How To Use Customized Workflows To Deliver Fast Results with PowerLog

Prepared For

PowerLog User Group Meeting

Prepared By

Dorian Holgate, P. Geol.
Principal Consulting Petrophysicist

24 October 2013

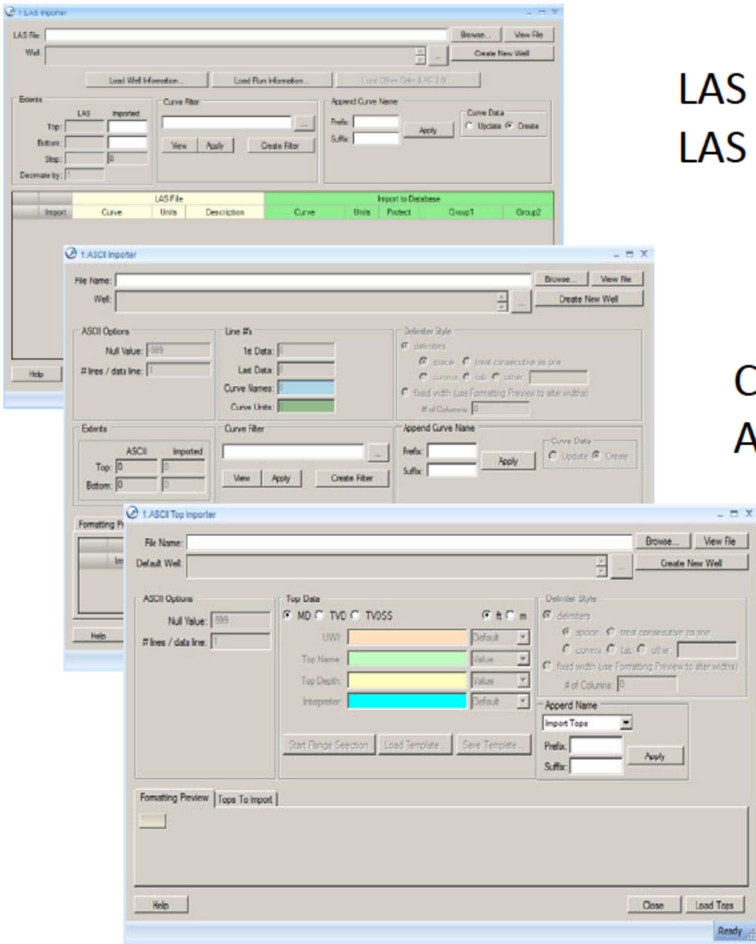
Index

- Advantages of using a Customized Workflow
- Example Workflow
  1) Data Mining and Data Import
  2) Preprocessing
  3) Define Zones and Zone Parameters
  4) Run Base Calculation Sequence
  5) Review Reservoir Results
  6) Run Mechanical Calculation Sequence
  7) Review Mechanical Results
  8) Export Results
- Review

