

# **How To Use Customized Workflows To Deliver Fast Results with PowerLog**

## **Prepared For PowerLog User Group Meeting**

**Prepared By**

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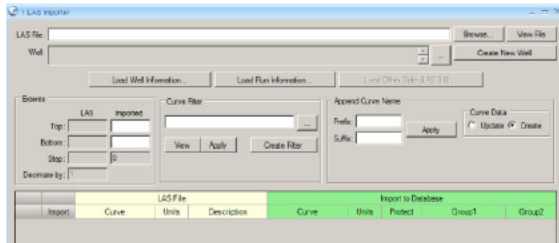
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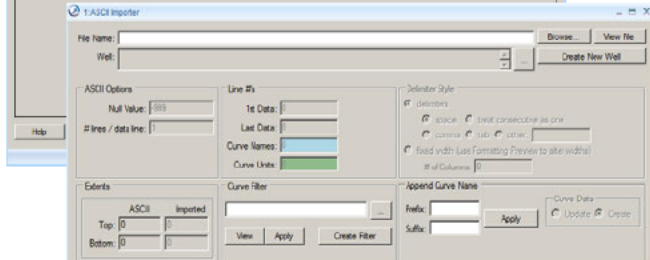
# Advantages of using a Customized Workflow

- Run calculations through one window (module)
  - no more opening and closing several windows to change an input parameter
- Instantaneously see outputs based on assigned input parameter(s)
  - depth plots update each time the subroutine is run
  - great for sensitivity analysis, etc.
- Calculation setup is easily saved using PowerLog screens
  - easy recall for new wells or new projects
- Highly flexible, allowing evaluation of several reservoir types
  - conventional and unconventional, with or without kerogen
  - clastic and carbonate
- Allows for continuous improvement
  - with each project run, the calculation sequence is improved and becomes more robust

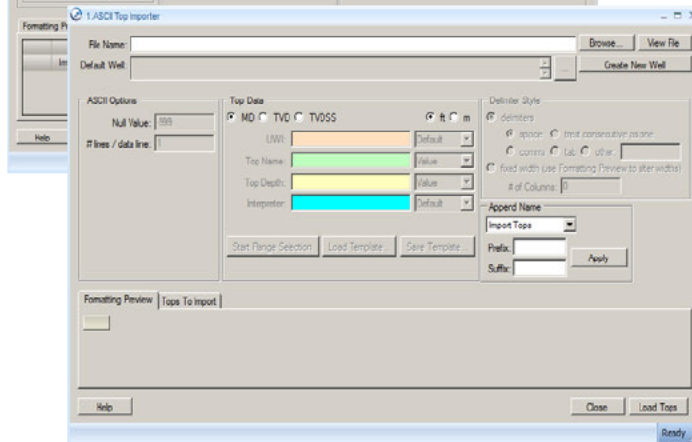
# Data Mining and Data Import



LAS files are imported using PowerLog's LAS file importer

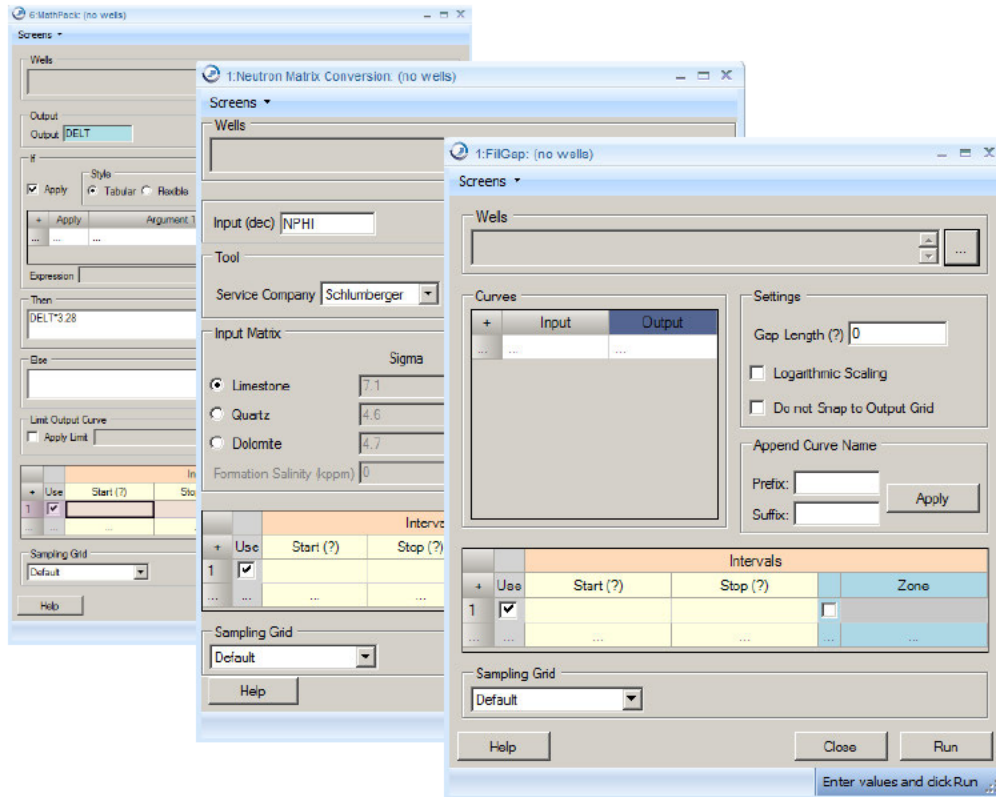


Core data is imported using PowerLog's ASCII importer



Tops are imported using PowerLog's ASCII top importer

# Preprocessing



- Mathpack is used to perform unit conversions
- The Neutron conversion matrix module is used to convert neutron porosity scales
- The FillGap module is used to fill gaps in the raw data
- Other modules, as required are used to finish preprocessing work

# Preprocessing

2.Dorian\_XRDwtpct\_to\_XRDvolfrac\_to\_XRDvoldisp: (no wells)

Screens ▾

Inputs Outputs

	Suggested Value	Value	Description
1	XRDqtz_volfrac	XRDqtz_volfrac	XRDqtz_volfrac
2	XRDpyr_volfrac	XRDpyr_volfrac	XRDpyr_volfrac
3	XRDlms_volfrac	XRDlms_volfrac	XRDlms_volfrac
4	XRDdolo_volfrac	XRDdolo_volfrac	XRDdolo_volfrac
5	XRDclay_volfrac	XRDclay_volfrac	XRDclay_volfrac
6	XRDqtz_voldisp	XRDqtz_voldisp	XRDqtz_voldisp
7	XRDpyr_voldisp	XRDpyr_voldisp	XRDpyr_voldisp
8	XRDlms_voldisp	XRDlms_voldisp	XRDlms_voldisp
9	XRDdolo_voldisp	XRDdolo_voldisp	XRDdolo_voldisp
10	XRDclay_voldisp	XRDclay_voldisp	XRDclay_voldisp

Append Curve Name

Prefix:

Suffix:

Apply

		Intervals			Zone for
	Use	Start (?)	Stop (?)	Zone	Parameters
1	<input checked="" type="checkbox"/>			<input type="checkbox"/>	
...	...	...	...	...	...

