

Fracture Simulation Parameters

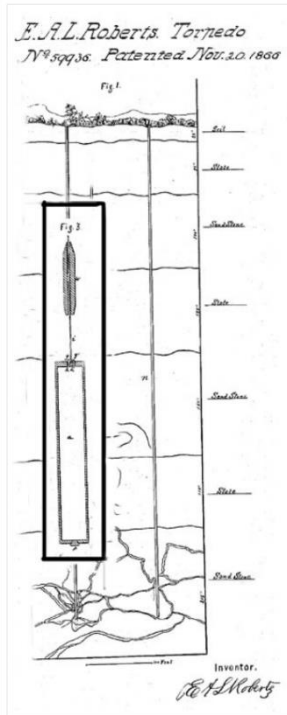
Addressing the Needs of Completion Engineers—A Petrophysical Perspective

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cgg.com



History of Fracture Simulation



Torpedoes filled with gunpowder (later nitroglycerin) were lowered into wells and ignited by a weight dropped along a suspension wire onto a percussion cap.



Pouring nitroglycerin was risky enough in late 19th century oilfields. Doing it for an illegal well "shooting" led to the term "moonlighting."



Photographs comparing of the first hydraulic fracturing operation in 1947 with a modern shale gas frac-pad



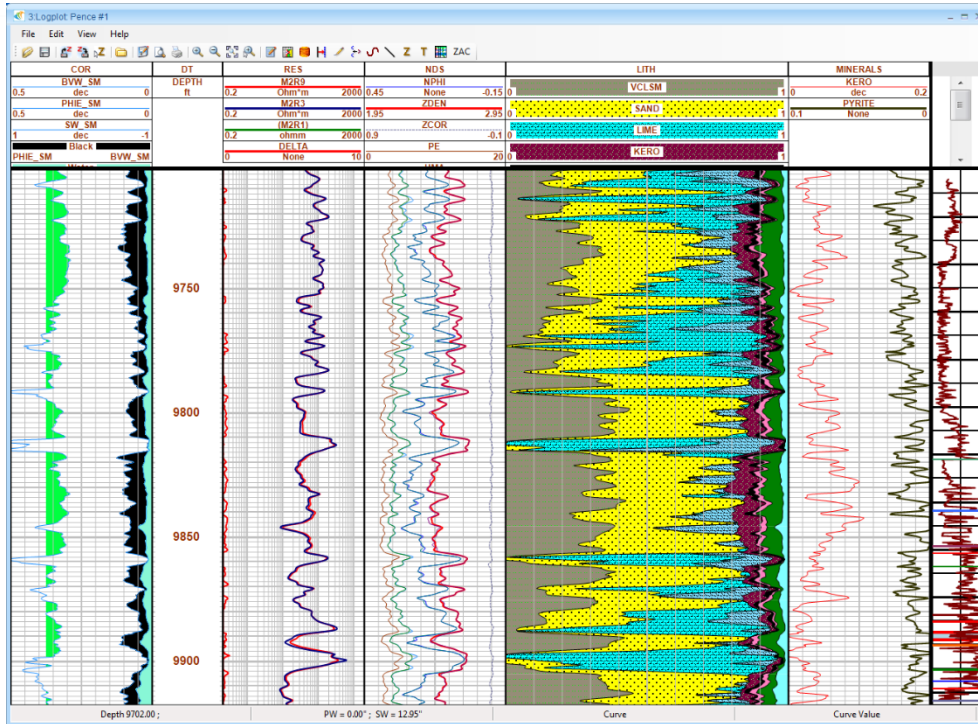


The Elements of Frac Design

- Detailed petrophysical analysis of zone of interest
- Computation or estimation of elastic properties
- Determination of rock and fluid properties
- Interval averaging of log values for input into simulator
- Parameter testing to insure rock and fluid properties match well test results
- Transfer of rock and fluid properties into simulator and run simulation



Petrophysical Evaluation



Parameters of Interest

- Water Saturation
- Porosity
- Permeability
- Clay Volume
- Lithology



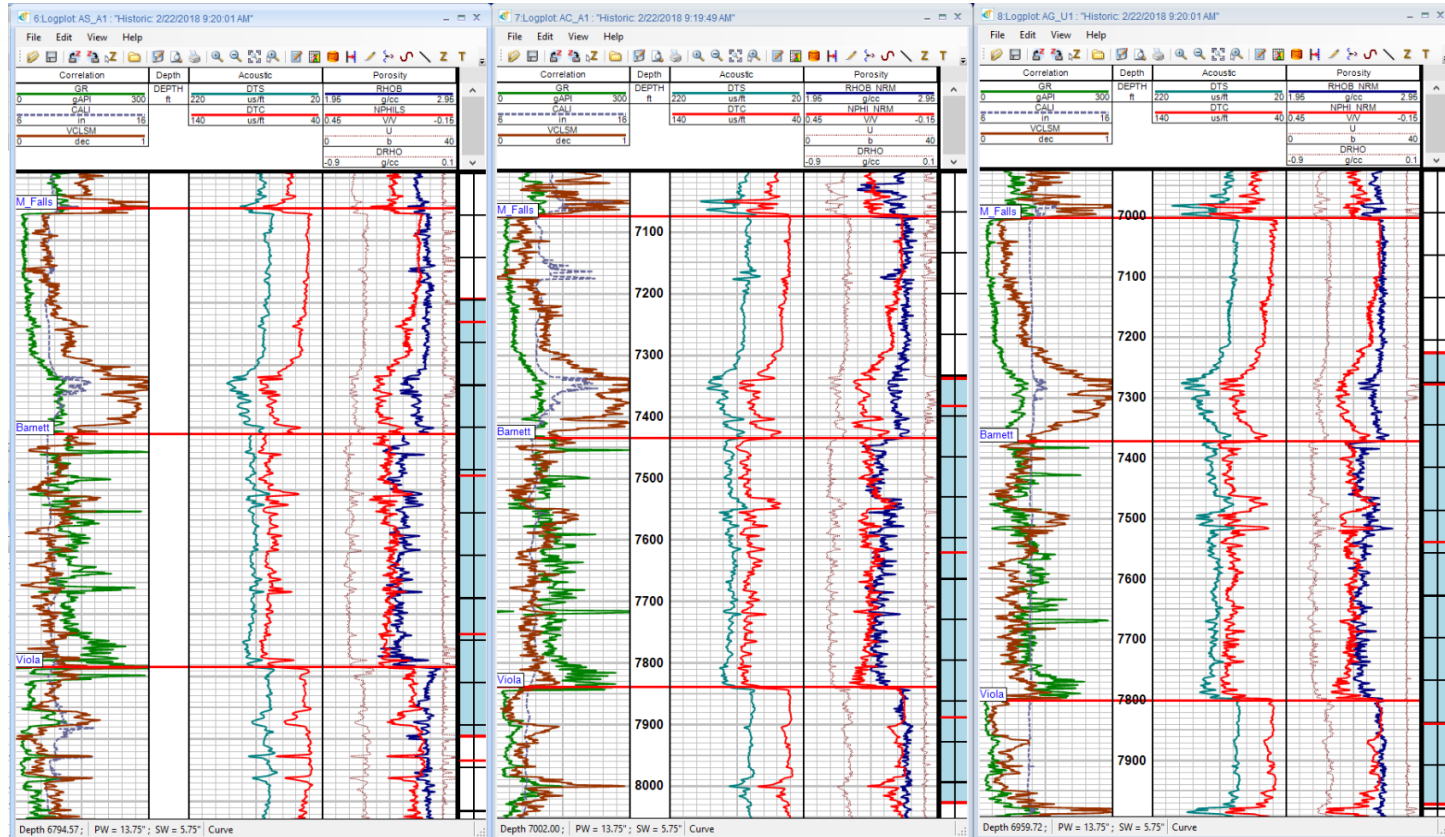


Determining Elastic Properties (wells with log data)

- Deterministic computations where compressional sonic, shear sonic, and density curve are measured over the zone of interest
- Computation of synthetic acoustics when DTS (shear acoustic log) and/or DTC (compressional acoustic log) are not acquired
 - Estimated from other logs in the well (RHOB, NPHI, DTC, GR, etc.) (Synthetic Curve Generation)
 - Generated using Deep Learning Models with Python Extensions (also using other curves)
 - Determined from a detailed rock physics model constructed over zone of interest
- Empirical equations for estimation of elastic properties when minimal logs are present



Barnett Wells with Measured DTC and DTS



Generate Synthetic DTS from Nearby Wells

1.Synthetic Curve Generator: "Historic: 2/22/2018 11:19:38 AM"

Screens ▾

Model Calculation | Model Information | Curve Editing/Generation

Reference Curve

Use	Curve	Min Value	Apply	Max Value	Apply	Log	Coef
<input checked="" type="checkbox"/>	DTS	60	Clip	260	None	<input type="checkbox"/>	

Calibration Curves Information

+	Use	Curve	Min Value	Apply	Max Value	Apply	Log	Coef
<input checked="" type="checkbox"/>	DTC		40	Clip	140	None	<input type="checkbox"/>	0.9230093
<input checked="" type="checkbox"/>	NPHLS		0	Clip	0.4	None	<input type="checkbox"/>	0.9214168
<input checked="" type="checkbox"/>	RHOB		2	Clip	3	None	<input type="checkbox"/>	0.7581958
<input checked="" type="checkbox"/>	GR		0	Clip	300	None	<input type="checkbox"/>	0.7079704
<input checked="" type="checkbox"/>	&RILD		0	None	0	None	<input checked="" type="checkbox"/>	0.6660436

Discriminators (Pass = Include Sample)

Output Samples
Samples Curve: _____

Use Cross Products
1 < Power < 4

Output Calibration Model
Shear _____ Browse...

Apply Tabular Flexible Logic AND OR

+	Apply	Argument 1	DISC	Argument 2
...

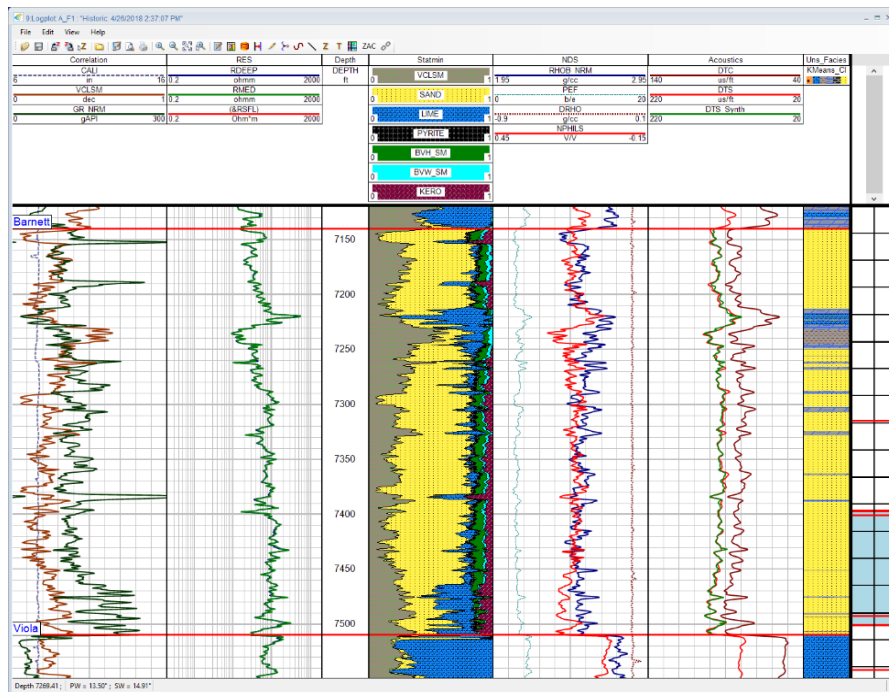
Expression _____

Help Compute 1st Order Regression Coefficient For Each Curve Close Run Parameters Calculation History Ready