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

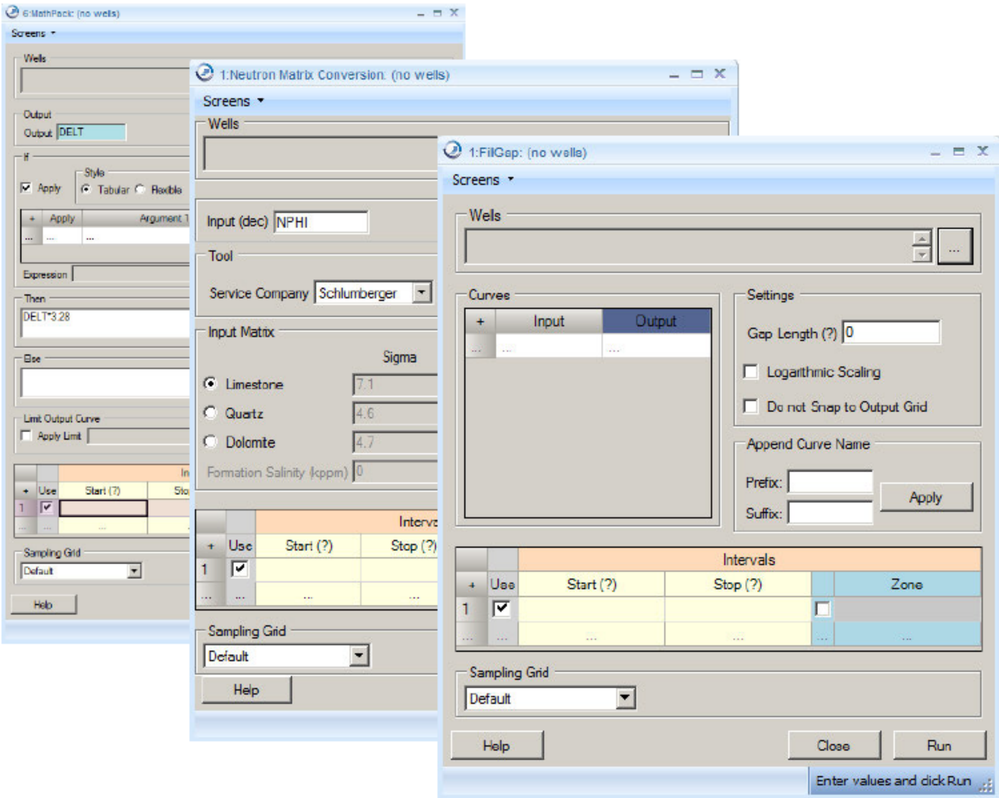


LAS files are imported using PowerLog's LAS file importer

Core data is imported using PowerLog's ASCII importer

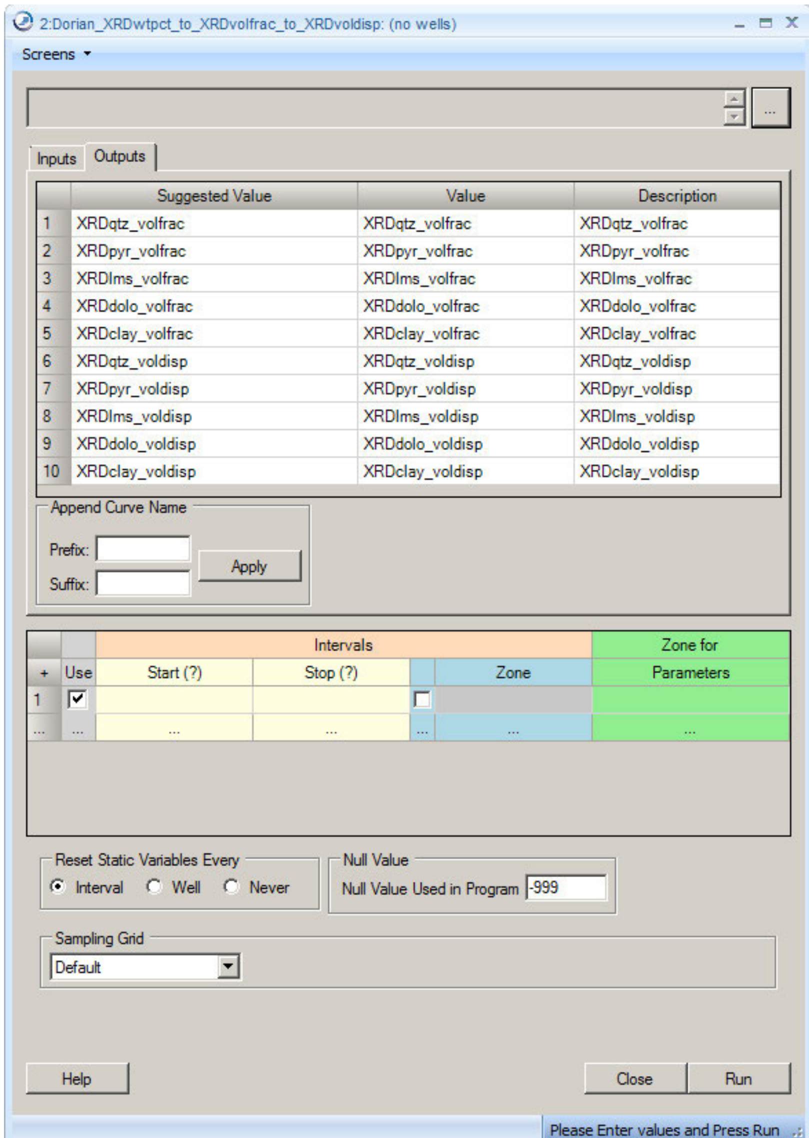
Tops are imported using PowerLog's ASCII top importer