Reset Static Variables Every

☒ Interval ☐ Well ☐ Never

Null Value

Null Value Used in Program -999

Sampling Grid

Default

Help Close Run

Please Enter values and Press Run

## XRD SCAL Data

- Must convert weight percent to volume fraction to integrate with petrophysical analysis
- Very important for kerogen and pyrite

## Curve alias table is used to define input logs

```
Editor - <Coran_Alias_Table_with_input_and_output>
```

**File**   **Edit**   **Help**

**Alias Editor**

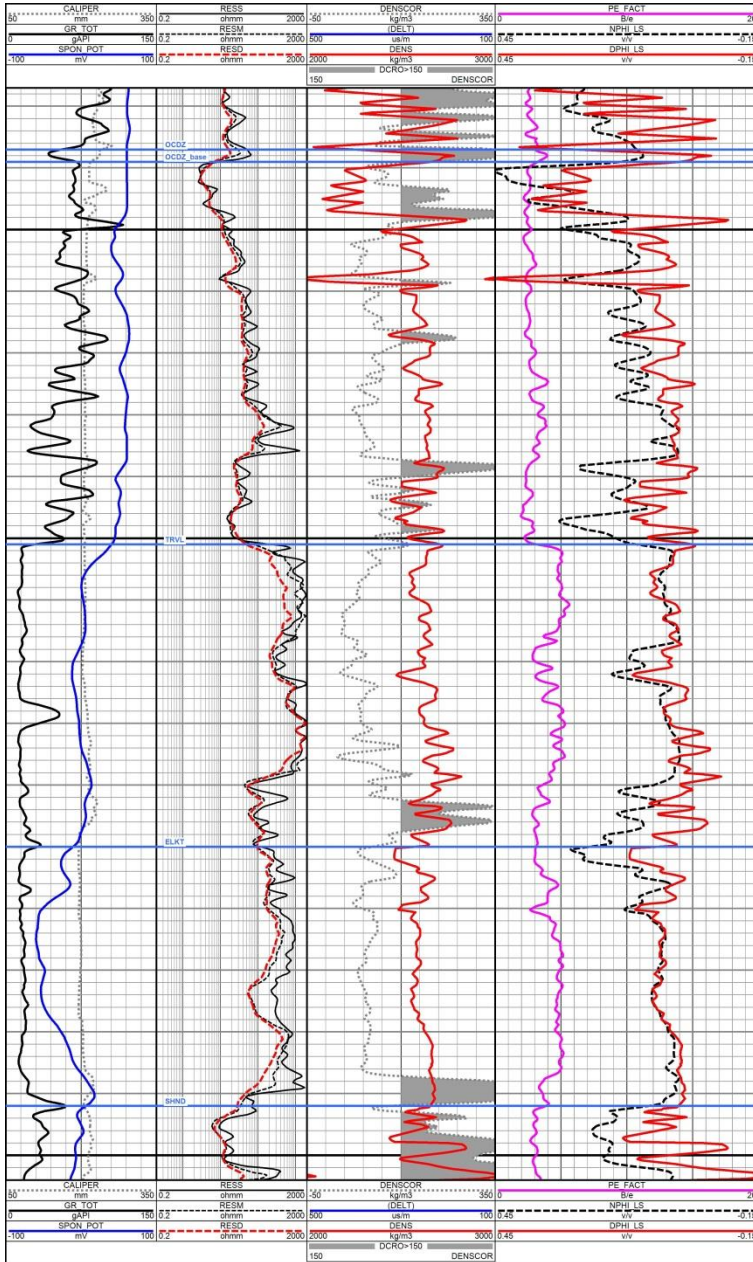
**Instructions**  
Enter each alias on a separate line, with the alias name first and the curve names separated by tabs, commas, or spaces.  
You can also copy and paste aliases from Excel.  
If you mix delimiters (sometimes using a comma, sometimes a tab, for example), the editor will correct and standardize the  
delimiters when you save the table or check View in Comma-Separated Format.

☒ View Comma Separated

```
1 $CALinput HCAL_ON HR_HCAL CAL HCAL CALI CALX CAX CALD CLDC GZ GALS
2 $CHFF CHFF CHFF
3 $COR_GRinput HR_GR_EDTC GRGC
4 $CORE_BULK CORE_BULK DENS CORE RC_BULK FSS_BULK
5 $CORE_GRAIN CORE_GRAIN GRAIN CORE RC_GRAIN CORE_GSNMN FSS_GRAIN
6 $CORE_GRtot CORE_GRTOT CORE_TOTAL GAMMA
7 $CORE_RMAX CORE_RMAX RMAX CORE RC_RMAX FSS_FERN
8 $CORE_FHI CORE_FHI FHI CORE RC_FHI CORE_POR FSS_FHI
9 $CORE_SO CORE_SO SO_CORE RC_SO FSS_SO
10 $CORE_SW CORE_SW SW_CORE RC_SW FSS_SW
11 $CORE_TOC CORE_TOC
12 $DELTAinput DELT_NRM DTCC_ON DELTNRM DTNRM DTGNRM AURNM MSIP_DTCC DTCC DTF DELTC DT DTC DT4P DT24 DT36 AC AU DELT
13 $DELTSFASTinput DELTSFAST FASTSHEAR DTSX DTS HSIP_DTM DTSM DT4S
14 $DELTSLWinput DTM ON DTM DEITS DELTSLOW SLOWSHEAR DTSY
15 $DELTSLWINput DELTSLOW SLOWSHEAD DTSY
16 $DENSGRinput NDRA_ON NR_NDRA DRHO DOOR NDRA ZOOO CORR DC DENSCOR
17 $DENSIinput DENS_NRM DENSNORM RHOT_ON DENSEdit DENSNRM DENNM RHOBNM IDENNRM DENSDS DENDS DEM RNOS RMOS RHOT IDEN DENSPL DENS
18 $DNFMI_DSinput DNFI_DSDM DNFI_DSPL PZDL
19 $DPHILSinput DPFI_LSDM DPFL DPFI DPFIL SPL PLZLS
20 $DPHIS_Sinput DPFI_RSOM NR_DPFI_SAN PHID_SS PHIDS DPHISS DPFI_SAN DPRS DPRS DPMS PZSS DPFI_SSPL
21 $NPFI_DSinput NPFI_DS CNCE CNCFOL TNFM_DOL NPFI_DSPL
22 $NPFI_LSinput NPFI_LS HR_MPO_LIM MPO LIM NPFI NPOS CNCLFS NPRL CNCLS CMC NPFI LSPL TNFM LIM NPFI LSMOUT
23 $NPFI_SSinput NPFI_SS NRM TNPM_SS_ON NPFI SSedit NPFIedit SSPL NR_MPO_SAN CNCFSS NPFI_SSERM NPSANRM NPSANRM NPNSERM CMCSER NM NPI SSPLNRM PMIN_SS NPMISS NPOR_SAN NPSS NPAS NPMS CMCSS TNPM SAN NPFI SAN NPFI SSPL
24 $PEinput PEZF_ON PESYN HR_PEFS HR_PEFZ FE PEZ PEF POPE PEFZ LSPe
25 $TOTALinput POTZ HFK
26 $rawDELTAinput rawDELTAinput DELT MSIP_DTCC DTCC DTF DELTC DT DTC DT4P DT24 DT36 AC AU
27 $rawDPFI_SSinput rawDPFI_SSinput DPFI_SS HR_DPFI_SAN PHID_SS PHIDS DPHISS DPFI_SAN DPRS DPRS DPMS PZSS DPFI_SSPL
28 $rawNPFI_SSinput rawNPFI_SSinput NPFI_SS HR_MPO_SAN CNCFSS PHIN_SS NPFISS NPOR_SAN NFSS NPFS CNCSU TWH SAN NPI SSPL
29 $RESSinput RLAA_ON RS AOAO AOAO RT RTAT RTAO MRB MRB DEES AMOPQ ANT90 IID RIID LIID RIID ROAO DEEP AT90 ATM AF60 DLLL DVIR RESD_40WD DB90 LL_EDIT LL LM_EDIT LN AGRT LWD_RPCIX_DS AIT9 DEEP_20K _20KD LWD_UD4 LAT RESEP RESP
30 $RESSinput RLAA_ON HR_AOAO AOAO MIR3 M2R3 RT40 MRES MYR2 ILM RIUM RT30 RO30 MEDIMUM AT30 MLRAC AF30 RLAA R400 DR30 RESM_10XM AIT3 MED_10K _20KM LWD_UD5 RESM
31 $RESSinput HR_AOIO AOIO AH0IO ANTHO MIR1 M2R1 SFLL SFLL SFLL LSDDS LIS FEFC ROZO GUARD ATIO MSFL MLRIC AF20 DSLL RLAI RLII DR24 SN_EDIT SN AOKX R200 LWD_RPCIX_DS LWD_UD6 RT20 AIT1 RESS
32 $SPinput SP_ON SP SPQC SPDLL SPR
33 $THORinput THOR HTMO
34 $TOT_GRinput GR_ON GRGC HR_GR GR GRGM HGR SGR GRD GRS GRX LWD_MG GAM GR_IOT
35 $UDAINinput UDAM UDMA
36 $WAHM WAHM WAHM WALK2
37 $WCAR WCAR WCAR_WALK2
38 $WCLA WCLA WCLA_WALK2
39 $WCOA WCOA WCOA_WALK2
40 $WEVA WEVA WEVA_WALK2
41 $WFVR WFVR WFVR_WALK2
42 $WOPT WOFT WOFT_WALK2
43 $WSID WSID WSID_WALK2
...