Wells and Intervals

AS_A1; A_A1; AC_A1;

Well	Interval	Sampling Grid
1 AS_A1	WorkingInter...	Default
2 A_A1	WorkingInter...	Default
3 AC_A1	WorkingInter...	Default



Deep Learning Model for Synthetic DTS

jupyter Multiwell_deep_learning_Synthetic_Curve_Generator_v1.0 Last Checkpoint: 17 hours ago (autosaved)

File Edit View Insert Cell Kernel Widgets Help Python 3

Out[285]: Show or Hide code

This workflow uses deep learning to train a model and predict selected curves

Training Step 1: Define the zone, curves to fetch and the target for training the model

You can change the interval, grid or curves to fetch by modifying the fields below

Training Step 2: Preprocessing the dataset and splitting it for training

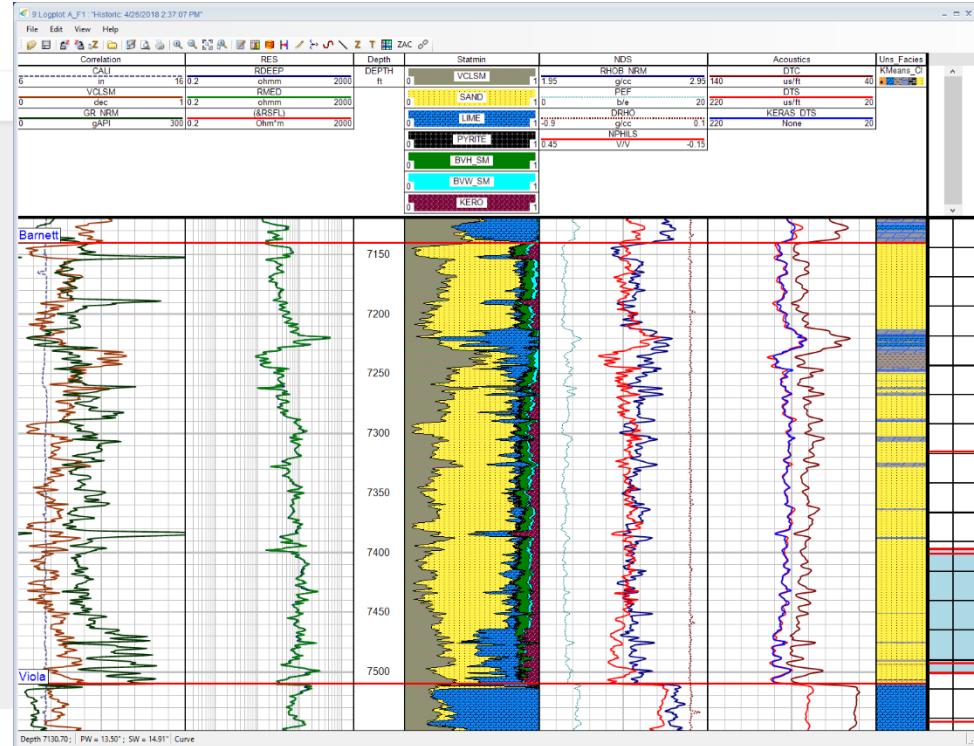
Preprocessing the data is an important step. This can involve dropping NULLS and optionally scaling the dataset. Scaling the dataset allows the algorithms to converge faster.

Training Step 3: Define and Calibrate the deep learning model and train the model.

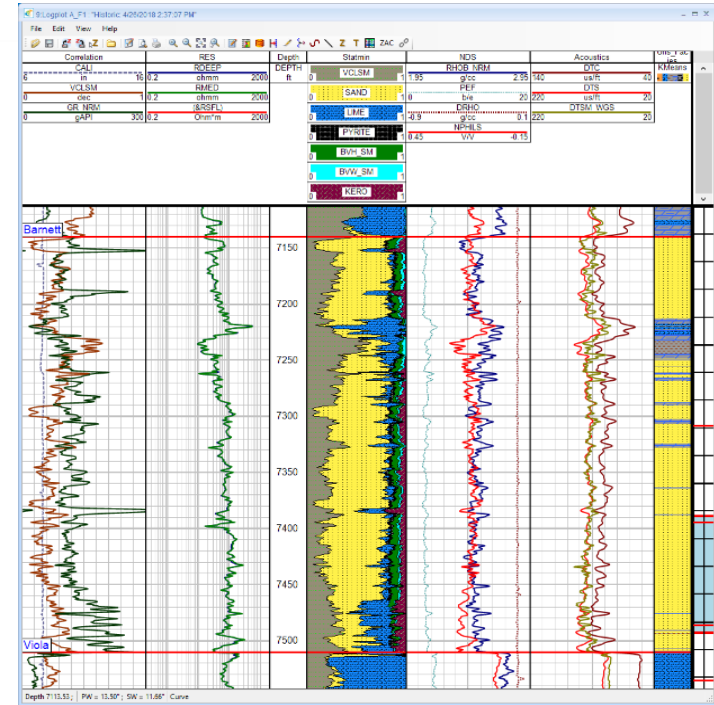
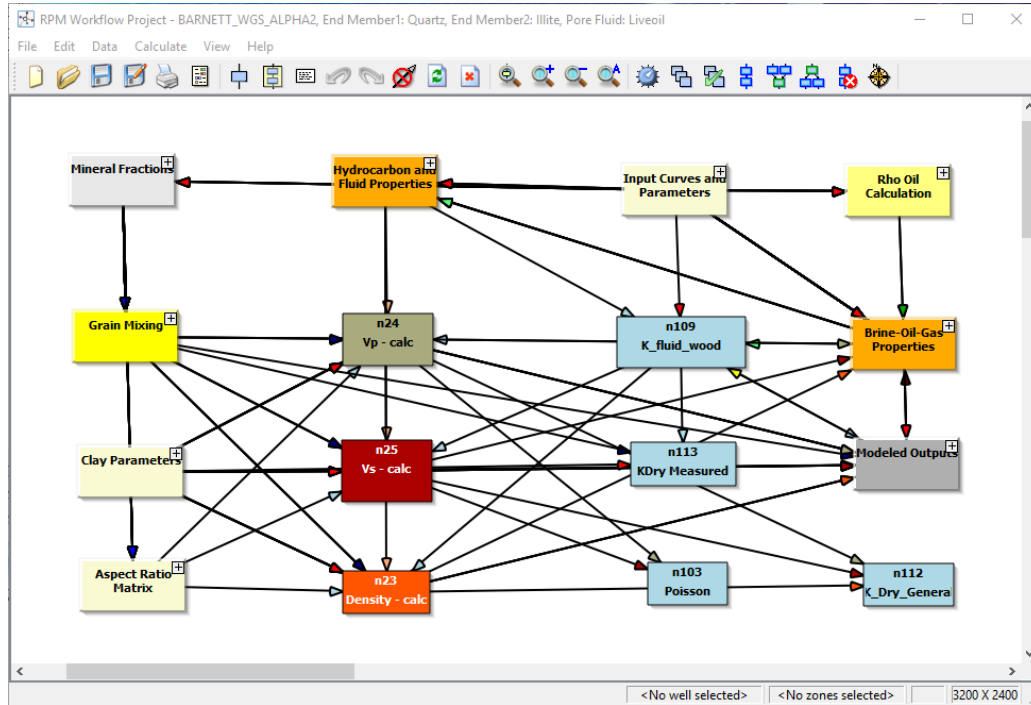
Training Step 4: Save the model for future predictions

Predictions Step 1: Load the model to predict

Predictions Step 2 :Select the well(s) in Powerlog to make a prediction



Rock Physics Models for Elastic Properties



Required inputs for rock physics modeling include lithology, porosity, water saturation, pressure, temperature, and fluid properties. The aspect ratio is estimated based on lithology.



Computing Elastic Properties (Python Script)

The screenshot shows the 'Elastic_Property_Calculator Multiwell' application. The 'Wells' section contains the well name 'A_A1; A_D1; A_F1; AC_A1; A6_U1; AS_A1; B_5WD1;'. The 'Inputs' section is expanded to show 'Bulk Density' with 'RHOB' and 'Velocity' with 'Vp' and 'Vs'. The 'Outputs' section shows 'Vp' with units 'ft/sec' and 'P Velocity'. Below this is a table for 'Intervals' with columns for 'Use', 'Start (ft)', 'Stop (ft)', 'Zone', and 'Zone for Parameters'. The first row is checked and labeled 'WorkingInterval'. At the bottom, there is a 'Sampling Grid' set to 'Default' and 'Run' and 'Close' buttons.

The screenshot shows the Spyder Python IDE with a Python script for calculating elastic properties. The script is as follows:

```
1 from plconnect.processing import debug
2 #from plconnect.functions import*
3
4
5 def run_extension(info):
6     data = info.curve_data
7     #code for run_extension that is invoked per well-interval
8
9     data.Kpy = (data.RHOB*((data.Vp*data.Vp) - (4/3)*(data.Vs * data.Vs)))*92.90304
10    data.Gpy = (data.RHOB*(data.Vs*data.Vs))*92.90304
11    data.Poispy = (((data.Vp**2) - (2*(data.Vs**2)))/(2*((data.Vp**2) - (data.Vs**2))))
12    data.Youngpy = (((data.RHOB*(data.Vs**2))*((3*(data.Vp**2)) - (4*(data.Vs**2)))/((data.Vp**2) - (data.Vs**2)))*92.90304
13
14
15
16
17 if __name__ == '__main__':
18     debug(__file__)
19
```

The right sidebar shows a 'Usage' help window and a 'Python console' window. The status bar at the bottom indicates 'Permissions: RW', 'End-of-lines: CRLF', 'Encoding: ASCII', 'Line: 12', 'Column: 125', and 'Memory: 41 %'.



Empirical Estimation of Elastic Properties

Multiplier to match known values when available

4:FracRat Calculations: Bourne #3 - "Historic: 4/13/2017 11:27:04 AM"

Screens ▾

Bourne #3

Setup Rock Properties Fluid Loss Properties GC Parameter Tuning

Young's and Poisson's
Poisson's Cal (dec) 1
Young's Cal 1

Young's Correction Method Lacy Sandstone, Shale, Limestone ▾

Density Input
Bulk Density (g/cc) ZDEN Bulk Density Shale (g/cc) 2.58

Sonic Input
DTC (us/ft) DTPM_WGS
DTS (us/ft) DTSM_WGS

Critical Stress
 Input Critical Stress Critical Stress Input (psi) 0

Fracture Toughness
Minimum (psi*in^{1/2}) 500 Maximum (psi*in^{1/2}) 1750

Rock Properties
Stress Gradient (psi/ft) StressGR
Stress (psi) Stress
Young's Modulus (psi) YM_ST
Poisson's Ratio (dec) P_RAT_ST
Fracture Toughness (psi*in^{1/2}) Frac_tough
Critical Stress (psi) Stress_Crit
Lithology Lith
Export...