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

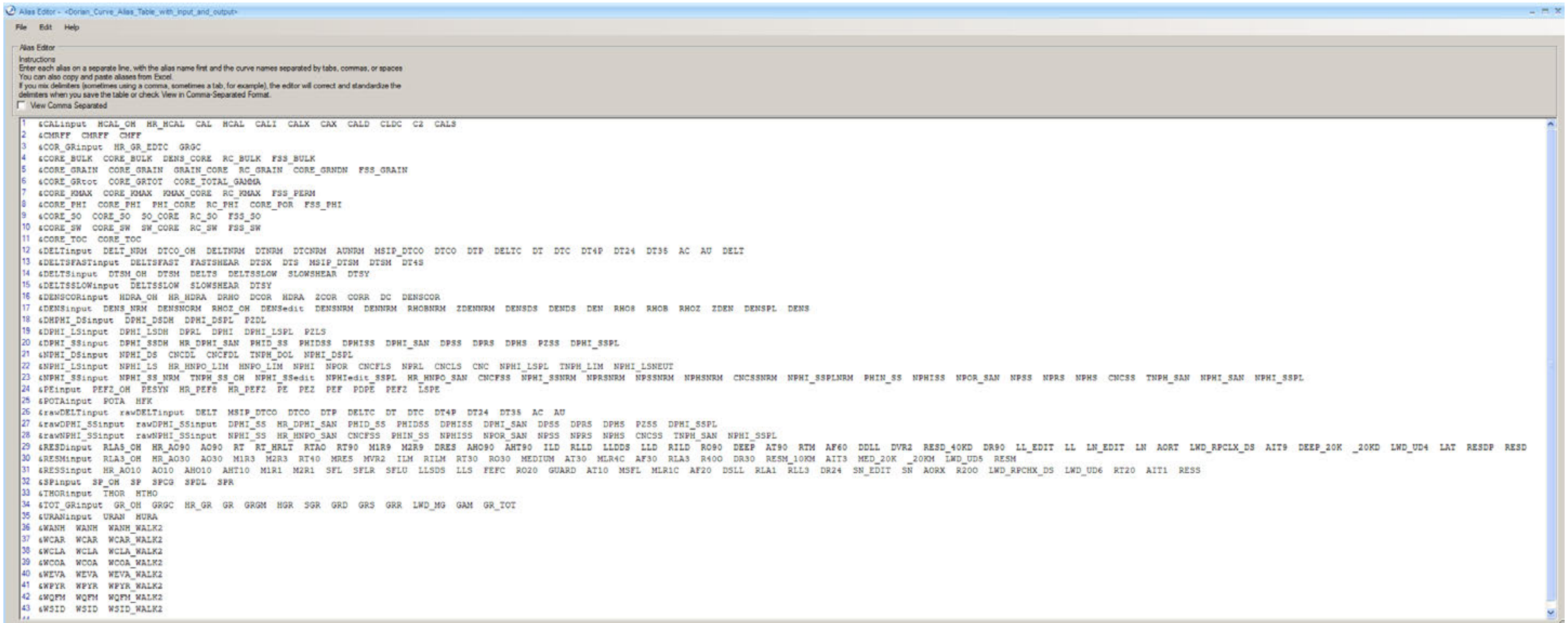


XRD SCAL Data

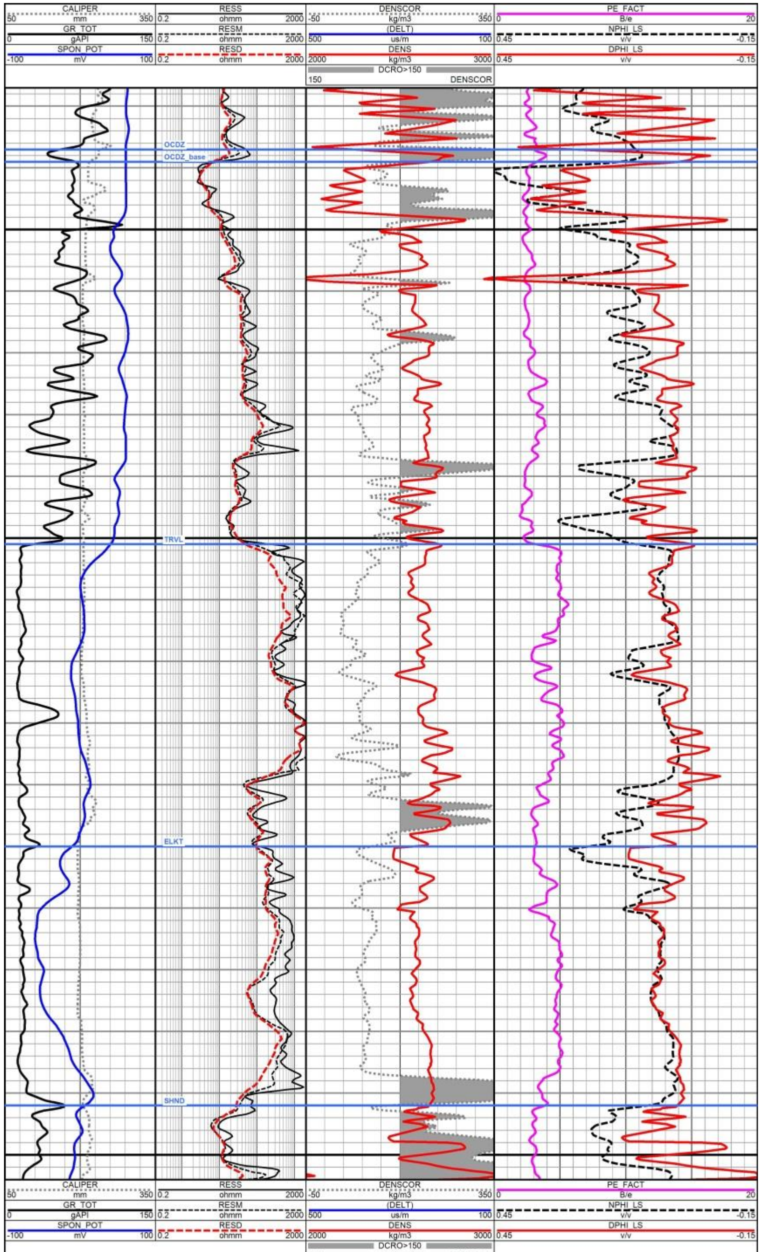
- Must convert weight percent to volume fraction to integrate with petrophysical analysis
- Very important for kerogen and pyrite

Preprocessing

Curve alias table is used to define input logs



