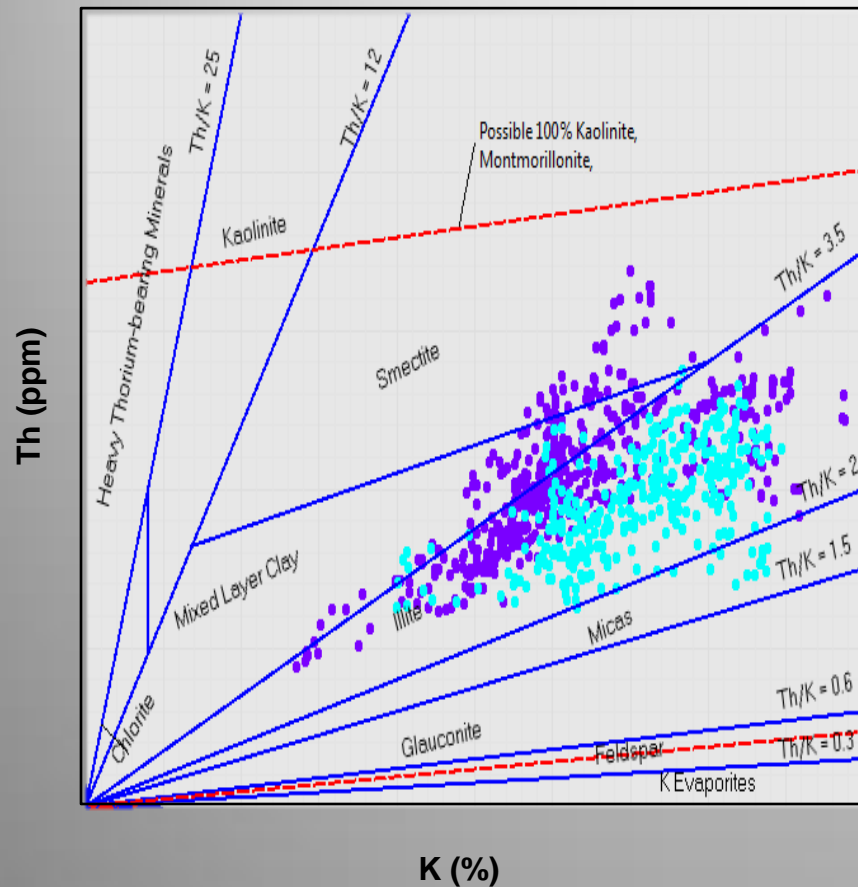
Formation A & B



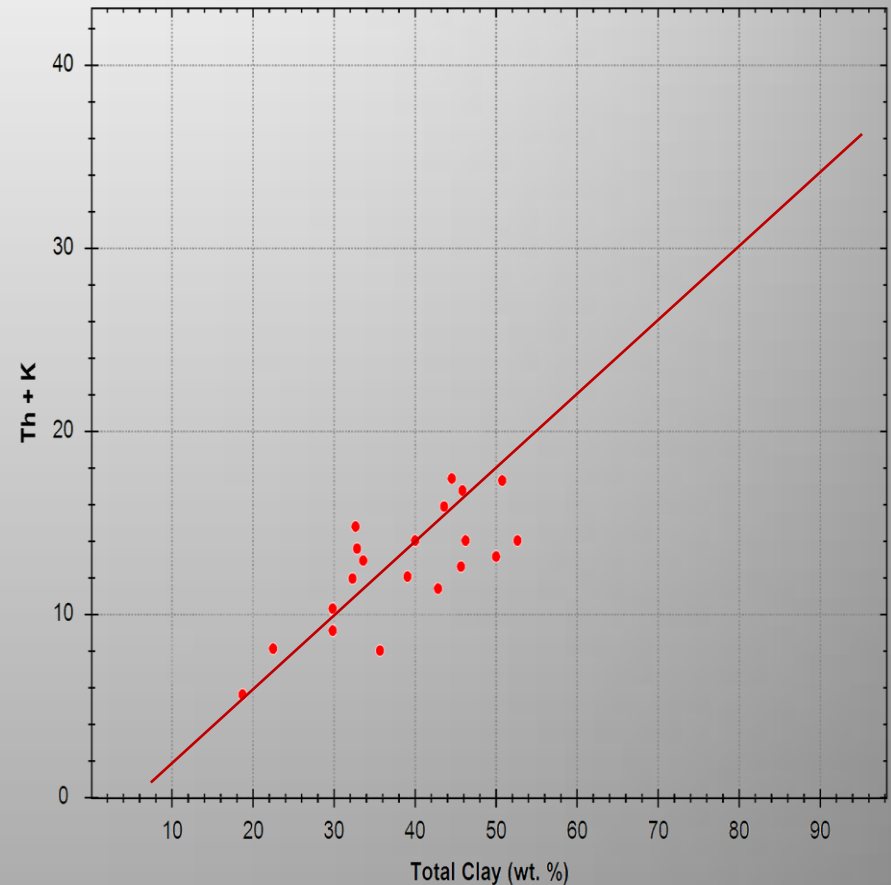
Correlations Established for Horizontal well