	Interval		Zone	Zone for Parameters
	Start (ft)	Stop (ft)		
1	Upper_WC-320	Mid_WC+300	<input checked="" type="checkbox"/> Upper_Wolfcamp	

Sampling Grid
Default ▾

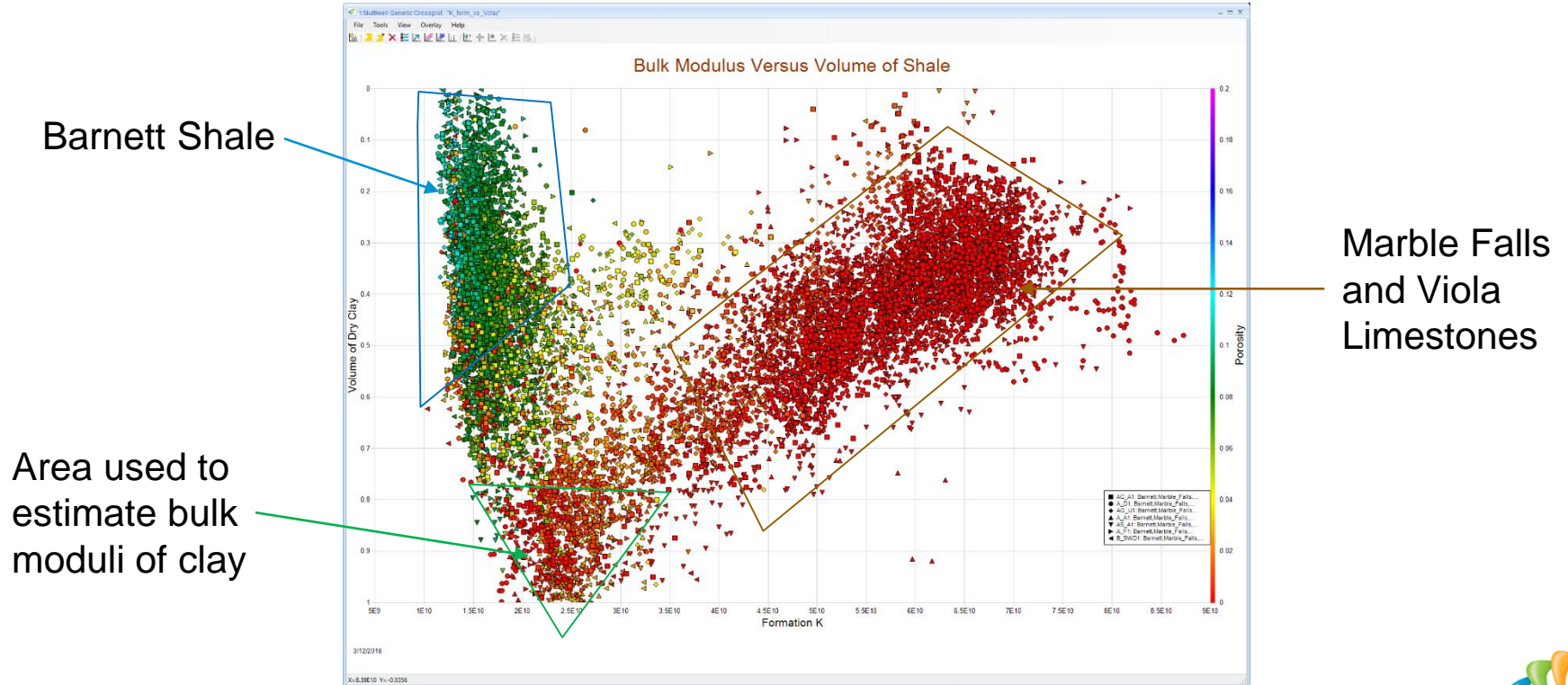
Help History Close Run

Enter values and click Run

- Empirical options for estimation of Poisson's Ratio and Young's Modulus
 - De-Hua Han
 - Castagna
 - Neutron

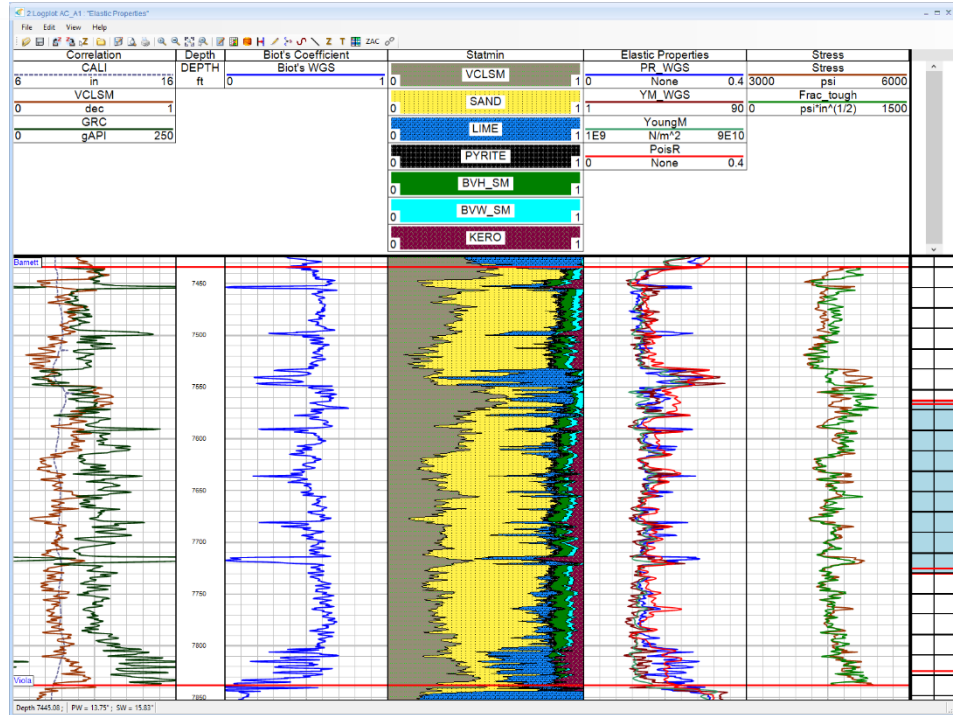


Bulk Moduli versus Vshale (Color Scale is Porosity)



Biot's Coefficient (Required Input for Some Simulation Packages)

The full rock physics modeling for elastic properties enables estimated determination of Biot's Coefficient along with the Poisson's Ratio and Young's Moduli. The Stress computations were performed in FracRAT.



Biot's = $1 - K_{dry}/K_o$ where K_o is KVRH, the bulk moduli of the rock framework (Mavko, Mukerji, and Dvorkin, The Rock Physics Handbook, 1998)



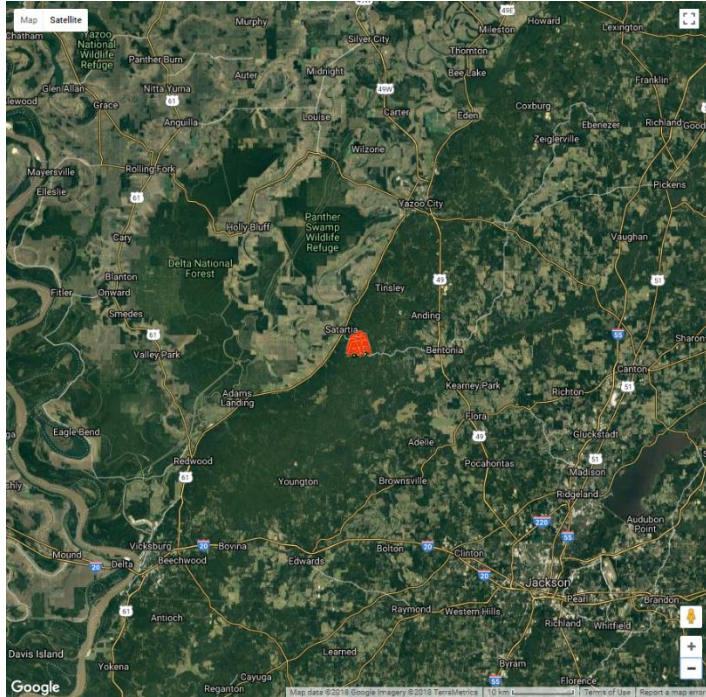


Frac Preparation Examples

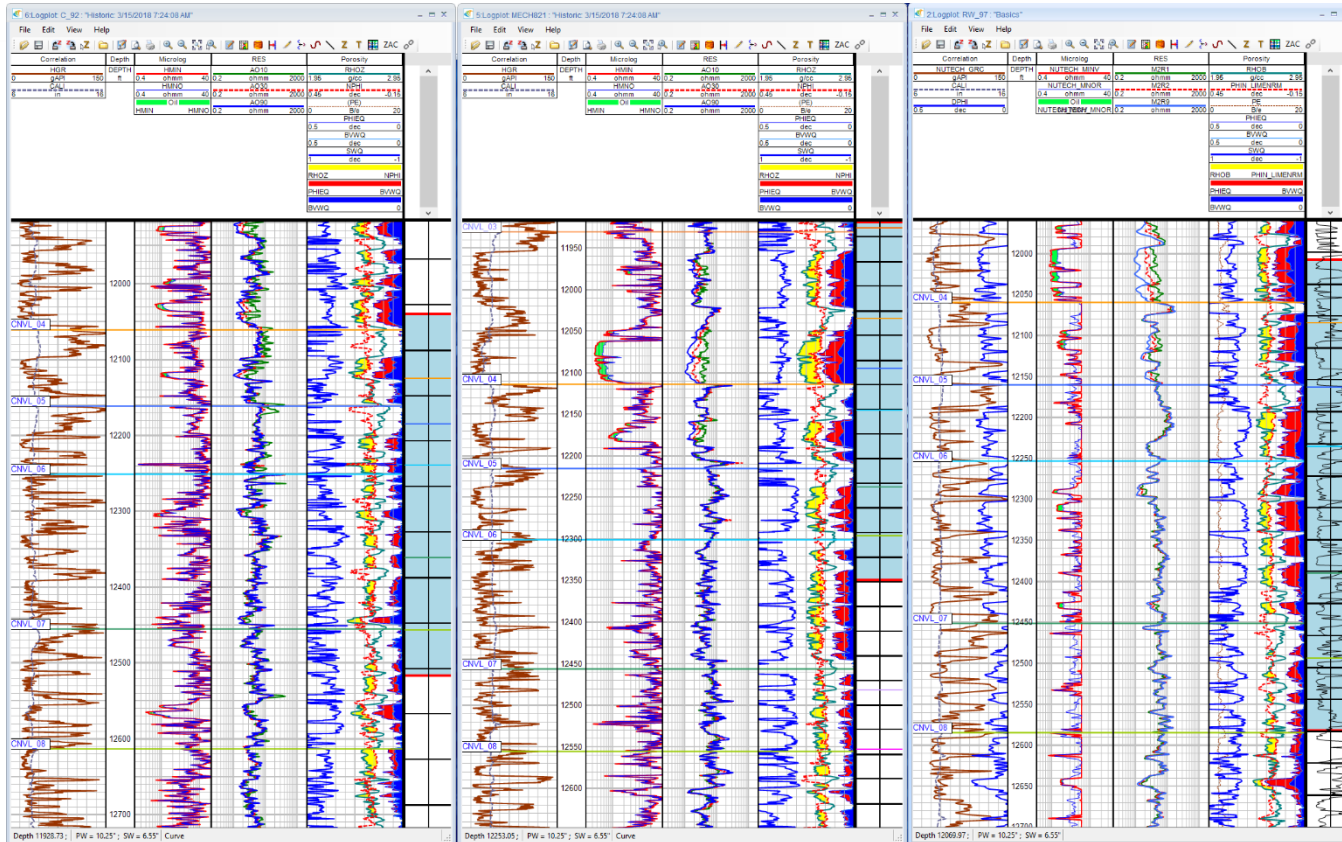
- **Mississippi tight gas sand example**
 - Cotton Valley formation, upper Jurassic age
 - Low porosity clastic sandstones (very common case globally)
 - Partially depleted after initial completion including frac
 - Post frac tracer survey very useful
 - Planned recompletion, never executed
- **West Texas Unconventional example**
 - Spraberry Wolfcamp formations, Permian age
 - High Kerogen content
 - Uranium salts associated with high Kerogen volume rocks
 - Actual frac design did not use analysis results



Mechanicsburg Field, Mississippi



Mississippi Tight Gas Sands



Generate Modeled DTC and DTS

1-Synthetic Curve Generator: "Historic: 6/20/2016 3:20:51 PM"

Screens ▾

Model Calculation | Model Information | Curve Editing/Generation

Reference Curve

Use	Curve	Min Value	Apply	Max Value	Apply	Log	Coef
<input checked="" type="checkbox"/>	DTSM	0	None	0	None	<input type="checkbox"/>	

Calibration Curves Information

Use	Curve	Min Value	Apply	Max Value	Apply	Log	Coef
<input checked="" type="checkbox"/>	&NPHI	0	None	0	None	<input type="checkbox"/>	0.7958981
<input checked="" type="checkbox"/>	&RSFL	0	None	0	None	<input checked="" type="checkbox"/>	0.583539
<input checked="" type="checkbox"/>	&RILD	0	None	0	None	<input checked="" type="checkbox"/>	0.4773054
<input checked="" type="checkbox"/>	&GR	0	None	0	None	<input type="checkbox"/>	0.2140206
<input type="checkbox"/>	&PE	0	None	0	None	<input type="checkbox"/>	0.004937515
<input type="checkbox"/>	&RHOB	0	None	0	None	<input type="checkbox"/>	0.003524255

Output Samples
Samples Curve: Test

Use Cross Products
1 < Power < 7
Output Calibration Model
Calc Browse...