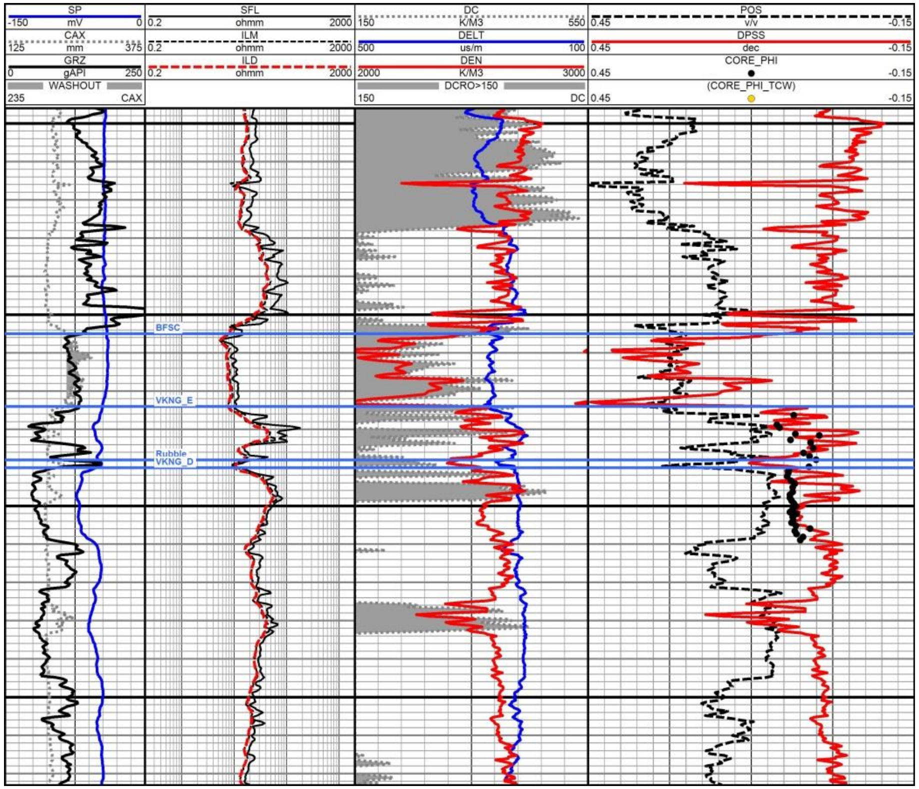
Preprocessing

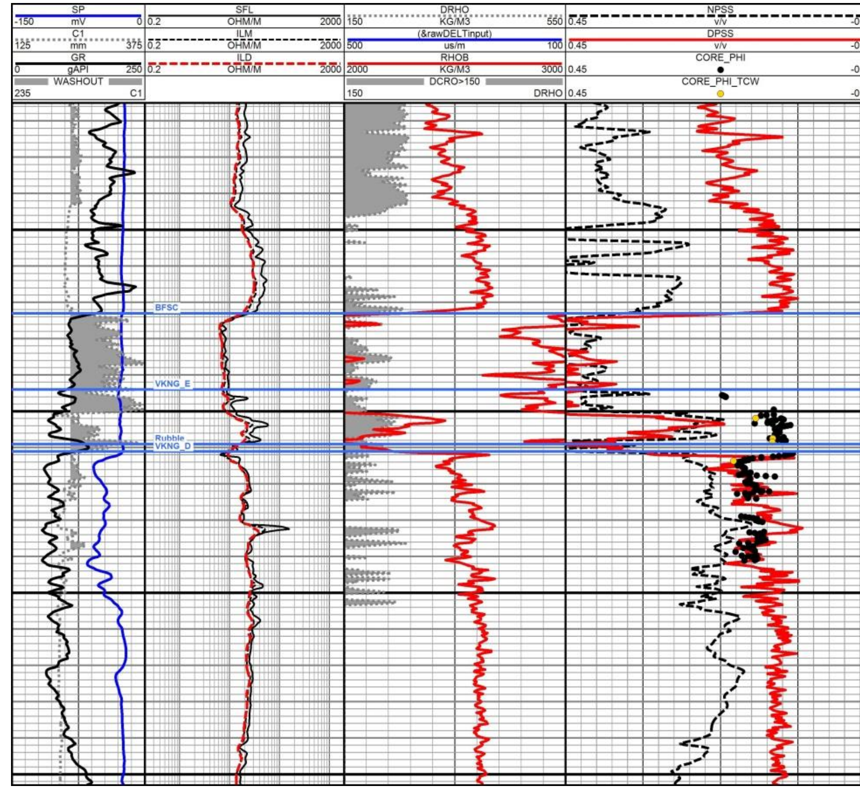


Visually check all key input logs

- 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

		Top			Bottom		
+	Zone	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		
...	...	...	...	...	...	...	...