```

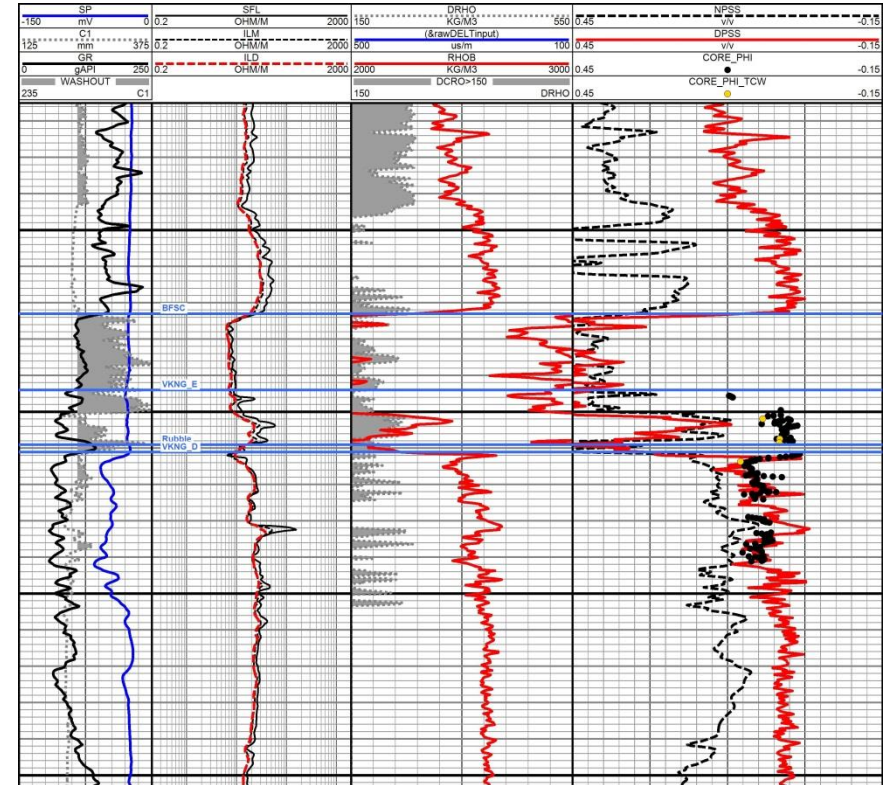
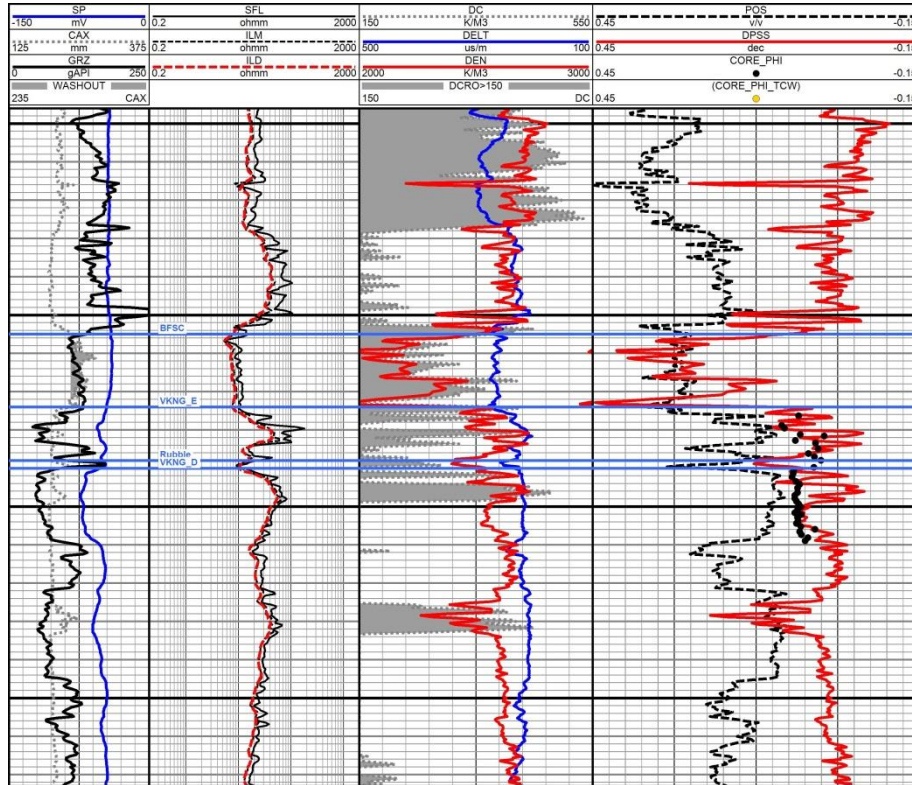
# Preprocessing



- Visually check all key input logs
- clastic over carbonate with some coal intervals



# Preprocessing



Visually check all key input logs

- the density log suffers from bad hole condition and must be edited

# Define Zones and Zone Parameters

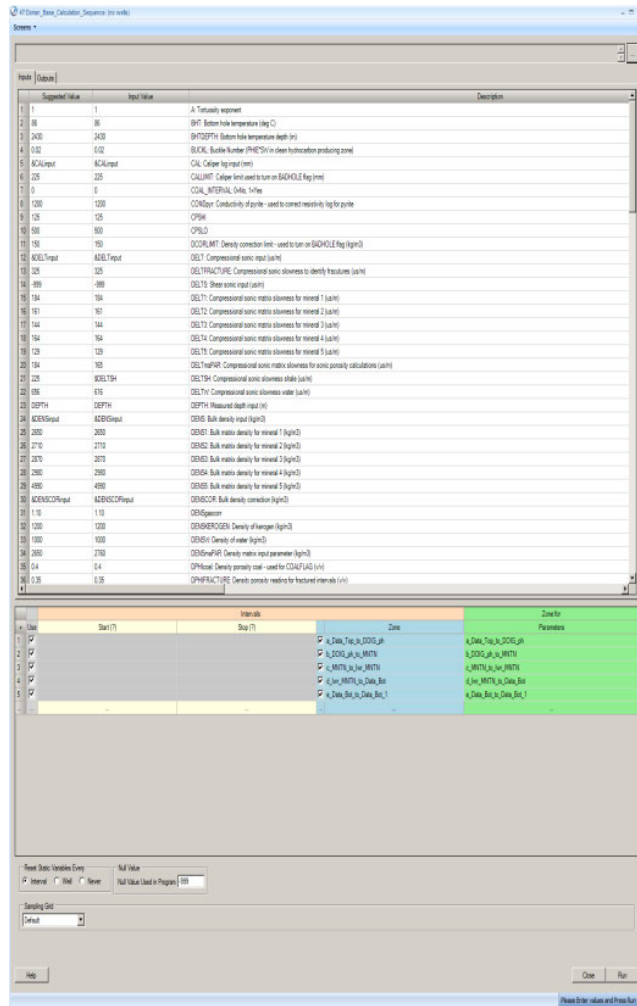
Make Zones Tool is used to define zones with tops

Zone Definitions							
+	Zone	Top			Bottom		
		1st Choice	2nd Choice	3rd Choice	1st Choice	2nd Choice	3rd Choice
1	a_Data_Top_to_OCDZbase	Data_Top			OCDZ_base	Data_Top	
2	b_OCDZbase_to_TRVL	OCDZ_base	Data_Top		TRVL		
3	c_TRVL_to_ELKT	TRVL			ELKT		
4	d_ELKT_to_SHND	ELKT			SHND		
5	e_SHND_to_Data_Bot	SHND			Data_Bot		
...	...	...	...	...	...	...	...