Discriminators (Pass = Include Sample)

Apply Style Logic
 Tabular Flexible AND OR

Apply	Argument 1	DISC	Argument 2
<input checked="" type="checkbox"/>	DCAL	<=	2

Expression

Help Compute 1st Order Regression Coefficient For Each Curve Close Run Parameters Calculation History Ready



Calculate Rock and Fluid Properties

2:FracRat Calculations: RW_97: "Historic: 3/8/2018 2:00:11 PM"

Screens ▾
RW_97

Setup Rock Properties Fluid Loss Properties QC Parameter Tuning

Young's and Poisson's
 Poisson's Cal (dec) Poisson's Method **Sonic** ▾
 Young's Cal Dynamic Youngs Method **Sonic** ▾
 Young's Correction Method **Lacy Sandstone** ▾

Density Input
 Bulk Density (g/cc) **RHOB_NRM** Bulk Density Shale (g/cc)

Sonic Input
 DTC (us/ft)
 DTS (us/ft)

Critical Stress
 Input Critical Stress Critical Stress Input (psi)

Fracture Toughness
 Minimum (psi^{1/2}) Maximum (psi^{1/2})

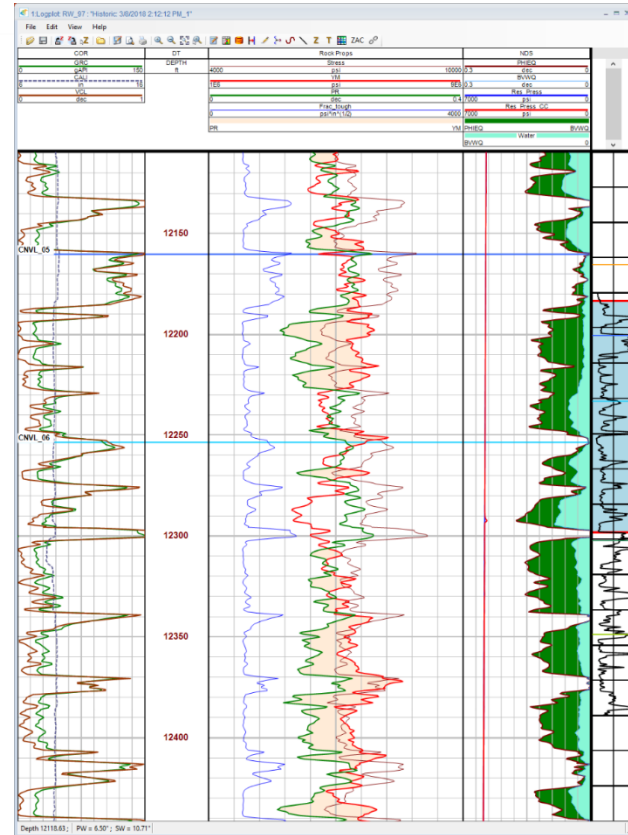
Rock Properties
 Stress Gradient (psi/ft) **StressGR**
 Stress (psi) **Stress**
 Young's Modulus (psi) **YM**
 Poisson's Ratio (dec) **PR**
 Fracture Toughness (psi^{1/2}) **Frac_tough**
 Critical Stress (psi) **Stress_Crit**
 Lithology **Lith**
 Export...

Interval	Interval		Zone	Zone for Parameters
	Start (ft)	Stop (ft)		
1	12100	12700	<input type="checkbox"/> WorkingInterval	

Sampling Grid
 Default ▾

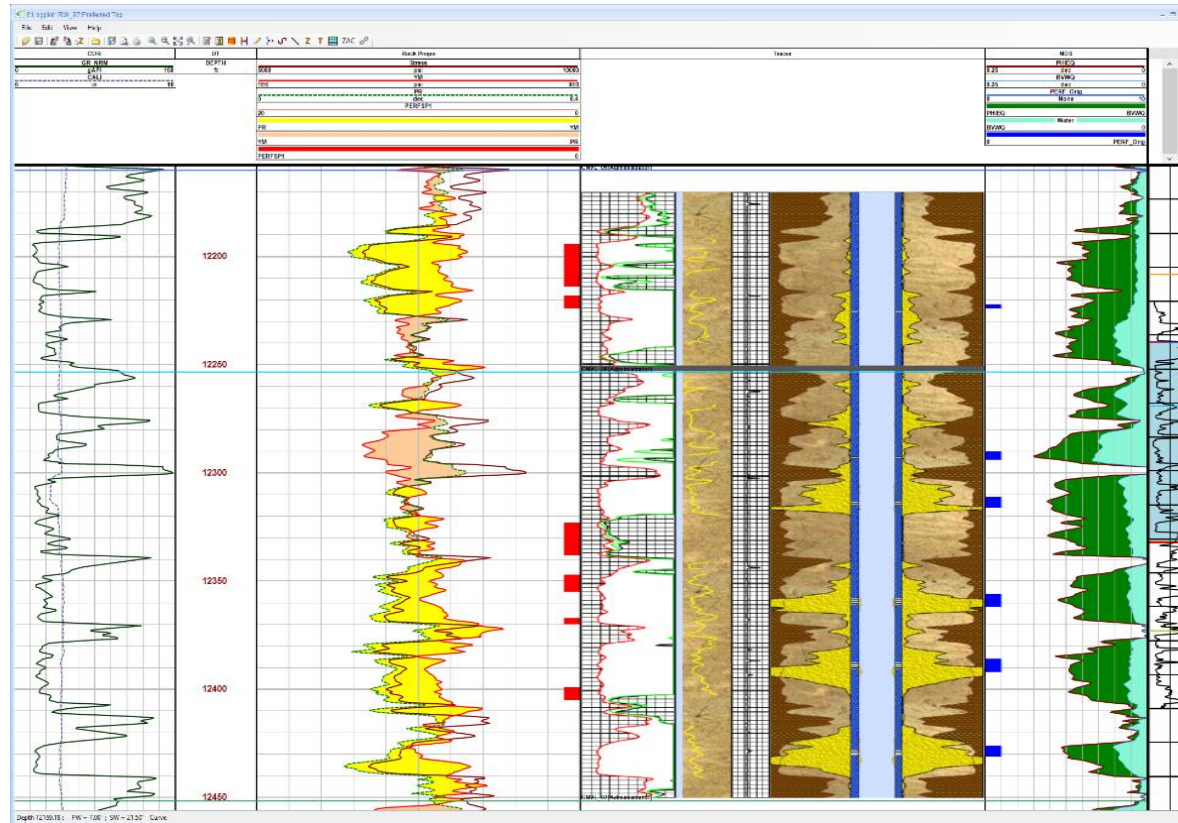
Help History Close Run

Calculation Complete





Post Frac Tracer Surveys





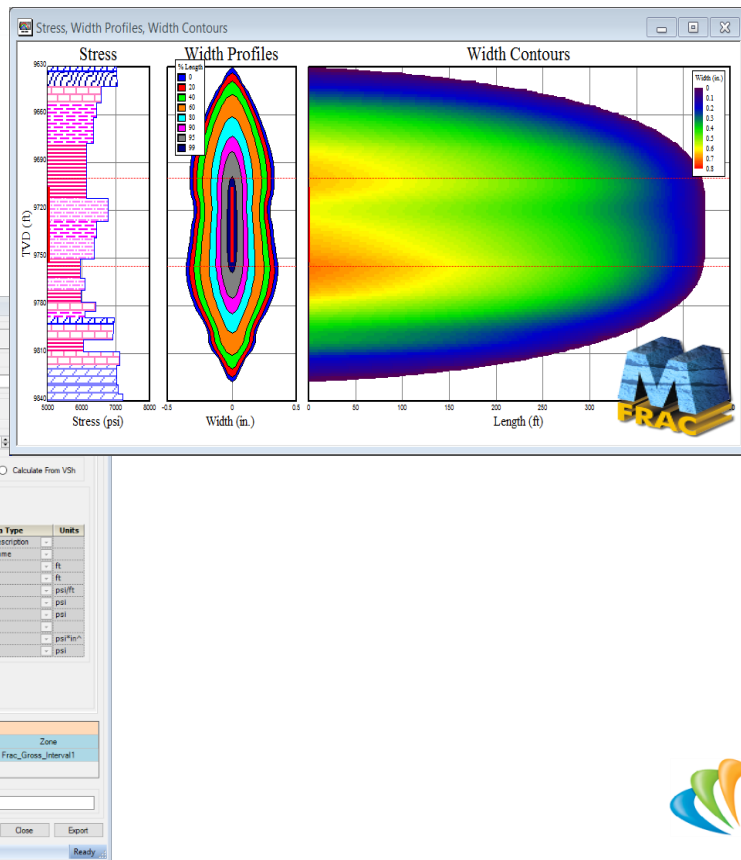
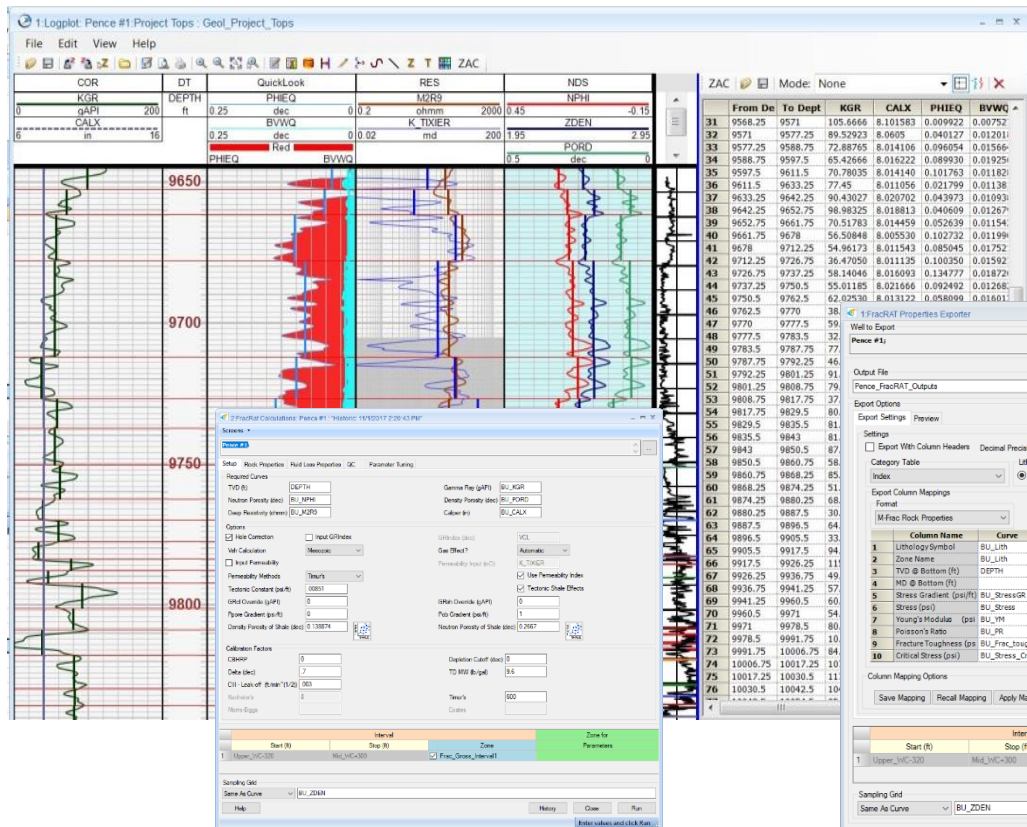
Spraberry Wolfcamp Unconventional Example

The next section deals with design of a frac in an unconventional reservoir with minimal log suite. No advanced acoustic data is available in any of these wells. There is no cartographic data associated with these wells, so no Google Maps can be displayed.