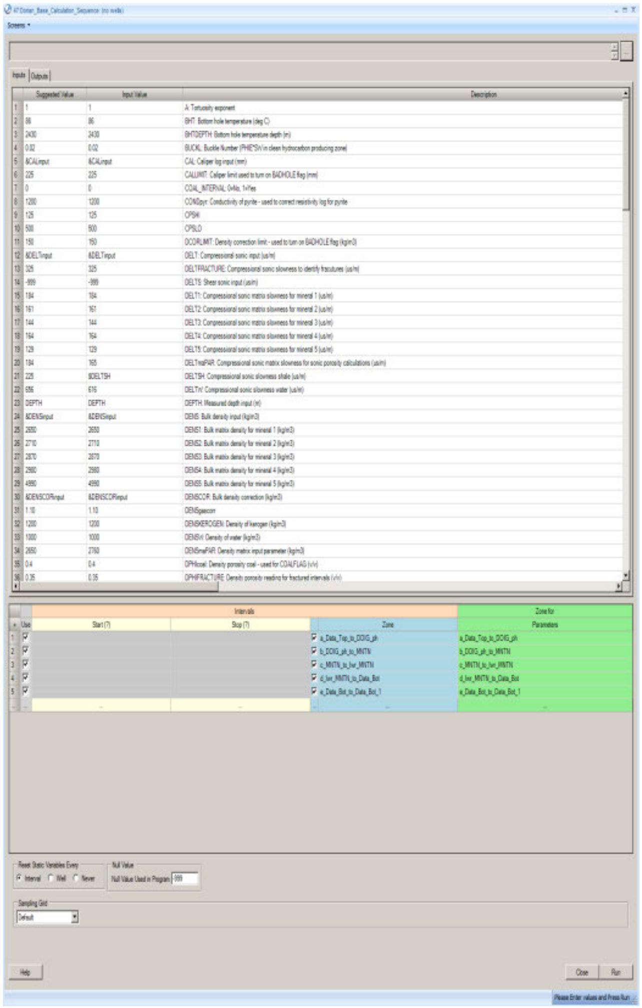
Zone Parameter Editor used to define parameters for calculation sequence

$ All Parameters | $ _DH | $ Archie | $ Cased Hole | $ Clay Volume | $ Dual Water | $ Juhasz | $ Log Run | $ Multi-Mineral | $ Quic

Z All Zones

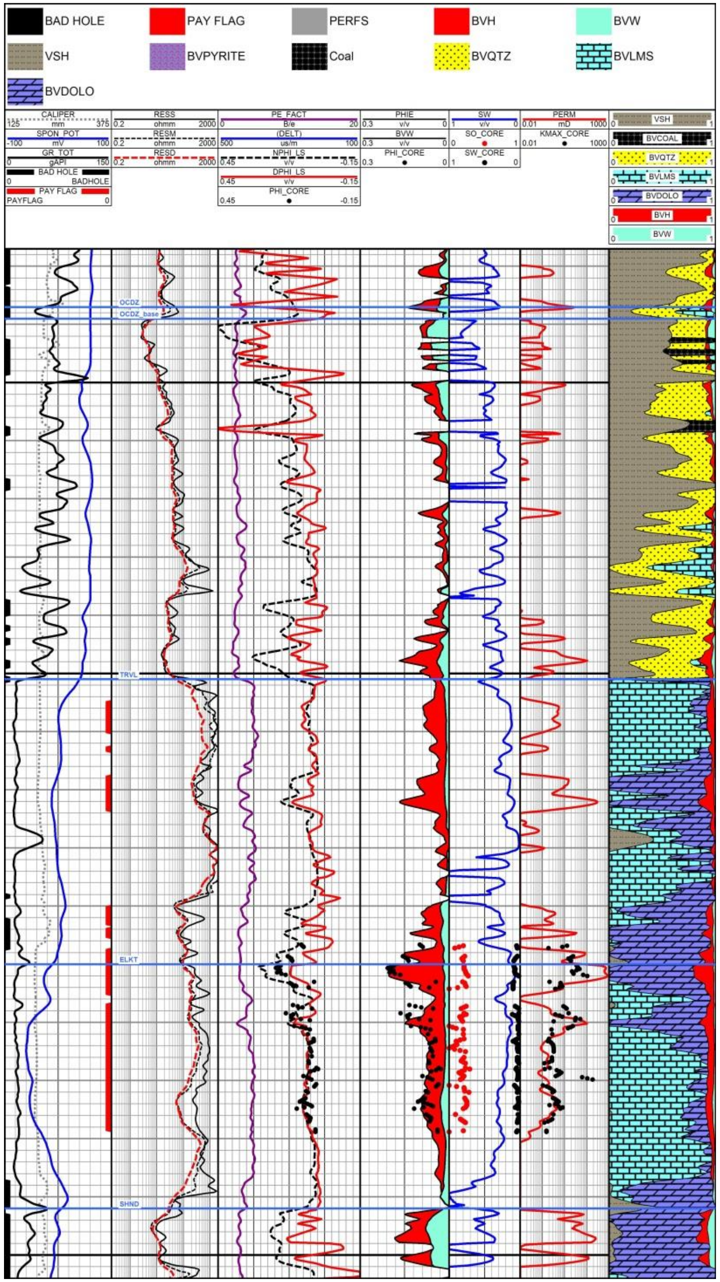
Well	Zone	Start	End	Depths	$GRWmax	$GRWmin	$LITHMODEL
100032301925W400	a_Data_Top_to_OCDZbase	Data_Top	OCDZ_base	1729 to 1735.5	110	25	8
100032301925W400	b_OCDZbase_to_TRVL	OCDZ_base	TRVL	1735.5 to 176...	100	25	8
100032301925W400	c_TRVL_to_ELKT	TRVL	ELKT	1768.5 to 178...	110	20	12
100032301925W400	d_ELKT_to_SHND	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, VSHRESD
- 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 Rw to geothermal gradient
  - A, M and N inputs
  - RESDSH input corrects for low resistivity shale
- Permeability
  - exponential model K(PHIE)
  - Wylie-Rose model
  - Lucia’s carbonate model