Clay Validations & Correlation

Clay Typing



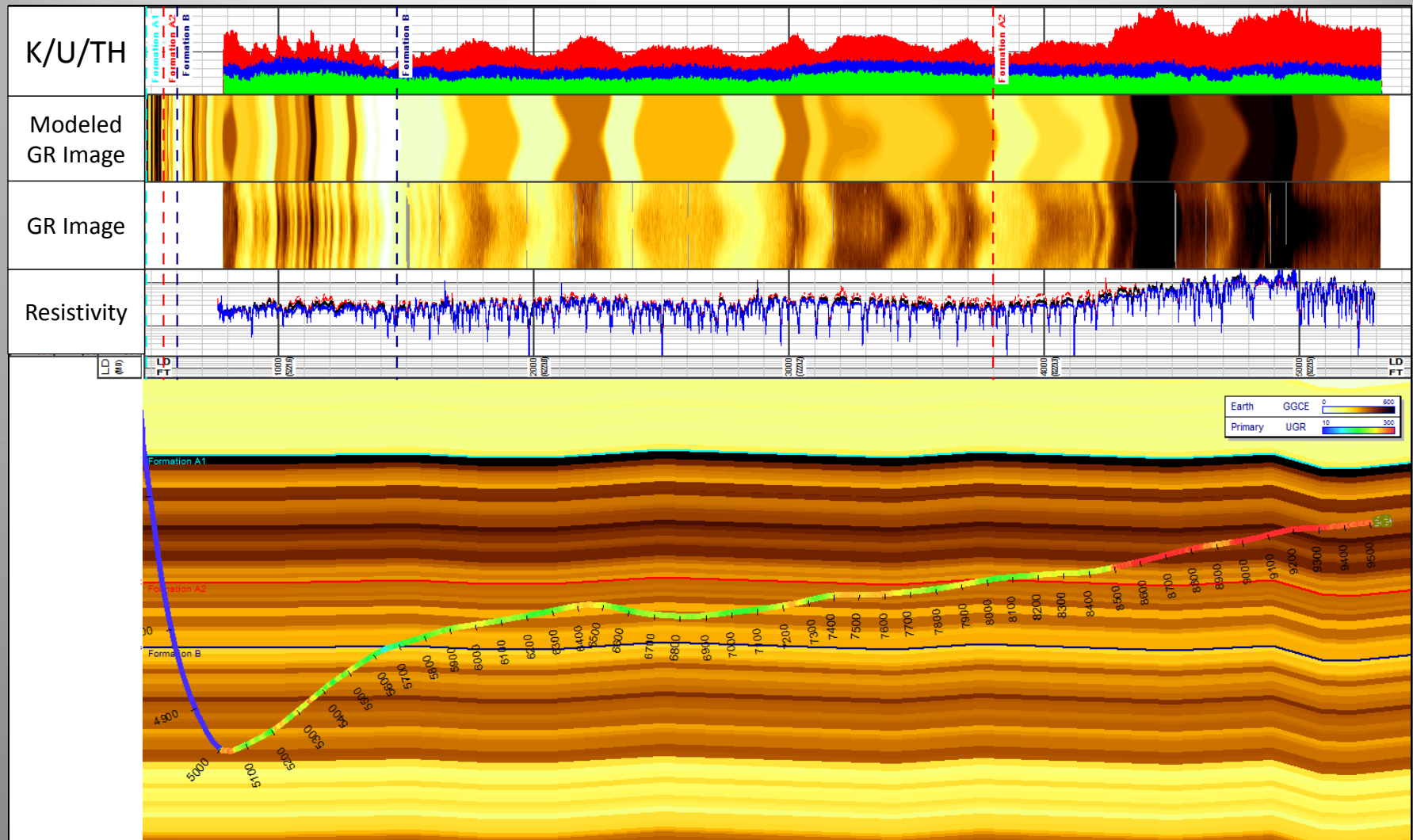