Zone Parameter Editor used to define parameters for calculation sequence

<div> <div></div> <div>All Parameters</div> <div>DH</div> <div>Archie</div> <div>Cased Hole</div> <div>Clay Volume</div> <div>Dual Water</div> <div>Juhasz</div> <div>Log Run</div> <div>Multi-Mineral</div> <div>Quick</div> </div>								
All Zones	Well	Zone	Start	End	Depths	\$GRWmax	\$GRWmin	\$LITHMODEL
	100032301925W400	a_Data_Top_to_OCDZbase	Data_Top	OCDZ_base	1729 to 1735.5	110	25	8
	100032301925W400	b_OCDZbase_to_TRVL	OCDZ_base	TRVL	1735.5 to 176...	100	25	8
	100032301925W400	c_TRVL_to_ELKT	TRVL	ELKT	1768.5 to 178...	110	20	12
	100032301925W400	d_ELKT_to_SHND	ELKT	SHND	1781.5 to 180...	110	10	12
	100032301925W400	e_SHND_to_Data_Bot	SHND	Data_Bot	1803.5 to 180...	110	20	12
	100032301925W400	EntireWell	WellTop	WellBottom	281.6 to 1833.2	110	20	12

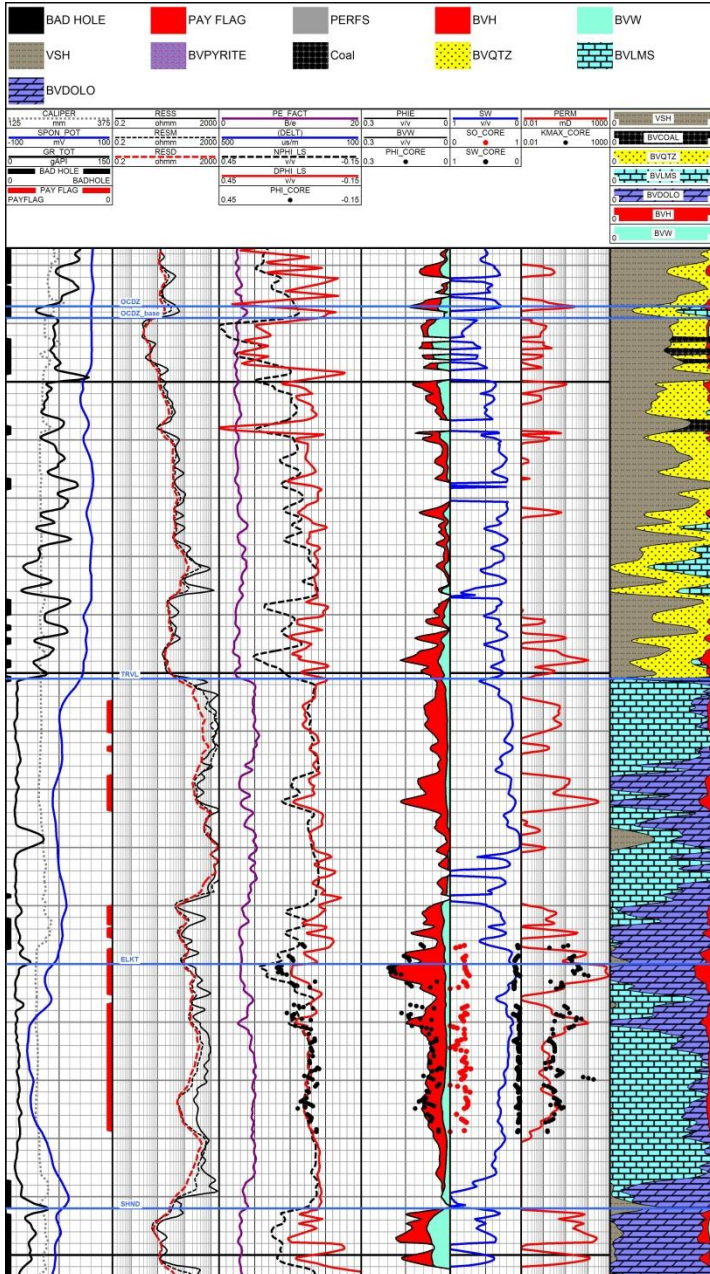
# Run Base Calculation Sequence



- Petrophysicist's shale volume (clay minerals and clay bound water)
  - VSHGR (linear and non linear models)
  - Spectral GR models
  - VSHXND, VSHSP, VSHRES
- Porosity models
  - PHIXND, PHIXNS, PHIS, PHIDcustom, PHIE(VSH)
  - bad hole flag
  - gas flag
  - fracture flag
- TOC
  - Issler, and Passey models
  - volume fraction kerogen
- Lithology
  - PE, DENSma, DELTma, UMA-DENS
  - coal flag
  - anhydrite flag
- Water Saturation using Modified Simandoux
  - temperature corrects  $R_w$  to geothermal gradient
  - A, M and N inputs
  - RESDSH input corrects for low resistivity shale
- Permeability
  - exponential model K(PHIE)
  - Wyllie-Rose model
  - Lucia's carbonate model



# Review Reservoir Results



## Clastic and Carbonate Example

- Custom calculation sequence, along with zonation parameters used to calculate reservoir parameters for clastic and carbonate intervals.
- Results used as input to reconstruct density and sonic logs
- Reconstructed logs then used to calculate mechanical rock properties

**Legend:**

- PAY FLAG (Red)
- BVW (Blue)
- BVLMS (Green)
- BAD HOLE (Black)
- GAS FLAG (Pink)
- BVDOL (Blue with dots)
- PERS (Grey)
- VSH (Brown)
- BVKEROGEN (Orange)
- X-OVER (Light Blue)
- BVH (Red)
- BVQTZ (Yellow)

**Table 1: Well Parameters**

Parameter	Value
CALIPER	11.25
SPON POT	150
GR TOT	250
PAY FLAG	0
BAD HOLE	0
RES	0.2
RESD	0.2
PE FACT	0
DELT	20
NPHI_SS	0.45
DPHI_SS	0.45
PHIE	0.3
BVWBKL	0
PERM	1
VSH	0
BVQTZ	0
BVDOLO	0
VKEROGEN	0
BVH	0
BVW	0

**Table 2: Rock Properties**

Property	Value
RES	0.2
RESD	0.2
PE FACT	0
DELT	20
NPHI_SS	0.45
DPHI_SS	0.45
PHIE	0.3
BVWBKL	0
PERM	1
VSH	0
BVQTZ	0
BVDOLO	0
VKEROGEN	0
BVH	0
BVW	0