FracRAT (a module of PowerLog) is used to generate the rock and fluid properties for input into the fracture simulation software package. In this case we are using Mfrac for simulation.

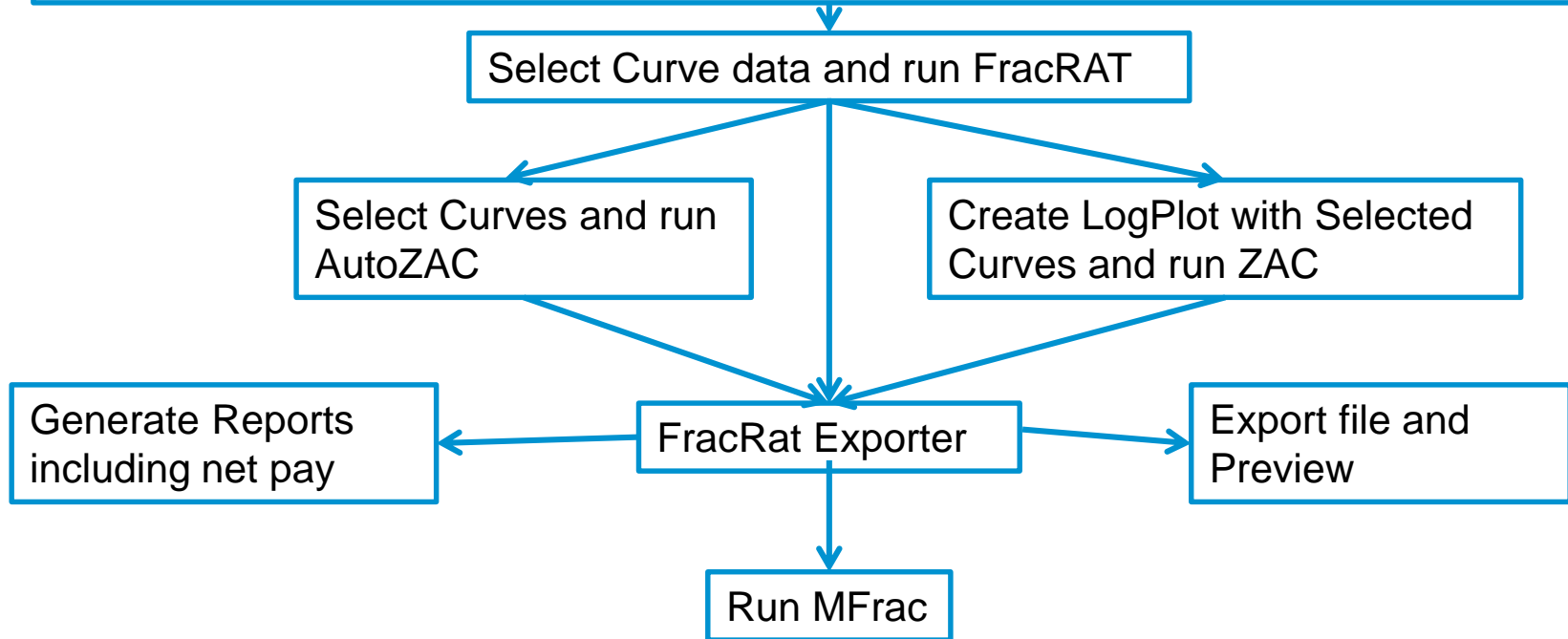


Elements of PowerLog Frac - MFrac Workflow



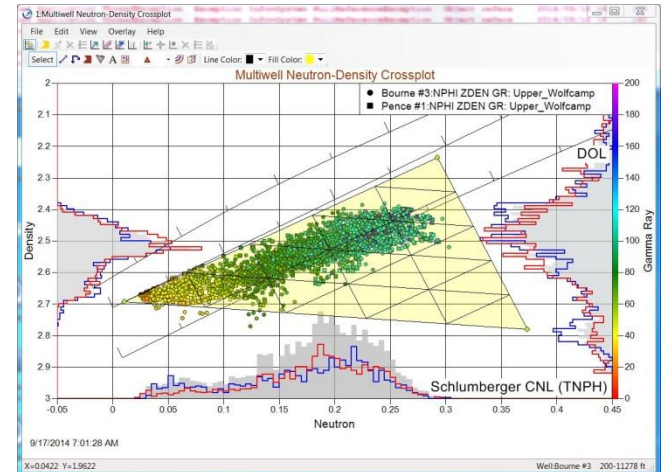
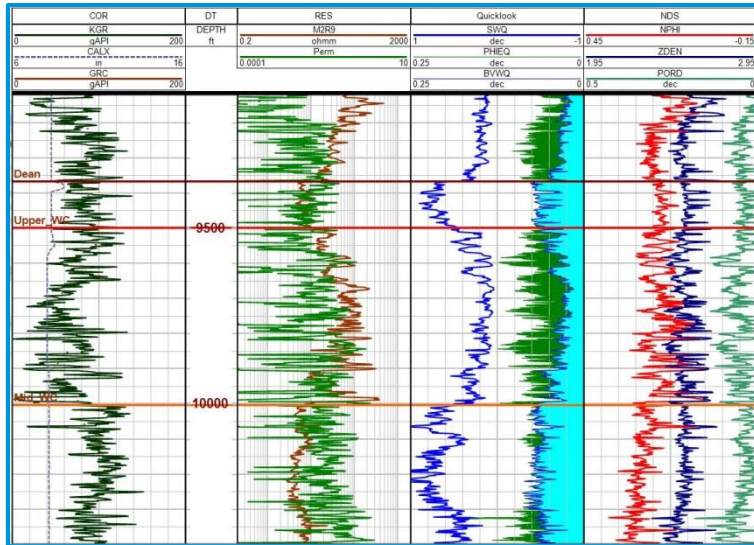
PowerLogFrac Workflow

Load well data into PowerLog, edit curves, process curves, generate new curve data, compute TVD, etc.

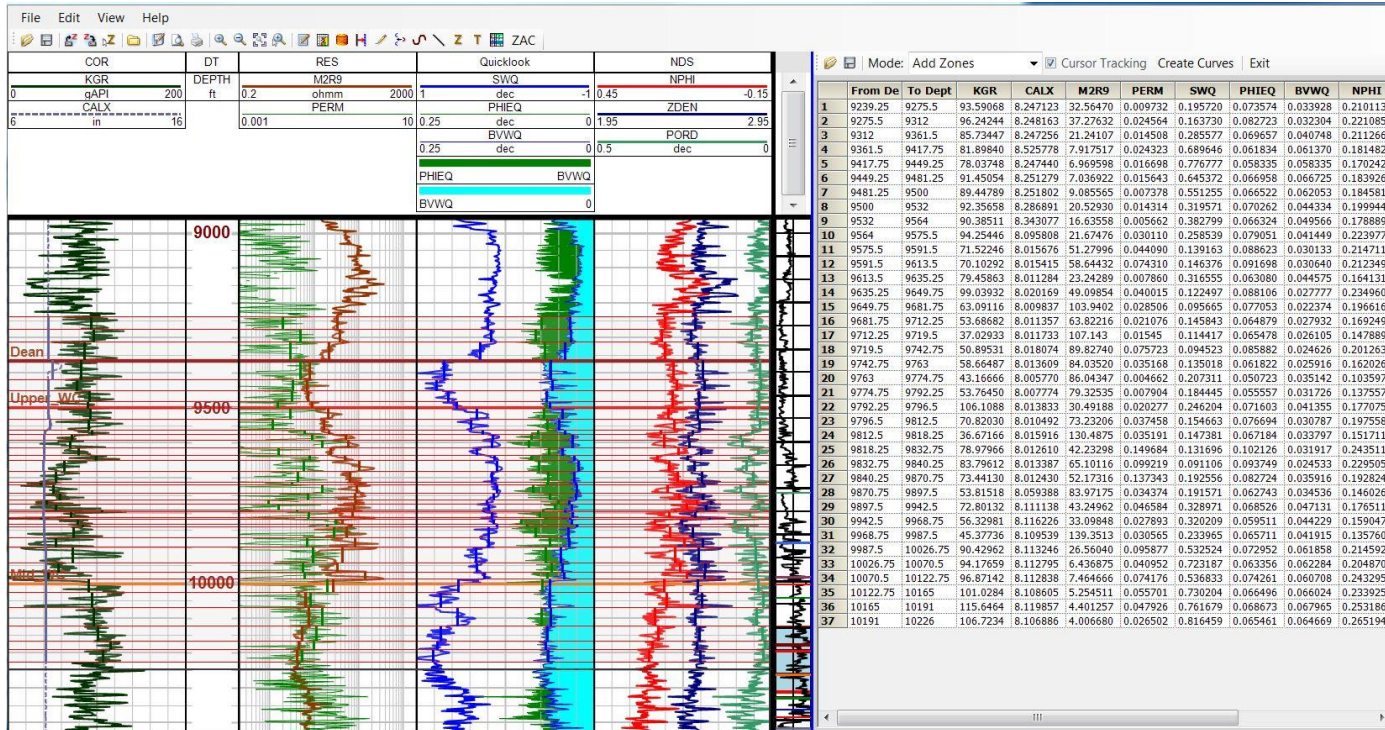


PowerLog: Petrophysical package

Load well data, edit curves, process curves, generate new curve data, compute TVD, etc.



ZAC (Zone Average Calculator)



FracRAT Module Setup Tab (Tab 1)

The screenshot displays the '1:FracRat: Pence #1' window with the 'Setup' tab selected. The window is divided into several sections for configuring well parameters:

- Required Curves:** Fields for TVD (ft) [DEPTH], Neutron Porosity (dec) [BU_NPHI], Deep Resistivity (ohmm) [BU_M2R9], Gamma Ray (gAPI) [BU_KGR], Density Porosity (dec) [BU_PORD], and Caliper (in) [BU_CALX].
- Options:** Includes checkboxes for Hole Correction (checked), Input GRIndex, and Input Critical Stress. Other options include Vsh Calculation (Mesozoic/C), Permeability Methods (Timur's), and various override and gradient fields.
- Calibration Factors:** Fields for BHRP (psi/ft), Delta (dec), CIII - Leak-off (ft/min^{1/2}), Depletion Cutoff (dec), TD MW (lbs/gal), and Timur's.
- Interval Table:** A table with columns for Interval, Start (ft), Stop (ft), Zone, and Zone for Parameters. Row 1 shows 'Upper_Spra' to 'Wet_Lime' in the 'Zone' column.
- Sampling Grid:** A dropdown menu set to 'Same As Curve' with 'BU_NPHI' entered in the adjacent field.