Clay Volume



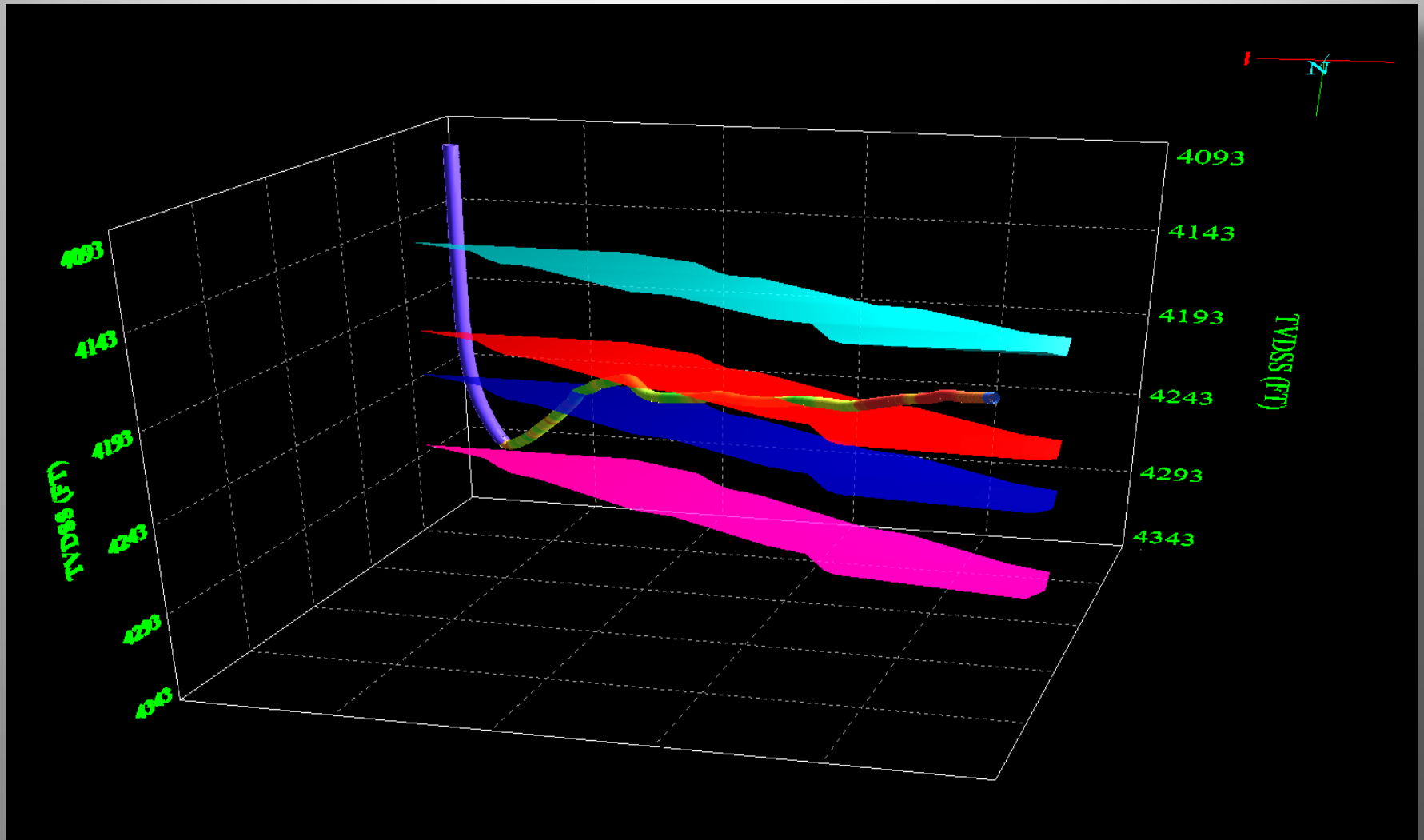
Correlations Established for Horizontal well