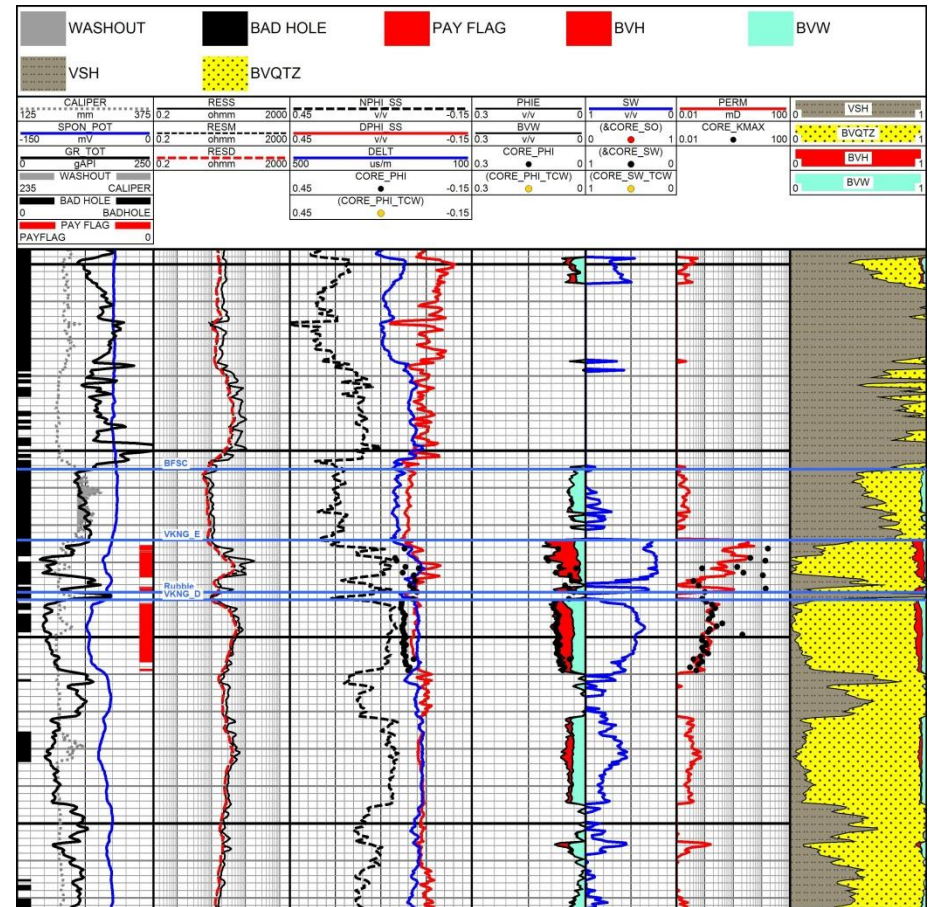
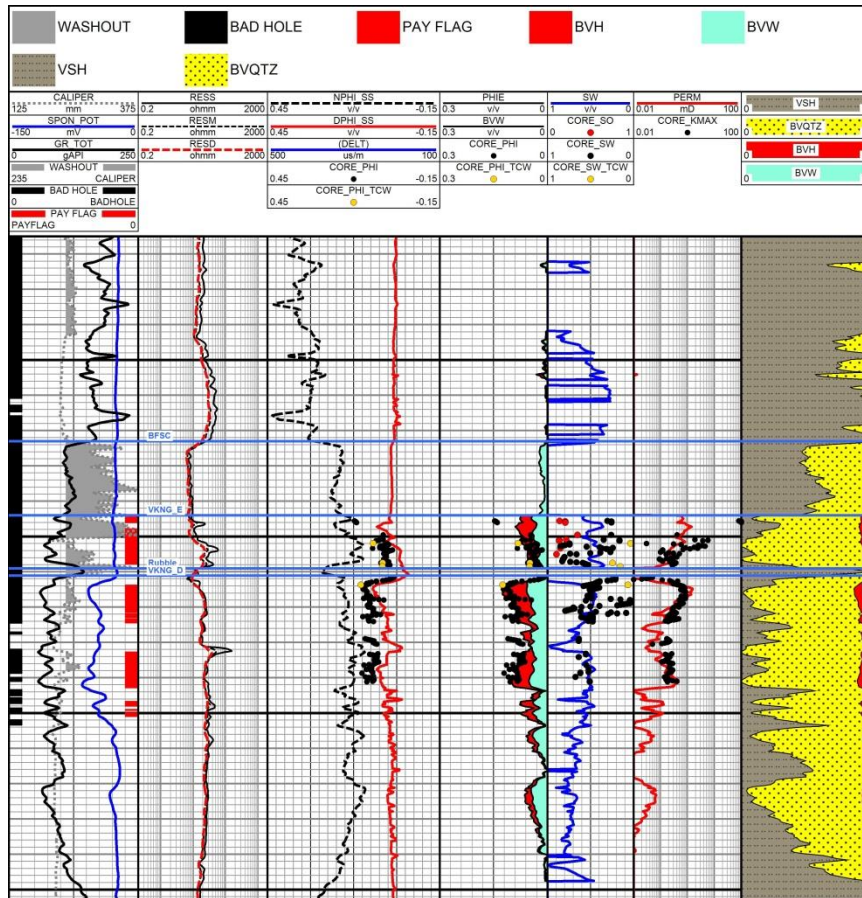
**Table 3: Well Data**

Depth (ft)	Caliper (in)	SPON POT (psi)	GR TOT (in)	PAY FLAG	BAD HOLE	RES	RESD	PE FACT	DELT	NPHI_SS	DPHI_SS	PHIE	BVWBKL	PERM	VSH	BVQTZ	BVDOLO	VKEROGEN	BVH	BVW
0	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
100	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
200	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
300	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
400	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
500	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
600	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
700	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
800	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
900	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0
1000	11.25	150	250	0	0	0.2	0.2	0	20	0.45	0.45	0.3	0	1	0	0	0	0	0	0

- Custom calculation sequence used to define this conventional reservoir interval



# Reservoir Results



## Clastic Example with Rough Bore Hole

- Logs edited to correct problems over bad hole interval
- Results used as input to reconstruct density and sonic logs
- Reconstructed logs then used to calculate mechanical rock properties

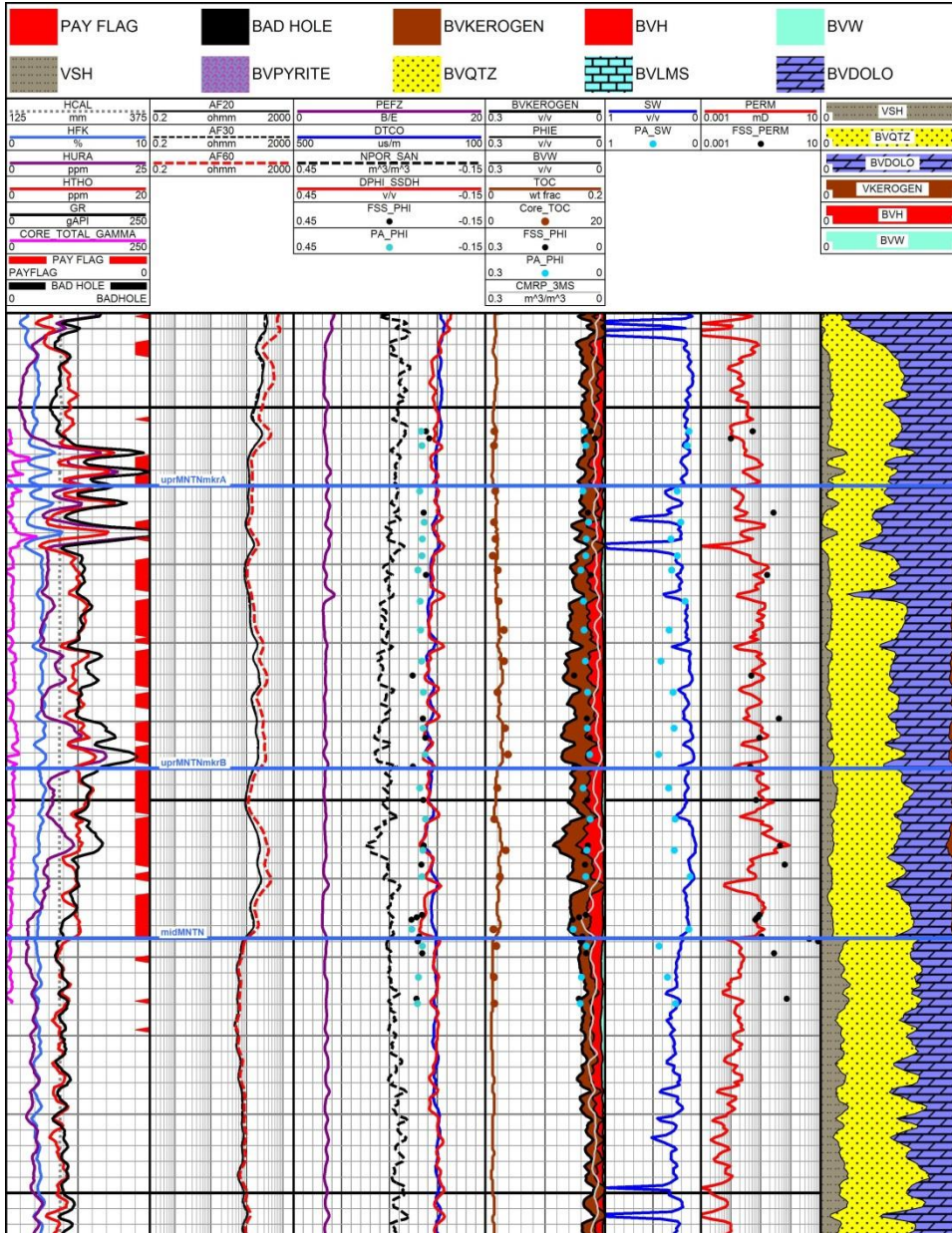
The image displays a detailed geological log plot. The leftmost column shows depth in feet, ranging from 0 to 2500. The plot is divided into several vertical sections, each containing different data series. The top section includes a legend with color-coded boxes: PAY FLAG (red), BAD HOLE (black), BVH (red), BVW (cyan), VSH (brown), BVQTZ (yellow), BVLMS (blue), BVDOL (blue), and BVANHY (purple). The main plot area shows various logs: CAUER, BTOY, GEM, GEN, GPH, Core GRIST, and GAPI on the left; RESS, RC\_PHI, RC\_PSI, RC\_SW, RC\_KAR, RC\_KMAX, PERM, and XRDlog\_voldisp on the right. The plot is overlaid with a grid and color-coded regions.