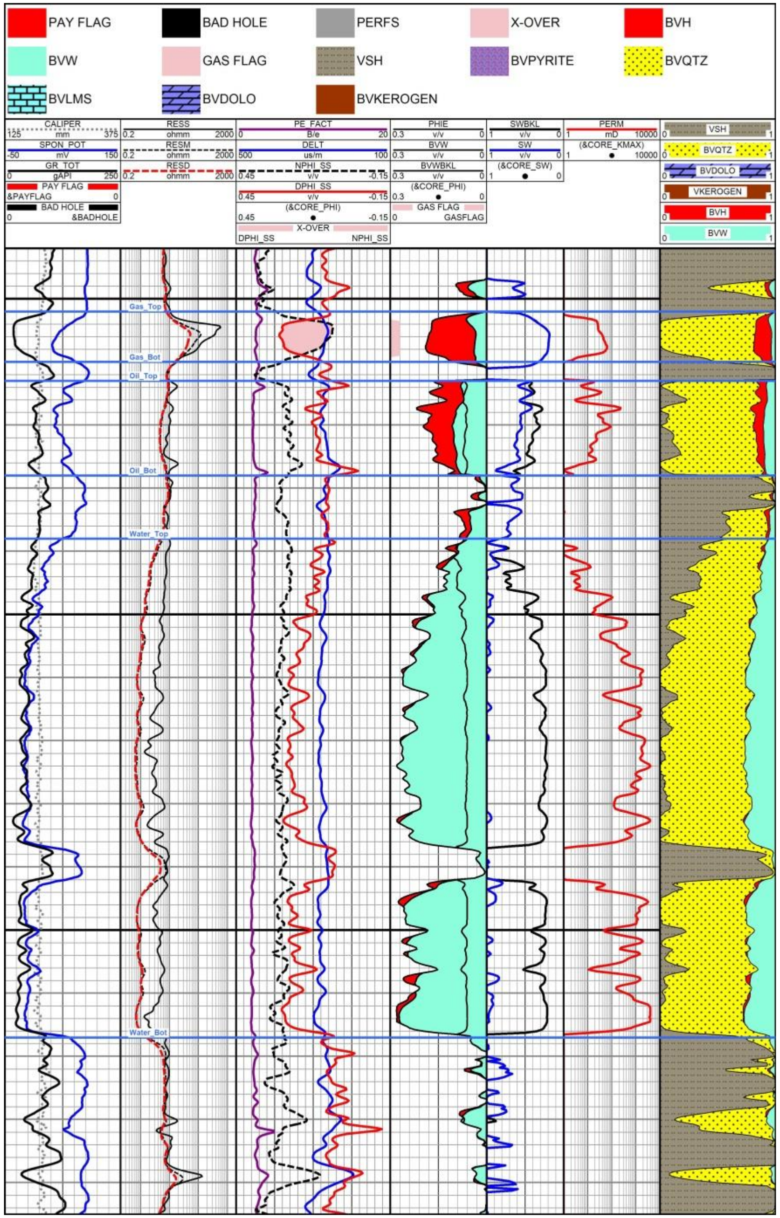
Review Reservoir Results



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

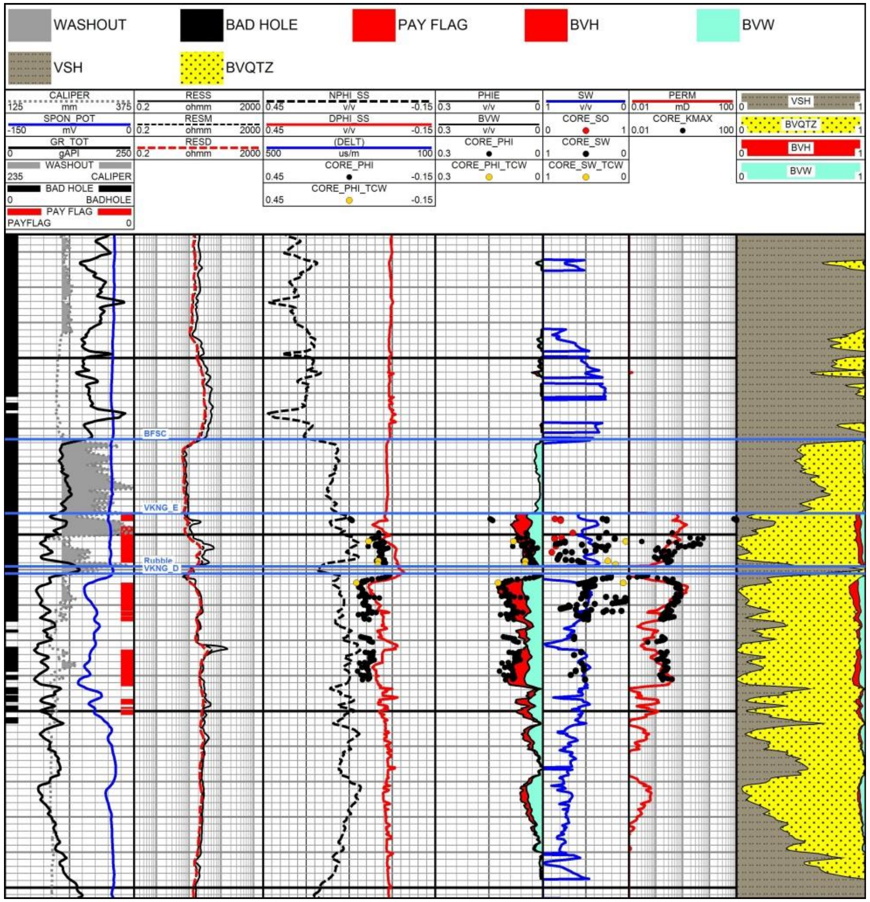
Review Reservoir Results

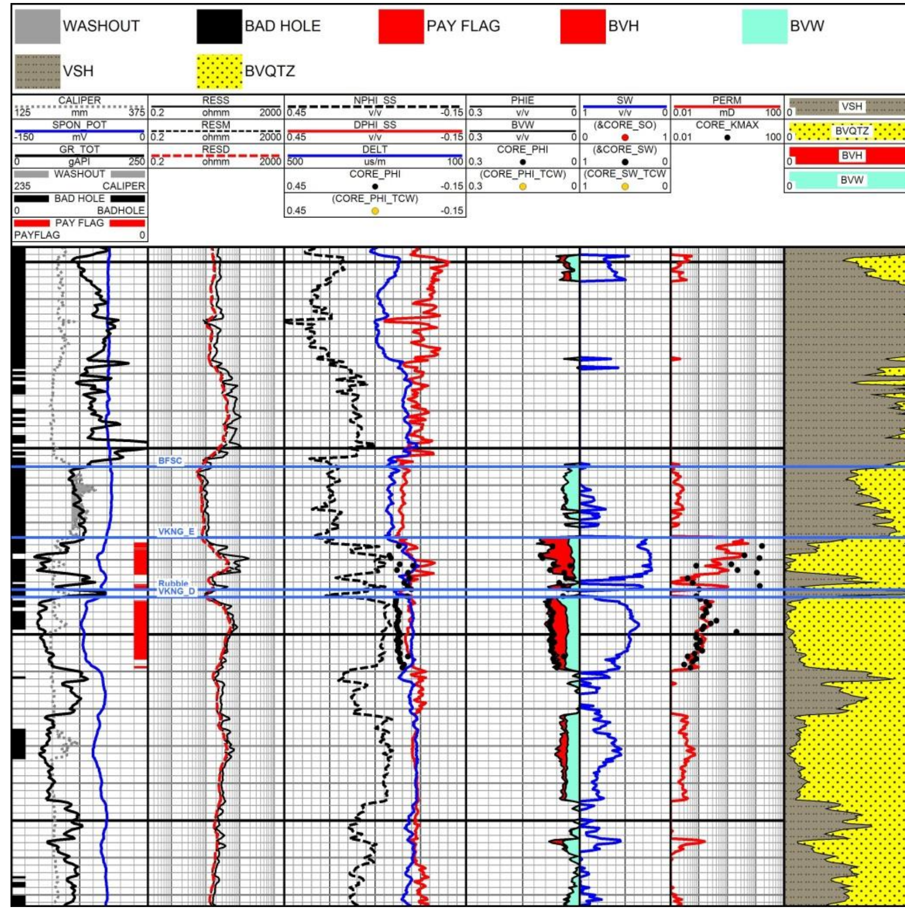


Gas Over Oil Over Water Example

- Custom calculation sequence used to define this conventional reservoir interval