Buttons for 'Help', 'Close', and 'Run' are located at the bottom of the window. A status bar at the bottom right reads 'Enter values and click Run'.

Select the curve data for input and set up parameters for determining many of the essential parameters for use in frac simulation

Has multiple options for computing Vsh and calculating permeability including allowing externally generated curve data.



FracRAT Module Rock Properties Tab (Tab 2)

2.FracRat: Pence #1

Screens ▾
Pence #1;

Setup | Rock Properties | Fluid Loss Properties | QC | Parameter Tuning

Young's and Poisson's
Poisson's Cal (dec) 1 Poisson's Method Neutron
Young's Cal 1 Dynamic Youngs Method Neutron
Young's Correction Method Lacy Sandstone, Shale, Limestone

Density Input
Bulk Density (g/cc) BU_ZDEN Bulk Density Shale (g/cc) 2.5015

Sonic Input
DTC (us/ft) DTC
DTS (us/ft) DTS

Critical Stress
 Input Critical Stress Critical Stress Input (psi) 0

Fracture Toughness
Minimum (psi-sqrt(in)) 500 Maximum (psi-sqrt(in)) 1500

Rock Properties
Stress Gradient (psi/ft) StressGR
Stress (psi) Stress
Young's Modulus (psi) YM
Poisson's Ratio (dec) PR
Fracture Toughness (psi-sqrt(in)) Frac_tough
Critical Stress (psi) Stress_Crit
Lithology Lith
Export...

	Start (ft)	Interval Stop (ft)	Zone	Zone for Parameters
1 Upper_Spra		Wet_Lime	<input checked="" type="checkbox"/> Frac_Gross_Interval	

Sampling Grid
Same As Curve ▾ BU_ZDEN

Help Close Run

Enter values and click Run

Choose the methodologies for computing Poisson's Ratio and Young's Modulus and set a range for fracture toughness

Generates the rock properties



FracRAT Module Fluid Loss Properties (Tab 3)

The screenshot displays the 'Fluid Loss Properties' tab in the FracRAT software. The interface is organized into several sections:

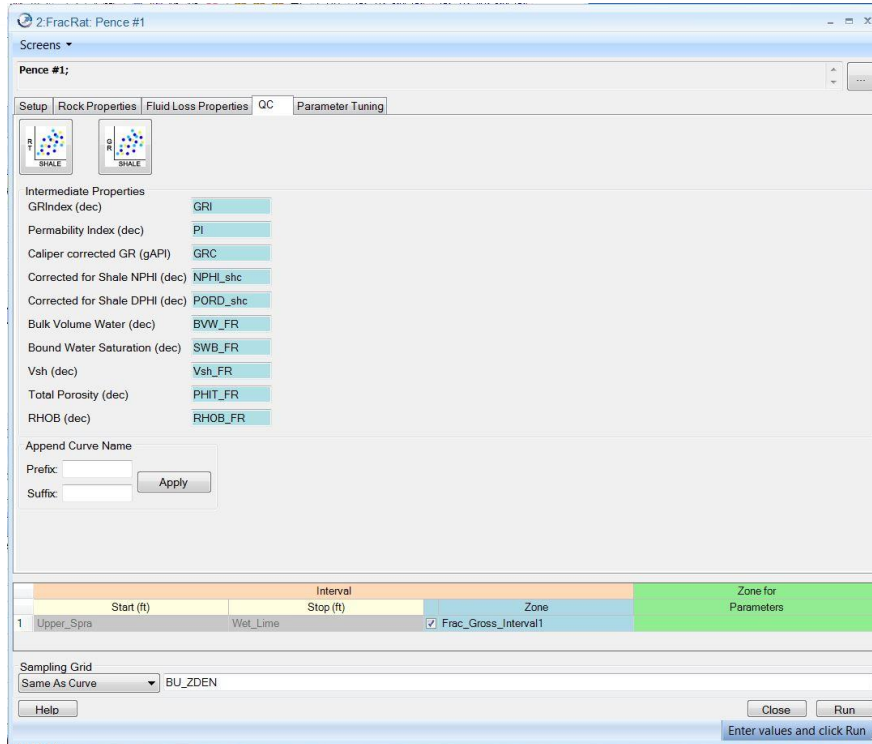
- Fluid Properties:** Includes input fields for Fluid Visc. Filtrate (cP) set to 1, Spurt Loss (gal/ft²) set to 0, Reservoir type set to Gas Reservoir, and Viscosity (cP) set to 0.25.
- Fluid Loss Properties:** A list of properties with corresponding buttons: Reservoir Pressure Gradient (psi/ft) (RPG), Reservoir Pressure (psi) (ISIP), Total Compressibility (1/psi) (TCOMP), Permeability (mD) (PERM_FR), Porosity (dec) (POR_FR), Fluid Viscosity Reservoir (cP) (FL_VIS_RES), Fluid Viscosity Filtrate (cP) (FL_VIS_FILTER), Cll (ft/min^{1/2}) (Cw), and Spurt Loss (gal/ft²) (Spurt_Loss). An 'Export...' button is located below this list.
- Fluid Loss:** Includes input fields for Total Compressibility Oil Reservoir (1/psi) set to 0.0000835, Compressibility of H2O Dominated Layers (1/psi) set to 0.000014364, and Vshale Cut-off (dec) set to .7.
- Interval and Zone Table:** A table with columns for Interval, Zone, and Zone for Parameters. The first row shows an interval from Upper_Spra to Wet_Lime, with the zone set to Frac_Gross_Interval1.
- Sampling Grid:** A dropdown menu set to 'Same As Curve' and a text field containing 'BU_ZDEN'.
- Buttons:** 'Help', 'Close', and 'Run' buttons are located at the bottom of the window.

Input the physical parameters like compressibility and viscosity for the fluids in the reservoir and mud.

Generates the fluid loss properties



FracRAT Module QC Tab (Tab 4)

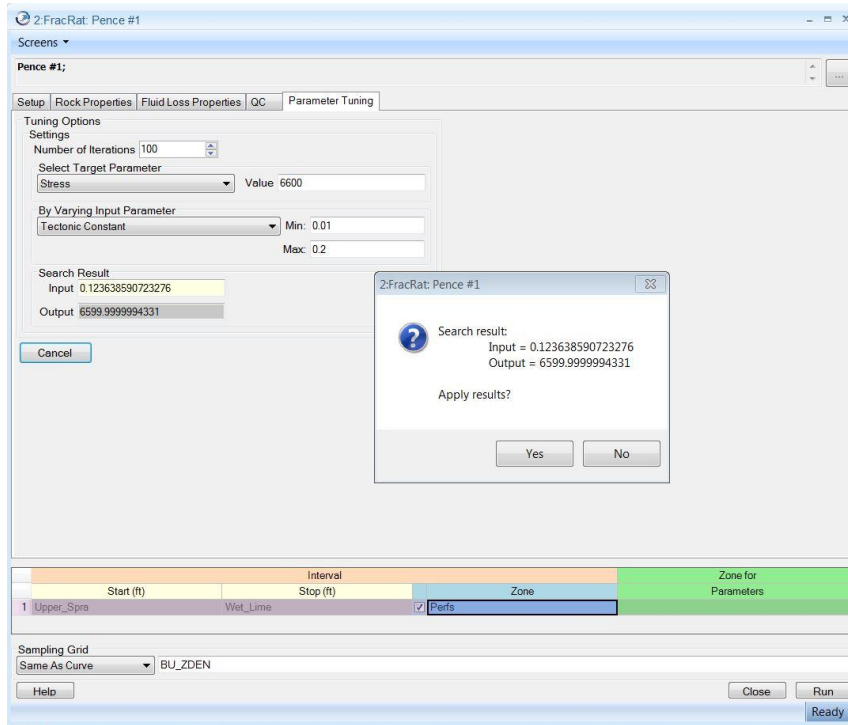


Outputs the transient curves used in the generation of the rock and fluid properties.

Enables users to insure quality of results



FracRAT Module Parameter Tuning Tab (Tab 5)



Important feature that will take known data from Minifrac Tests and give the user the ability to determine the exact input parameters required to match Minifrac results.

Essential in assuring valid simulation models



FracRAT Exporter

1:FracRAT Properties Exporter

Well to Export
Pence #1;

Output File
FracRat_Sales Meeting

Export Options
Export Settings Preview

Settings
 Export With Column Headers Decimal Precision 8

Category Table Lithology Options
 MFrac_Lithology Use Lithology Calculate From VSh

Export Column Mappings
 Format
 MFrac Rock Properties

Column Name	Curve	Data Type	Units
1 Lithology Symbol	Lith	Lithology Description	
2 Zone Name	Lith	Lithology Name	
3 TVD @ Bottom (ft)	DEPTH	Curve	ft
4 MD @ Bottom (ft)		Curve	ft
5 Stress Gradient (psi/ft)	StressGR	Curve	psi/ft
6 Stress (psi)	Stress	Curve	psi
7 Young's Modulus (psi)	YM	Curve	psi
8 Poisson's Ratio	PR	Curve	
9 Fracture Toughness (psi-in ^{1/2})	Frac_tough	Curve	(psi-in ^{1/2})
10 Critical Stress (psi)	Stress_crit	Curve	psi

Column Mapping Options

Interval	Start (ft)	Stop (ft)	Zone
1	Upper_Spra	Wet_Lime	<input type="checkbox"/>

Sampling Grid
 Same As Curve BU_NPH

1:FracRAT Properties Exporter

Well to Export
Pence #1;