- Results from custom calculation sequence match RCAL and SCAL data quite well, considering the laminated nature of the reservoir

- Results from custom calculation sequence match RCAL and SCAL data quite well, considering the laminated nature of the reservoir



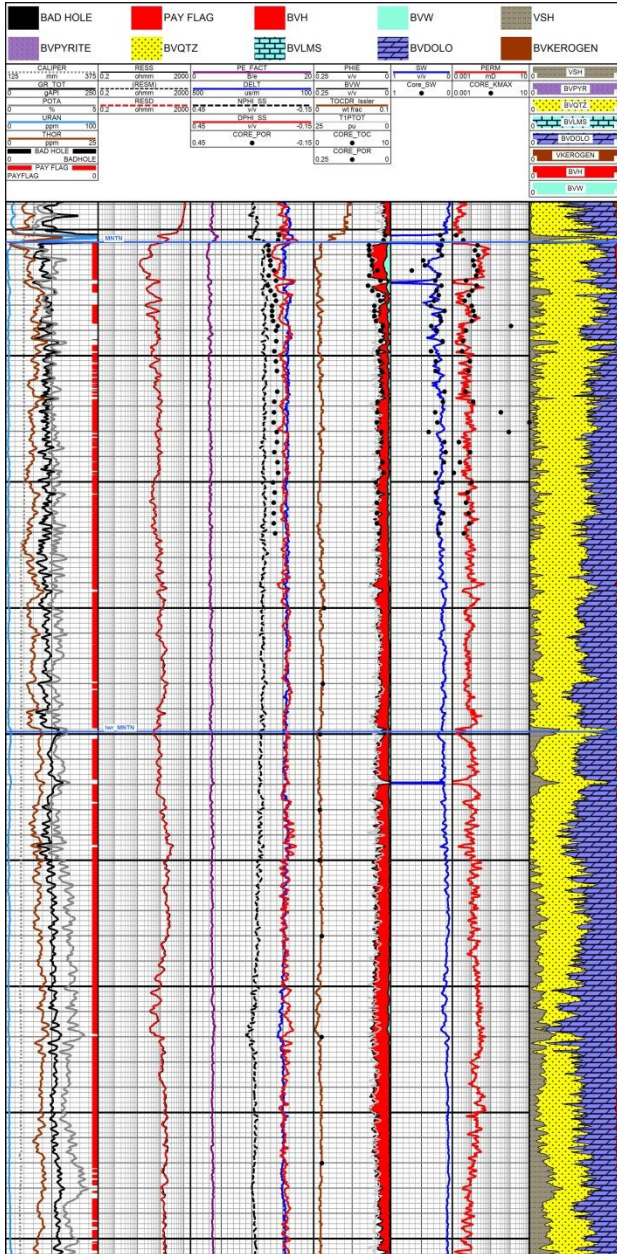
# Review Reservoir Results



Unconventional gas example  
with a kerogen correction  
applied

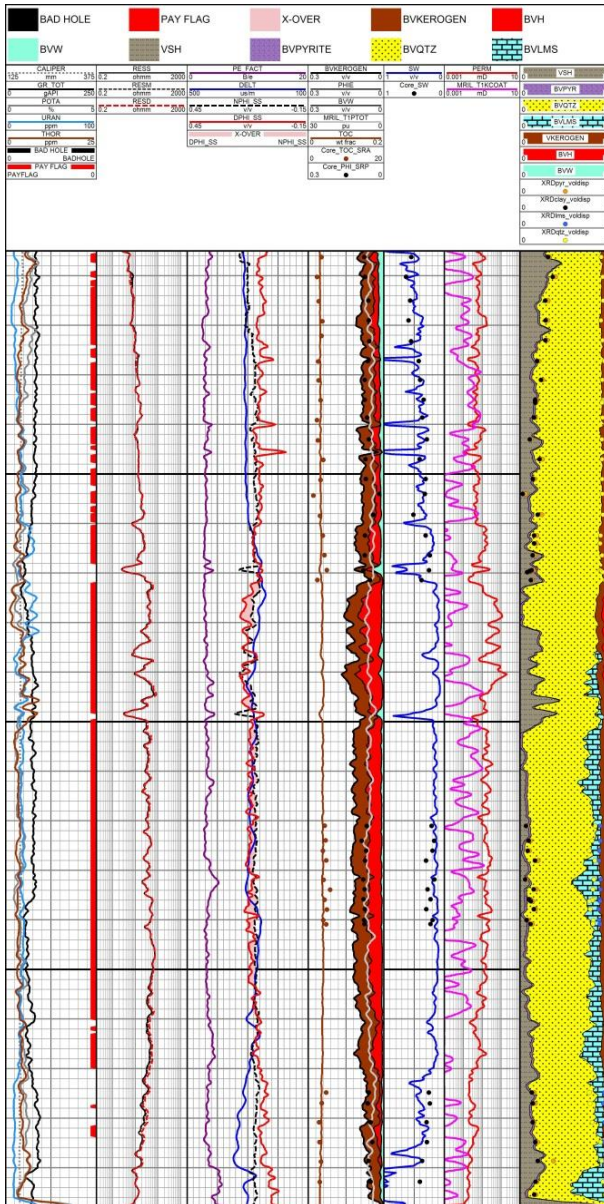


# Review Reservoir Results



Unconventional gas example  
without a kerogen correction  
applied

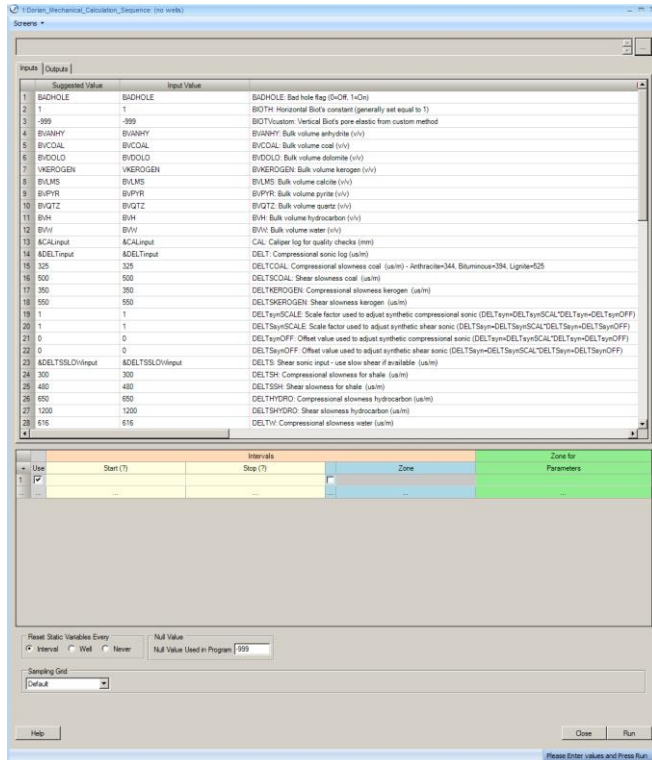
# Review Reservoir Results



## Unconventional shale gas example with a kerogen correction applied

- Results from custom calculation sequence match SCAL data very well
- Results used as input to reconstruct density and sonic logs
- Reconstructed logs then used to calculate mechanical rock properties

# Mechanical Calculation Sequence



For stimulation design modeling, the logs should represent a water filled reservoir.