Reservoir Results

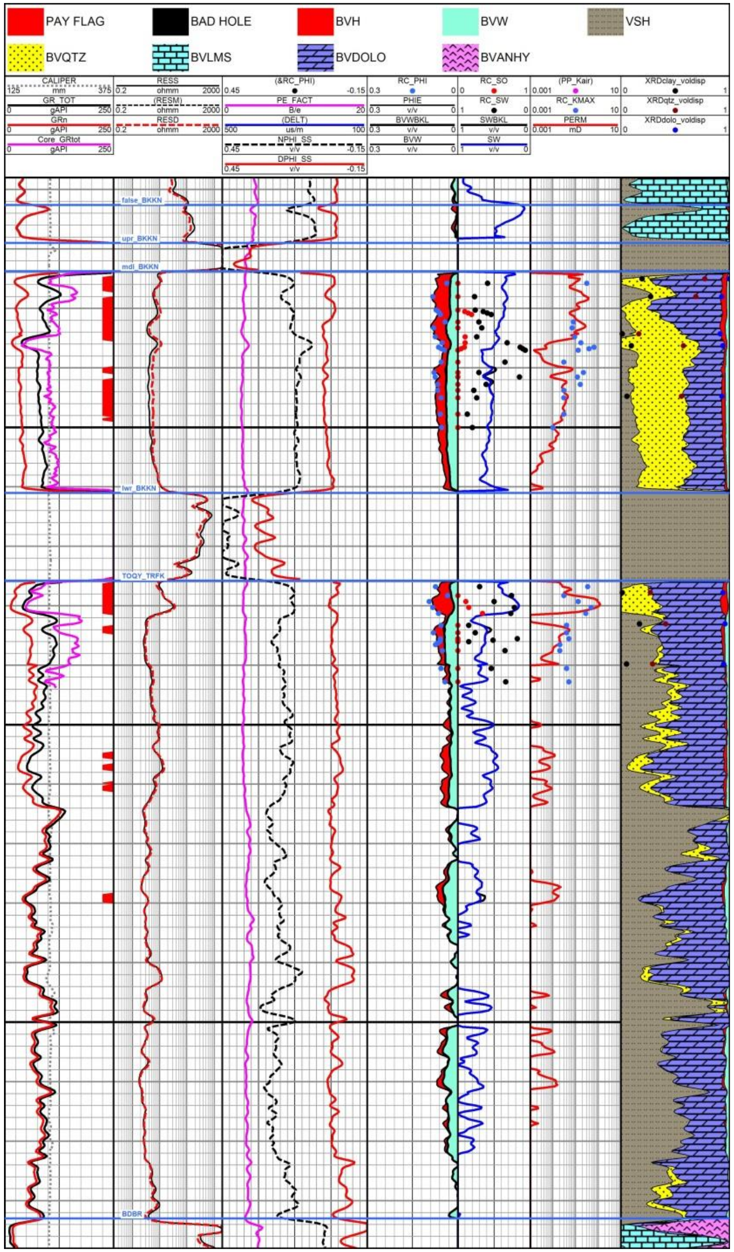




Clastic Example with Rough Bore Hole

- 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

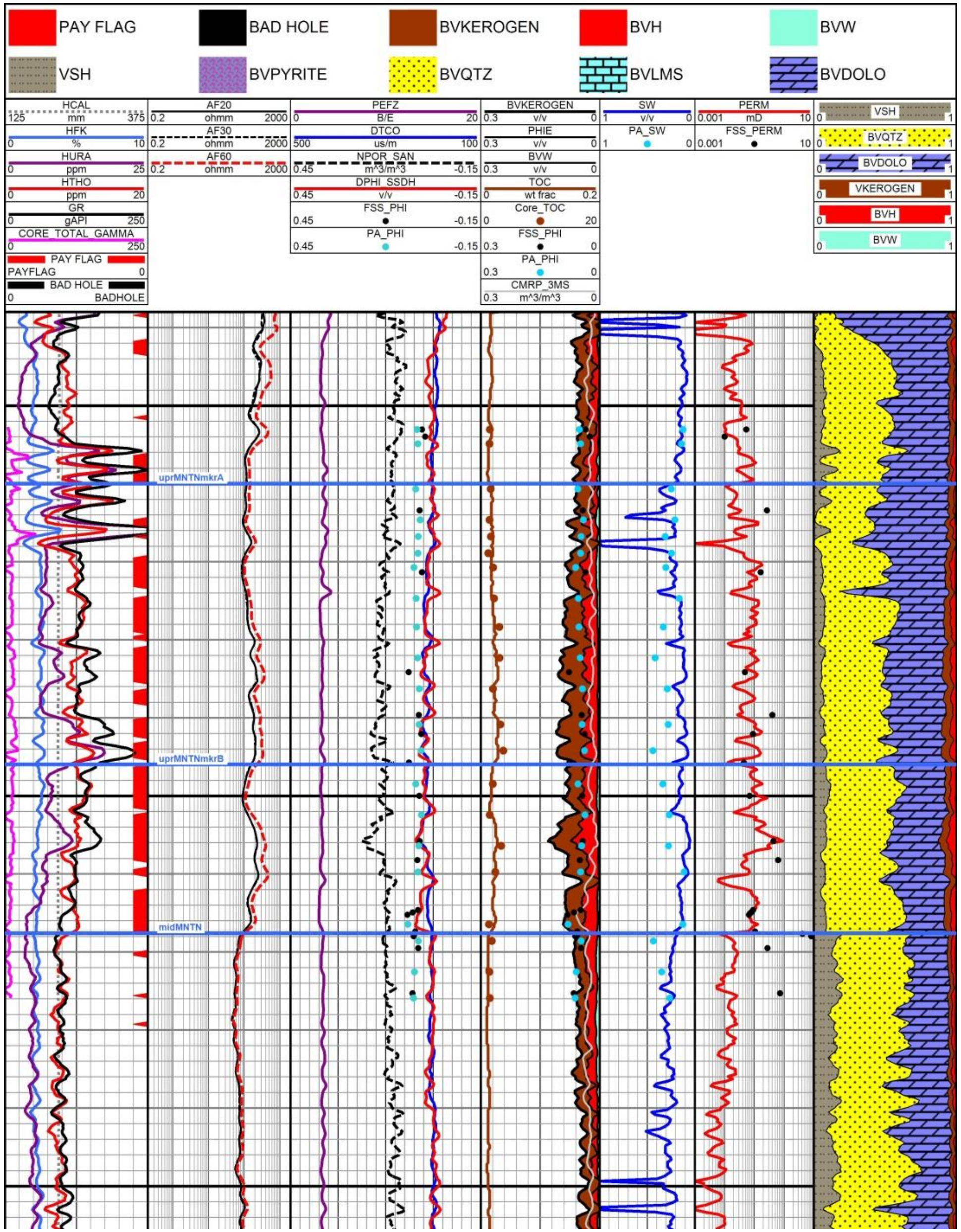
Review Reservoir Results



Tight Oil Example

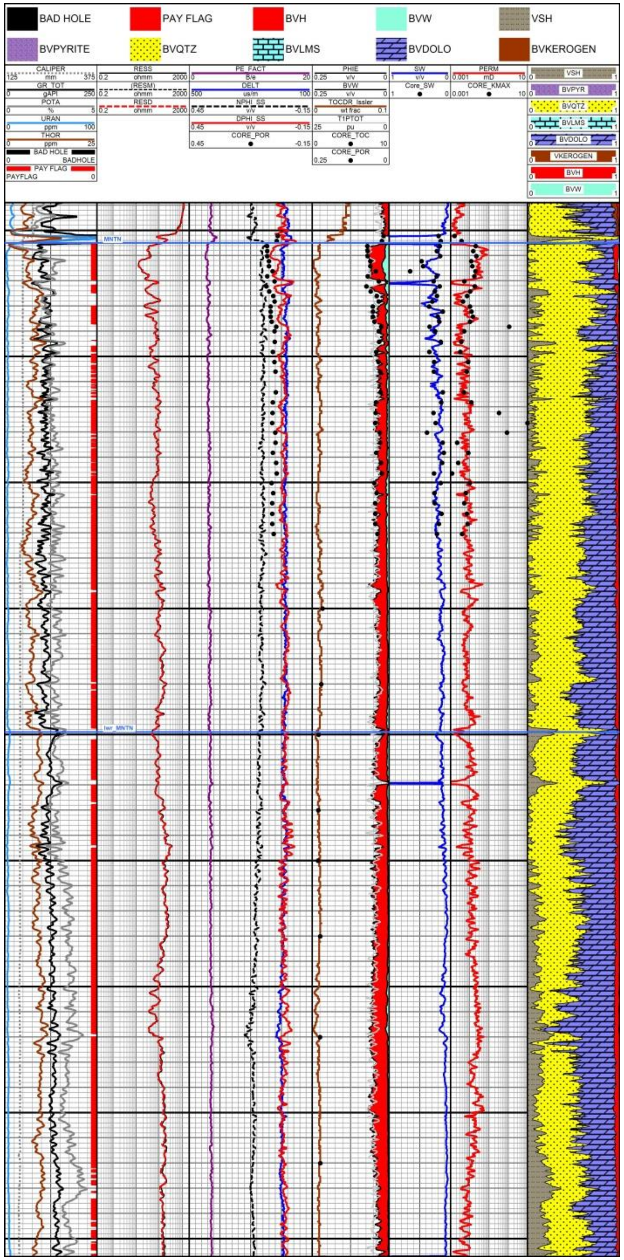
- Results from custom calculation sequence match RCAL and SCAL data quite well, considering the laminated nature of the reservoir