Output File
FracRat_Sales Meeting

Export Options
Export Settings Preview

Data Preview

	Lithology Sy	Zone Name	TVD @ Botto	MD @ Botto	Stress Grad	Stress (psi)	Young's Mod	Poisson's Ra	Fracture Tou	Critical Stres
5	3	16744703 1 Shly-Sand	9328.5		1.009747	9419.4249095	3324856.7482	0.24237763	838.08138118	0
6	3	16744703 1 Shly-Sand	9384.5		1.00743432	9454.2674116	3610078.8056	0.23020446	858.6018467	0
7	3	16744703 1 Shly-Sand	9406.75		1.00723951	9474.8502302	3635497.3246	0.22916112	872.31450974	0
8	7	12615935 1 V-Sdy Shale	9488.75		1.00872446	9571.5341809	3447301.8541	0.2370431	940.75020397	0
9	9	16744576 1 Sandy Shale	9513.5		1.01126003	9621.5736633	3142766.7534	0.25064266	1022.8407776	0
10	7	12615935 1 V-Sdy Shale	9533		1.00529803	9583.5061075	3901550.4067	0.21860961	947.46292235	0
11	7	12615935 1 V-Sdy Shale	9546		1.01102133	9651.2095841	3179921.2016	0.24892216	961.78424873	0
12	7	12615935 1 V-Sdy Shale	9559		1.01055725	9659.9167715	3231748.6125	0.24655195	901.49207624	0
13	2	16711935 1 V-Silty Sand	9576		1.01375275	9707.6963328	2895626.1153	0.26255789	748.88651012	0
14	2	16711935 1 V-Silty Sand	9587.75		1.01202969	9703.0876881	3070936.4748	0.25402121	703.44235723	0
15	3	16744703 1 Shly-Sand	9609.75		1.00521541	9659.8688278	3913405.1210	0.21815139	811.53605383	0
16	7	12615935 1 V-Sdy Shale	9634.5		1.01452702	9775.4240066	2811642.8075	0.236894188	997.17123908	0
17	2	16711935 1 V-Silty Sand	9650.25		1.00963206	9743.2018227	3338340.6715	0.24178174	722.20982278	0
18	1	8388863 16 Silty-Sand	9668.5		1.00926048	9758.0349144	3382413.3950	0.23984881	619.41457232	0
19	1	8388863 16 Silty-Sand	9684		1.00698552	9751.6477661	3668976.2161	0.22779664	627.65289888	0
20	4	8421631 16 Clean Sand	9695.75		1.00688242	9762.4801964	3682677.2722	0.22724137	573.43720439	0
21	1	8388863 16 Silty-Sand	9735		1.00470964	9780.8483548	3986972.3270	0.21535103	610.13749098	0
22	2	16711935 1 V-Silty Sand	9774		1.00498125	9822.6867181	3947252.6994	0.21685735	701.55885358	0
23	2	16711935 1 V-Silty Sand	9800		1.01162323	9913.9076551	3114279.6939	0.25197418	734.95598215	0
24	3	16744703 1 Shly-Sand	9844.25		1.01579694	9998.7589786	2704182.8851	0.27247387	866.3458665	0
25	1	8388863 16 Silty-Sand	9852		1.00502503	9901.5055848	3940896.6177	0.21709961	667.32611567	0
26	4	8421631 16 Clean Sand	9883.25		1.00444317	9927.1629874	4026427.2169	0.21386756	595.52846419	0
27	3	16744703 1 Shly-Sand	9893.75		1.00700145	9963.0205705	3666865.2444	0.22788235	827.02923399	0

Interval	Start (ft)	Stop (ft)	Zone
1	Upper_Spra	Wet_Lime	<input type="checkbox"/>

Sampling Grid
 Same As Curve BU_NPH



MFrac Rock Properties

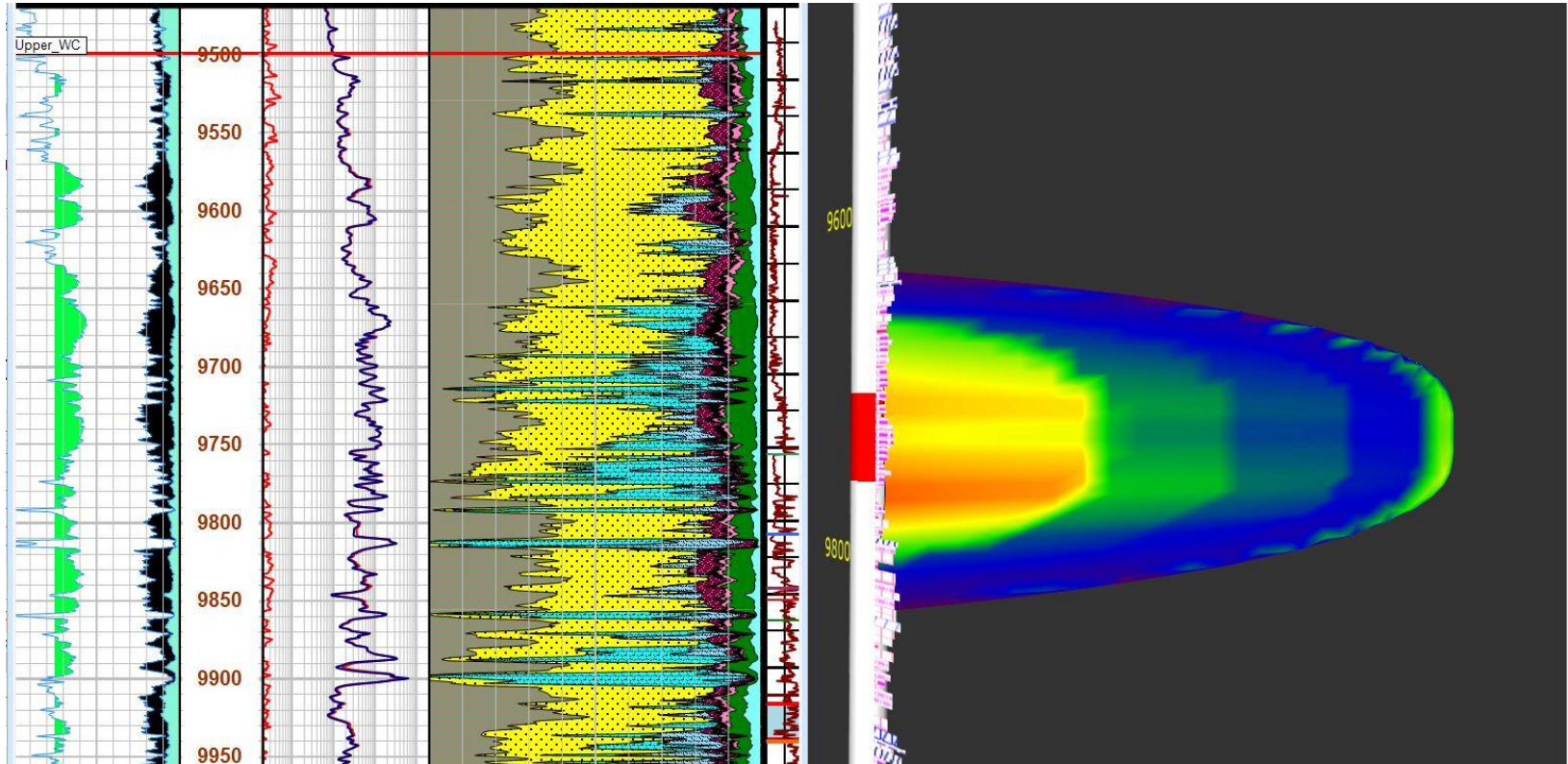
Rock Properties

	Lithology Symbol	Zone Name	TVD at Bottom (ft)	MD at Bottom (ft)	Stress Gradient (psi/ft)	Stress (psi)	Young's Modulus (psi)	Poisson's Ratio	Fracture Toughness (psi-in ^{1/2})	Critical Stress (psi)	Int: G
1		V-Sdy Shale	9253	9253	1.01851	9424.24	1.1181e+07	0.285189	973.157	0	
2		V-Silty Sand	9304.75	9304.75	1.01087	9405.85	1.4303e+07	0.248129	778.457	0	
3		Shly-Sand	9344.5	9344.5	1.01249	9461.2	1.4235e+07	0.256317	840.621	0	
4		V-Silty Sand	9367	9367	1.01088	9468.92	1.4799e+07	0.248205	796.742	0	
5		Shly-Sand	9385.75	9385.75	1.01139	9492.67	1.5555e+07	0.250804	835.053	0	
6		V-Silty Sand	9430.75	9430.75	1.00847	9510.6	1.7469e+07	0.23569	760.046	0	
7		V-Sdy Shale	9451.5	9451.5	1.01423	9585.98	1.3885e+07	0.264904	902.826	0	
8		Shly-Sand	9472.25	9472.25	1.01394	9604.32	1.3825e+07	0.263509	892.471	0	
9		V-Sdy Shale	9499.75	9499.75	1.01531	9645.17	1.2967e+07	0.270131	916.173	0	
10		V-Sdy Shale	9534.25	9534.25	1.01419	9669.58	1.3888e+07	0.264738	902.537	0	
11		V-Silty Sand	9560.25	9560.25	1.01199	9674.88	1.3149e+07	0.253824	793.57	0	
12		Silty-Sand	9589.5	9589.5	1.00747	9661.12	1.5528e+07	0.230387	678.612	0	
13		Shly-Sand	9619	9619	1.01335	9747.38	1.336e+07	0.260579	852.34	0	
14		Silty-Sand	9657	9657	1.005	9705.26	1.7225e+07	0.216949	612.756	0	
15		Clean Sand	9688	9688	1.00171	9704.55	2.1513e+07	0.198314	541.481	0	
16		Clean Sand	9714	9714	1.00301	9743.26	1.8373e+07	0.205801	549.039	0	
17		Clean Sand	9750.25	9750.25	1.00213	9771.03	2.257e+07	0.200758	579.01	0	
18		Silty-Sand	9777.75	9777.75	1.00479	9824.58	1.8923e+07	0.215792	635.466	0	
19		V-Silty Sand	9821	9821	1.01087	9927.71	1.3182e+07	0.248155	752.263	0	
20		Clean Sand	9867.5	9867.5	1.00116	9878.91	2.3095e+07	0.195097	543.768	0	
21		V-Silty Sand	9902	9902	1.00956	9996.67	1.5419e+07	0.241413	760.052	0	
22		Clean Sand	9943.5	9943.5	1.00293	9972.61	2.0955e+07	0.205323	586.982	0	
23		Clean Sand	9967.75	9967.75	1.00063	9974	2.3625e+07	0.191987	526.393	0	
24		Sandy Shale	9995.25	9995.25	1.02146	10209.8	1.0134e+07	0.298567	1028.74	0	
25		Shly-Sand	10054	10054	1.01531	10207.9	1.2552e+07	0.270163	895.872	0	
26		Sandy Shale	10117.8	10117.8	1.02077	10327.9	1.0367e+07	0.295468	1010.52	0	
27		Silty-Shale	10166.3	10166.3	1.02878	10458.8	7.797e+06	0.329612	1145.14	0	
28		Silty-Shale	10223.3	10223.3	1.02878	10517.4	7.797e+06	0.329612	1145.14	0	
29											





Frac Simulation Results





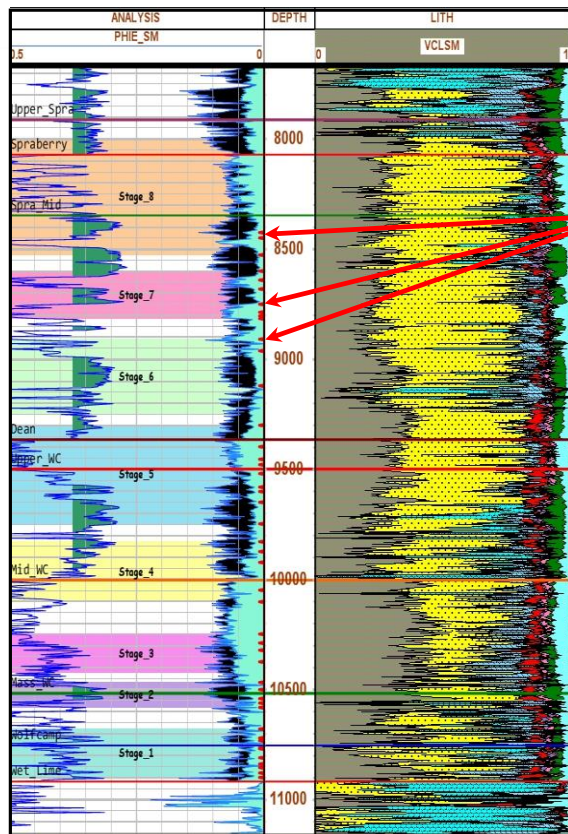
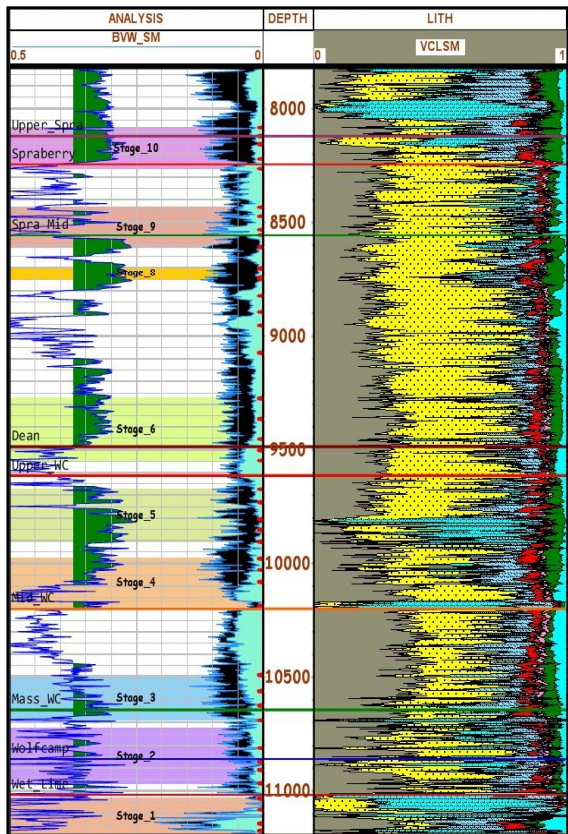
Perforations, Frac Stages, and Production History