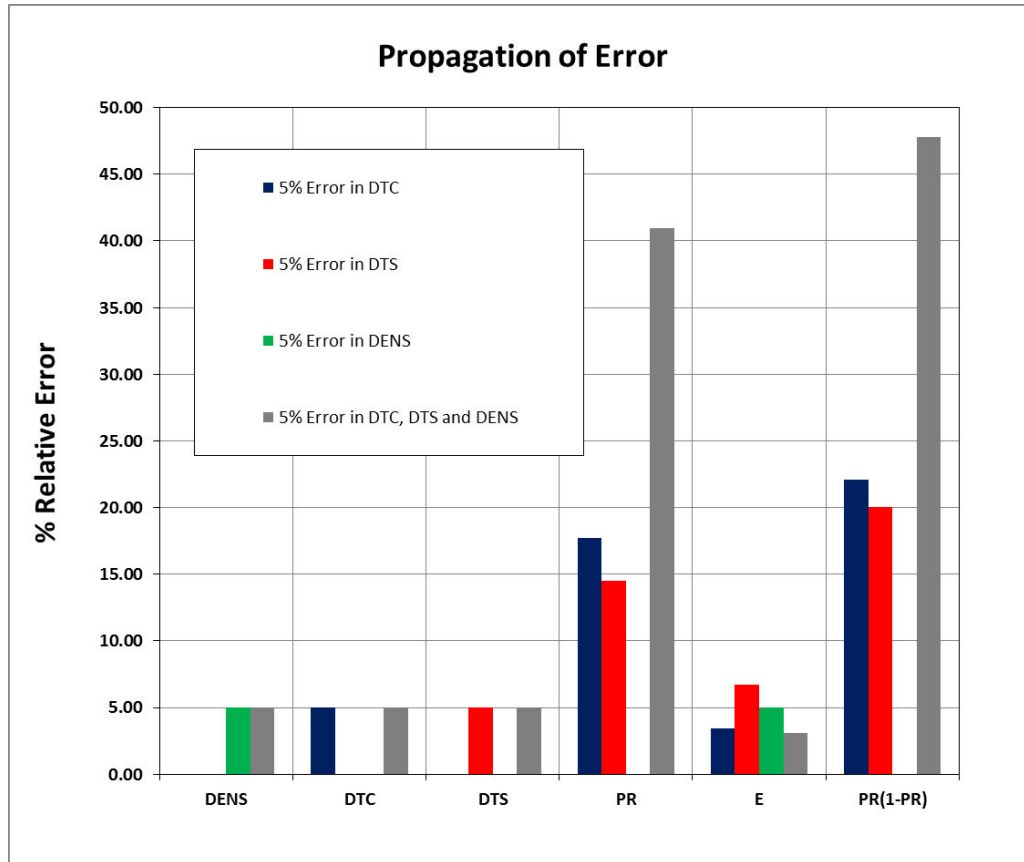
- Since logs read the invaded zone, light hydrocarbons (light oil or gas) make the density log read too low and the sonic log read too high, compared to the water filled case.

Rock mechanical properties are calculated based on reconstructed logs derived from the petrophysical analysis,

- for use in stimulation design programs

The reconstructed logs eliminate gas effect (if any) and low quality data caused by rough borehole.

# Mechanical Calculation Sequence



A small error with the sonic logs leads to a big error in closure stress

$$P_c = \frac{\nu}{(1-\nu)} \left[ D_{tv} \gamma_{ob} - \alpha_v (D_{tv} \gamma_p + P_{off}) \right] + \alpha_h (D_{tv} \gamma_p + P_{off}) + \varepsilon_x E + \sigma_t$$

# Mechanical Calculation Sequence

The calculation sequence first reconstructs the density and sonic logs, based on results from the quantitative analysis (reservoir results).

The reconstructed density and sonic logs are then used to calculate:

- Poisson's ratio
- Young's dynamic and static moduli
- bulk modulus
- shear modulus
- brittleness index

Effective porosity from the quantitative analysis is used to calculate:

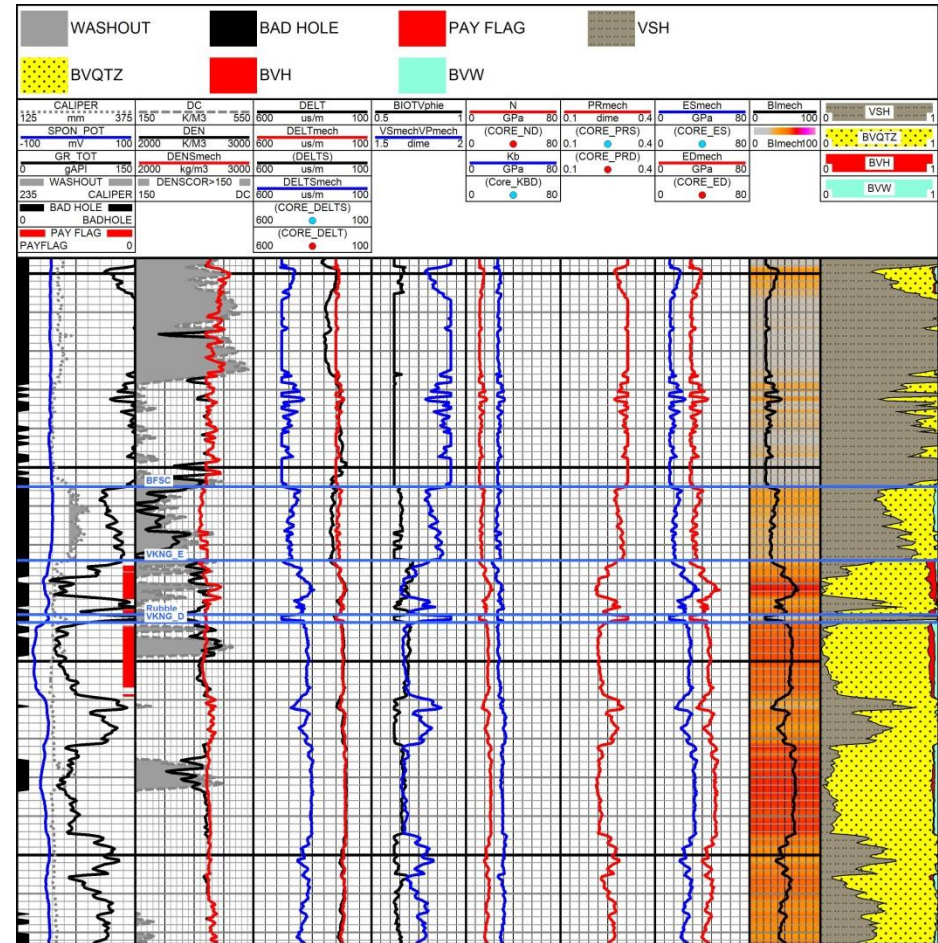
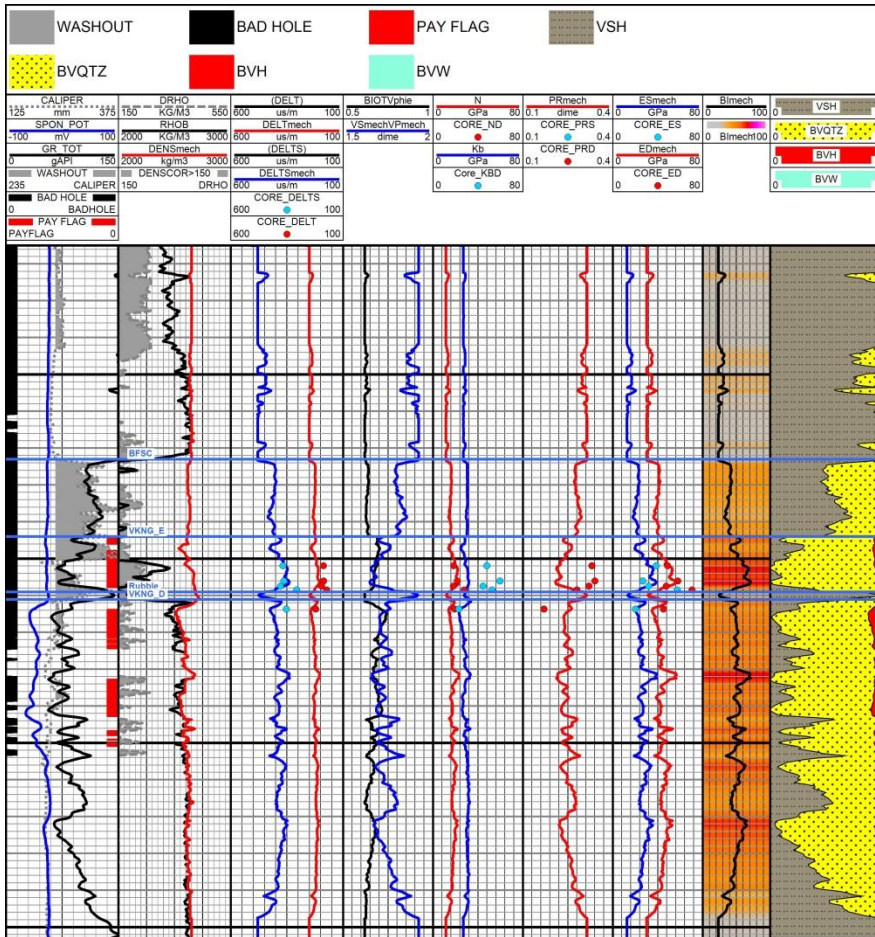
- vertical Biot's poroelastic parameter