Horizontal Well Execution

Horizontal Well Placement

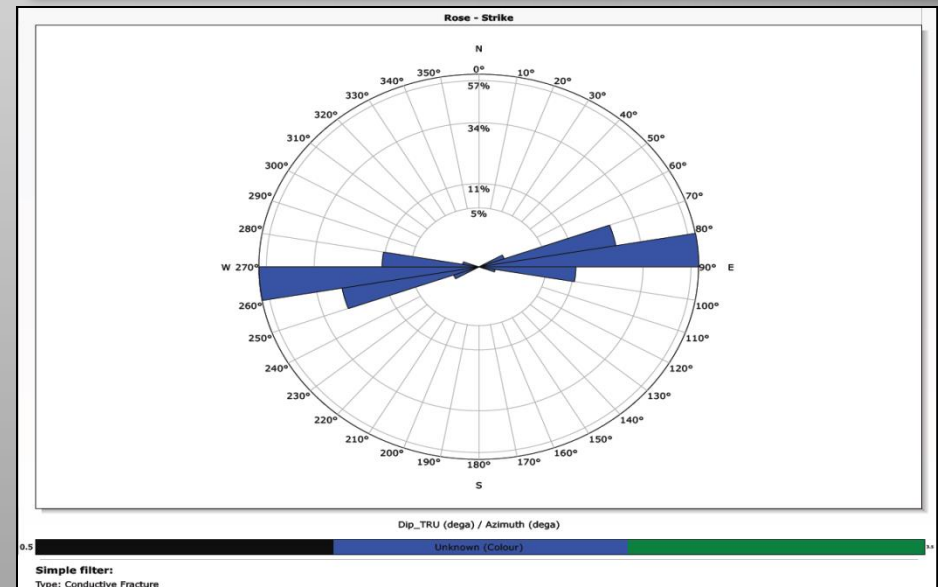
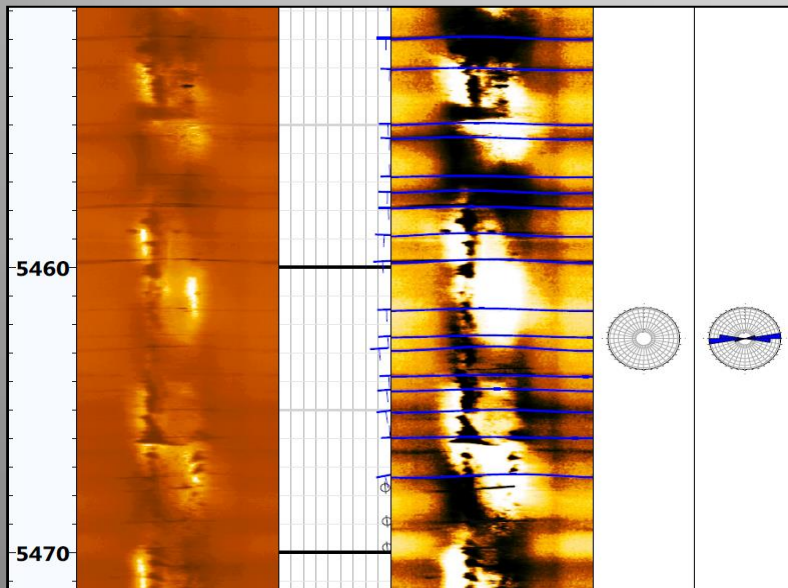
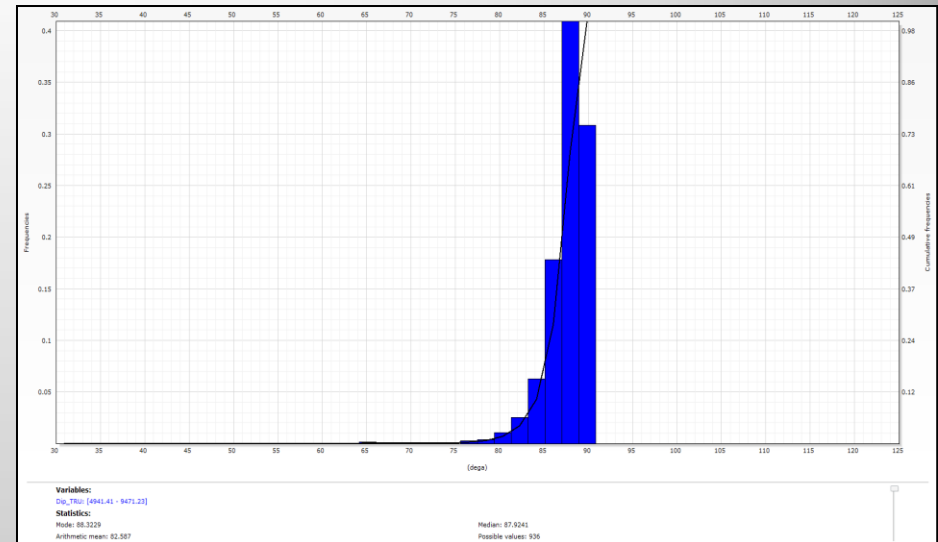


Horizontal Well Placement



Conductive Fractures

- Conductive Fractures: 865
- Dip: 88 deg.
- Strike: 270 – 90 deg.