Frac Stages are colored intervals

Bourne #3

22 Months Production
18,705 bbls oil
18,817 mmcf gas
39,797 bbls Water

Currently making
624 bbls/month oil



Perforations

Pence #1

35 Months Production
38,464 bbls oil
51,518 mmcf gas
56,012 bbls Water

Currently making
485 bbls/month oil



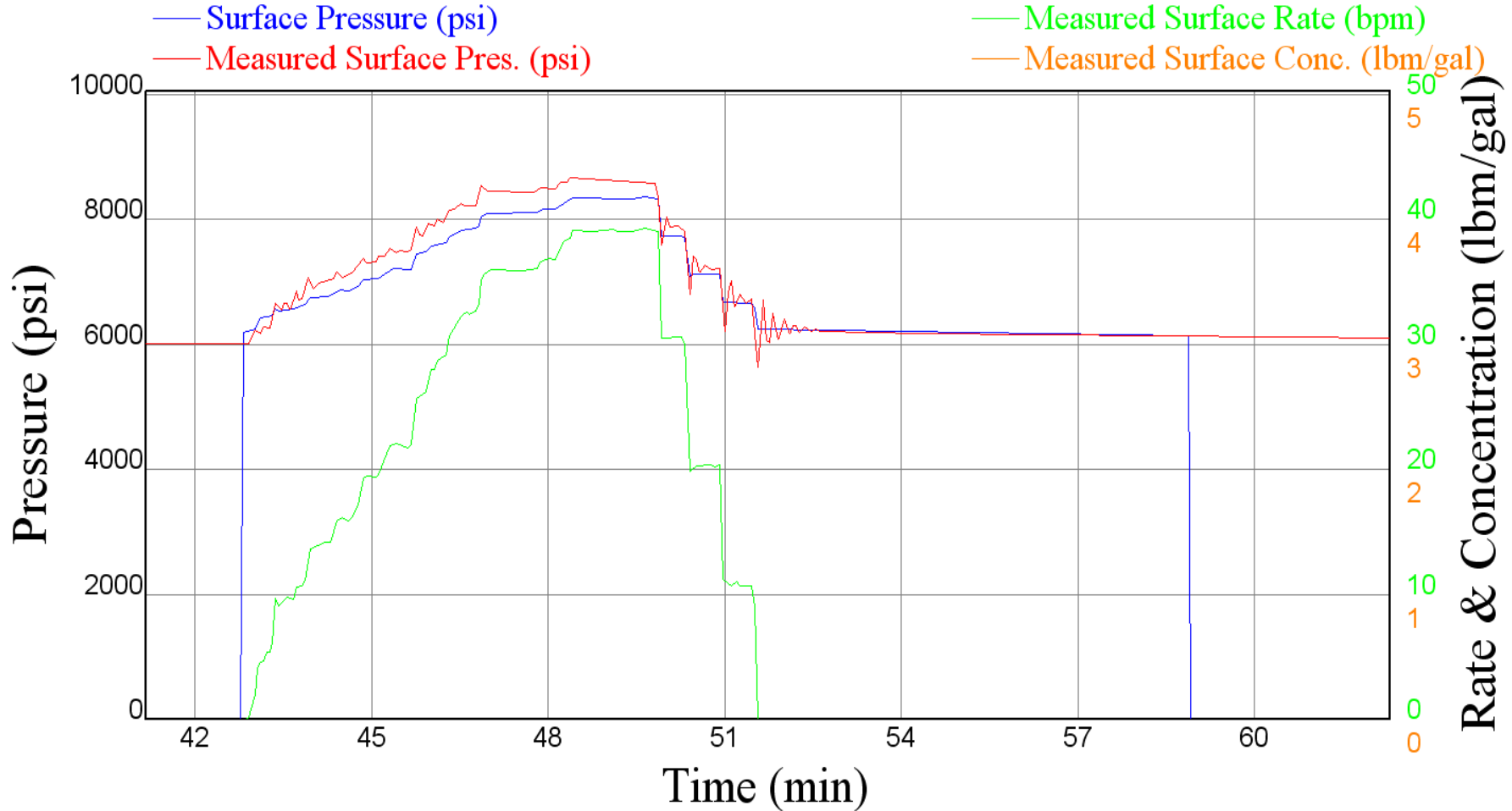


Simulation to Stimulation Workflow

- Generate a simulation model based on best available data
- Mini-fracs are required to calibrate simulation models
- FracRAT has parameter tuning to calibrate simulation models
- Calibrated simulation models accurately predict frac stimulation results



Surface Pressure



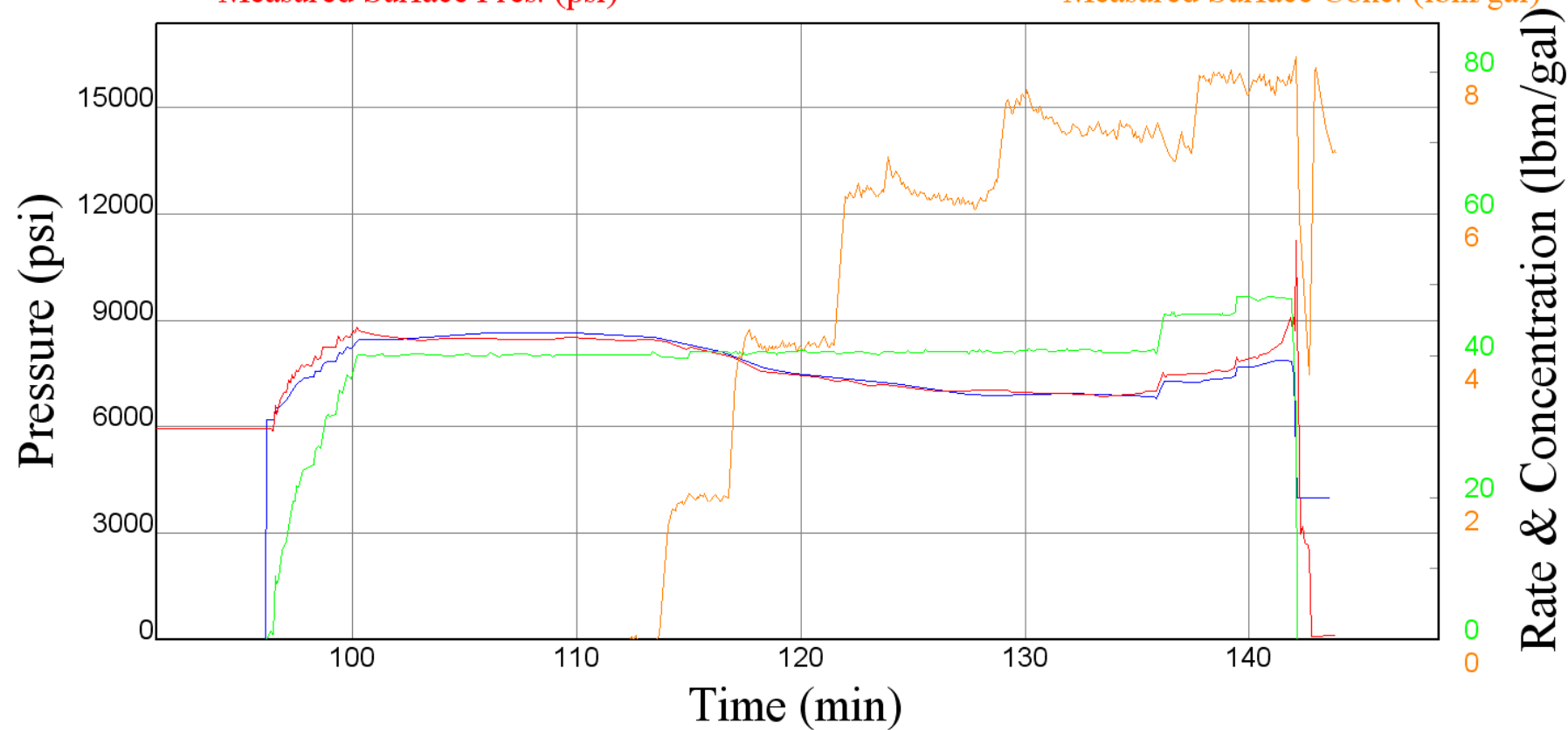
Surface Pressure

— Surface Pressure (psi)

— Measured Surface Pres. (psi)

— Measured Surface Rate (bpm)

— Measured Surface Conc. (lbm/gal)

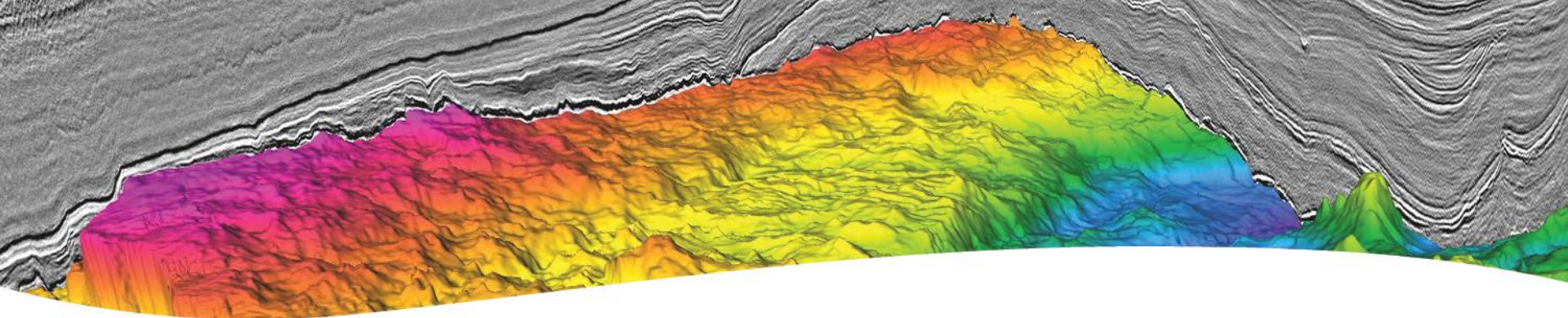




Conclusion

- Perf and frac everything is still a common practice when completing unconventional reservoirs
- Frac simulations are often not run for lack of data and the time involved in generating the models
- Petrophysical parameters are important factors in frac stimulation (and simulation) design
- The elastic properties needed as inputs to frac simulation can be deterministically or empirically derived.
- Tools like FracRAT can reduce the time needed to generate frac simulations
- Frac simulations should result in more effective fracs and improved commercial results





Thank you

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