Closure stress is also calculated and must be calibrated to local field conditions with a strain or stress correction factor.



# Clastic and Carbonate Example

# Review Mechanical Results



## Clastic Example with Rough Bore Hole

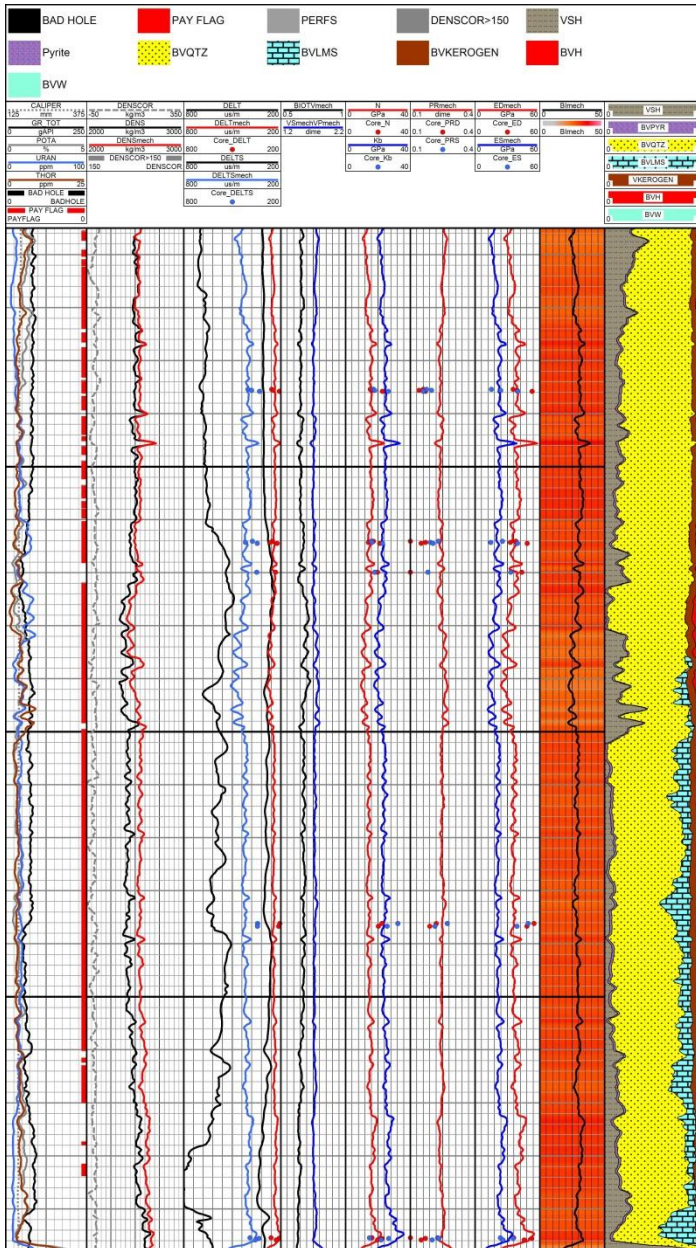
- Reconstructed density and sonic logs used to calculate mechanical rock properties



## Unconventional gas example without a kerogen correction applied



# Review Mechanical Results



Unconventional shale gas example with a kerogen correction applied

- Results from custom calculation sequence remedy erroneous sonic data and low reading density data

# Export Results

- Depth plots are exported in portable document format (pdf)
  - vector image files will not distort with resizing
  - templates are easily saved and recalled for future projects
    - RAW depth plot showing raw (unedited) log data
    - ANS depth plot showing reservoir results along with edited logs
    - MECH depth plot showing reconstructed density and sonic logs, along with mechanical property logs
  - PowerLog's PowerBatch module enables this process to be automated (a big time saver for multiwell projects)
- LAS files are exported using PowerLog's LAS File or Batch LAS File export modules
  - templates are used to export log data sets to match the depth plots
    - RAW, ANS and MECH LAS files are created
  - LAS files are easily imported into other software packages

# Review

- Customized calculation sequences deliver fast results with PowerLog
- Customized calculation sequences are very flexible
  - works in clastic and carbonate reservoirs
  - works in conventional and unconventional reservoirs, with or without kerogen
- Routinely used to reconstruct density and sonic logs for mechanical rock property calculations
- Allows for continuous improvement

# Appendix

# Porosity

Log Total Porosity (PHIT)			
Clay Bound Water	Irreducible Water (Capillary Bound)	Moveable Water	Hydrocarbon
	← Log or Core Effective Porosity (PHIE) →		
	Micro Porosity	← Macro Porosity →	
		← Connected Porosity →	
NMR CBW	3 ms	NMR Irreducible Water	33 ms ← NMR Moveable Fluids →

- Rock pore volume is divided into total and effective porosity.
  - Total porosity is calculated from logs and includes clay bound water (CBW).
  - Effective porosity includes micro and macro porosity, but excludes CBW.

# Total Stress Equation

$$P_c = \frac{\nu}{(1-\nu)} \left[ D_{tv} \gamma_{ob} - \alpha_v (D_{tv} \gamma_p + P_{off}) \right] + \alpha_h (D_{tv} \gamma_p + P_{off}) + \varepsilon_x E + \sigma_t$$

$P_c$  = closure pressure, kPa

$\nu$  = Poisson's Ratio

$D_{tv}$  = true vertical depth, m

$\gamma_{ob}$  = overburden stress gradient, kPa/m

$\gamma_p$  = pore fluid gradient, kPa/m

$\alpha_v$  = vertical Biot's poroelastic constant

$\alpha_h$  = horizontal Biot's poroelastic constant

$P_{off}$  = pore pressure offset, kPa

$\varepsilon_x$  = regional horizontal strain, microstrains

$E$  = Young's Modulus, GPa

$\sigma_t$  = regional horizontal tectonic stress, kPa

# Biot's Poroelastic Parameter