Results

Geometric. Stages
Eng. Stages

Combined Index

Relative Fracability

Cond. Fractures

TOC

Clay Volume

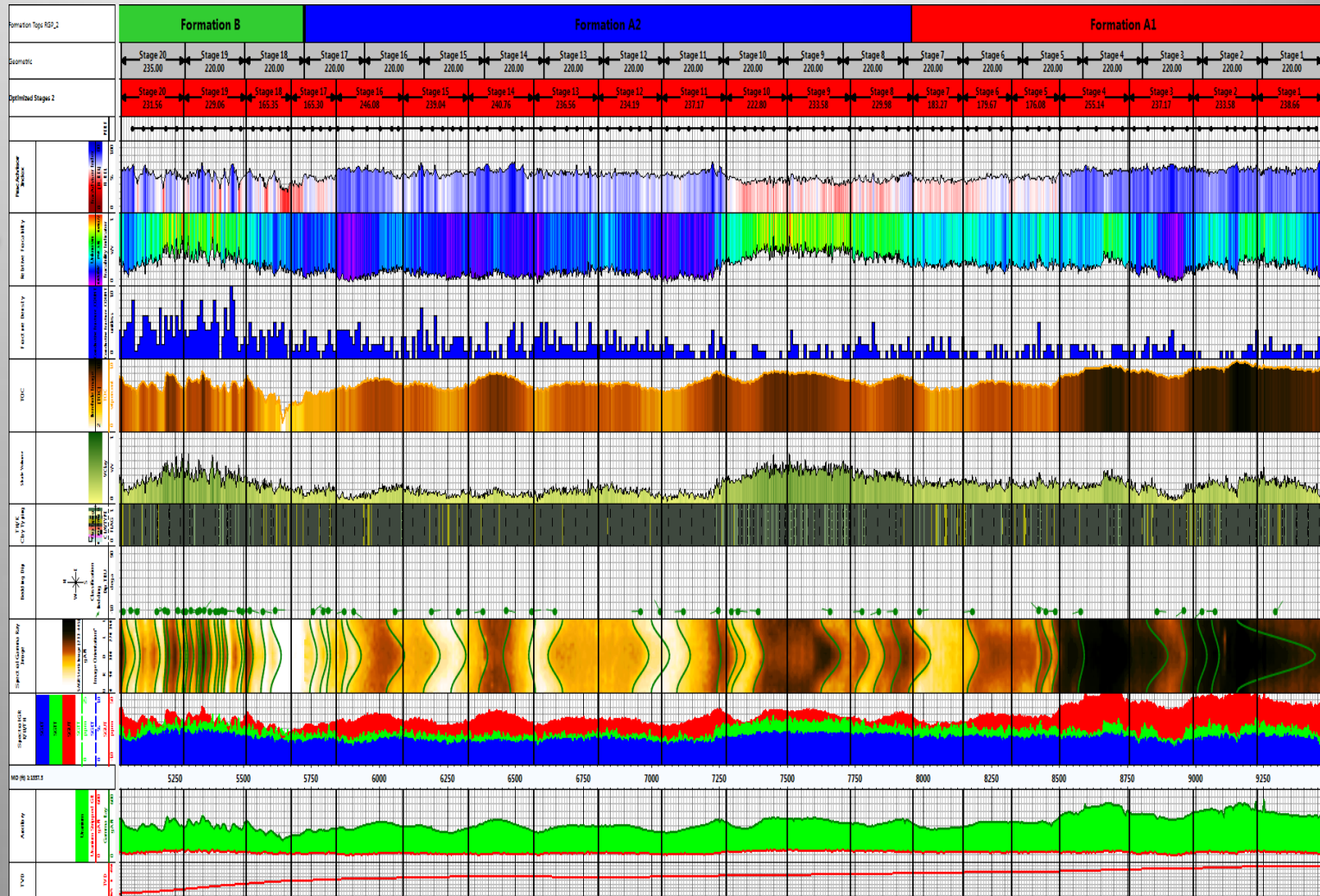
Clay Typing

Structural Dip

Spectral Image

K/TH/U

Gamma Ray



Conclusion

- Reservoir characterization in a horizontal well was improved with K/Th/U measurements.
 - TOC, Clay Volume, Clay Type
- Reservoir characterization accuracy is improved when correlations from vertical wells of multiple data acquisitions are established.
- Additional data acquisition can be added in horizontal well to improve characterization.
 - Micro-imager
 - Propagation Resistivity

Appendix

- Chou, M., Dickerson, D.R., (1979, October 3), Pyrolysis of Eastern Gas Shale- Effects of Temperature and Atmosphere on the Production of Light Hydrocarbons, Proceedings of the Third Eastern Gas Shales Symposium, p 211-223