Review Reservoir Results



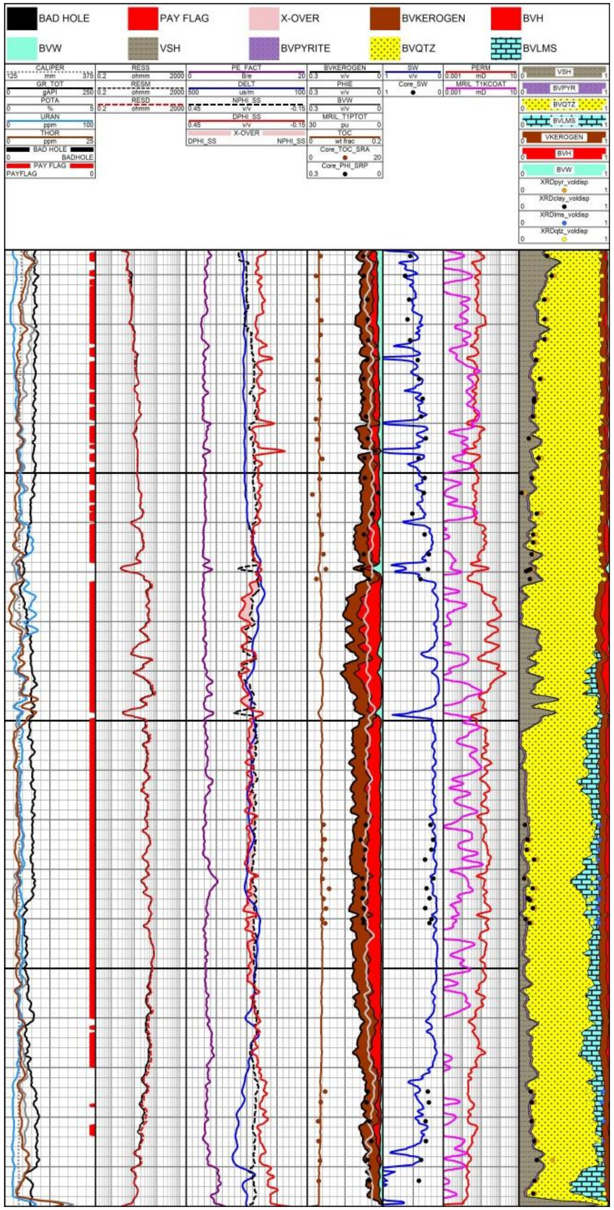
Unconventional gas example with a kerogen correction applied

Review Reservoir Results



Unconventional gas example without a kerogen correction applied

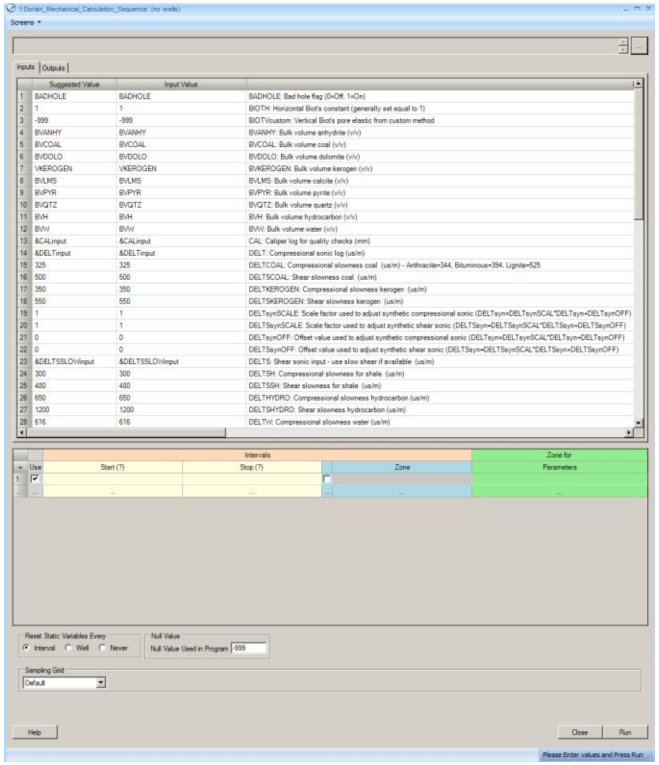
Review Reservoir Results



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.

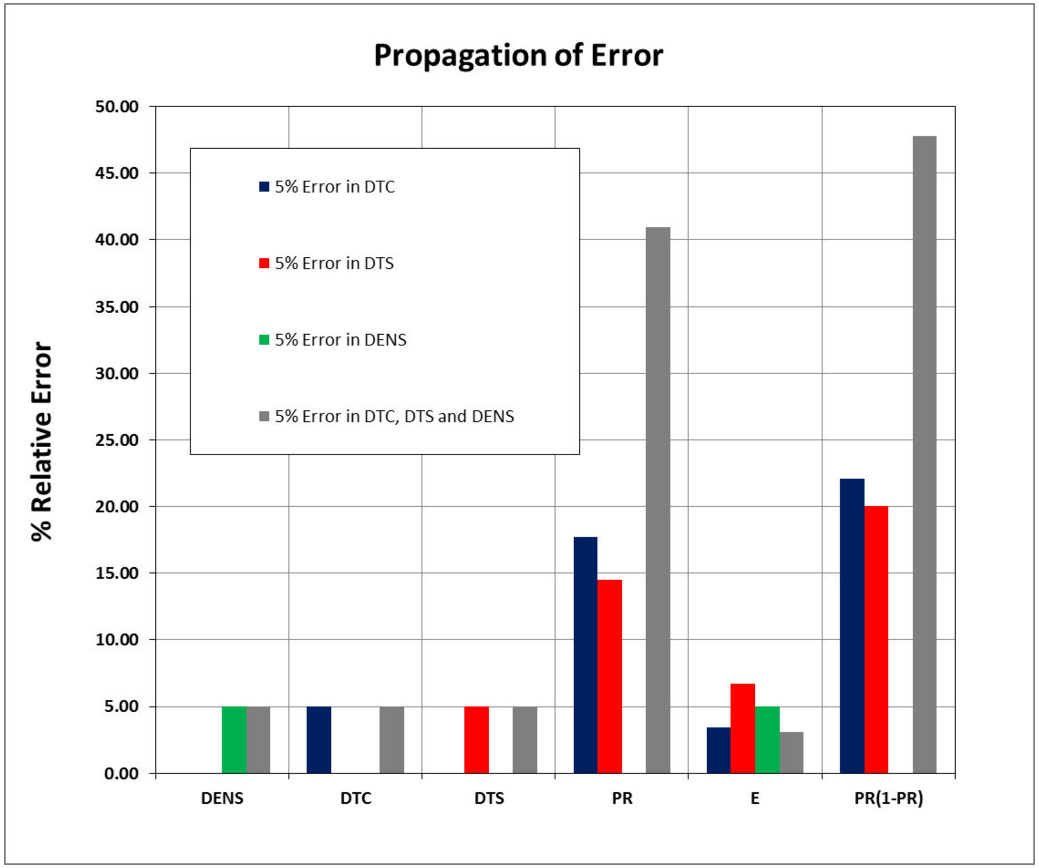
- Since logs read the invaded zone, light hydrocarbons (light oil or gas) make the density log read too low and the sonic log read too high, compared to the water filled case.

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

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

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:

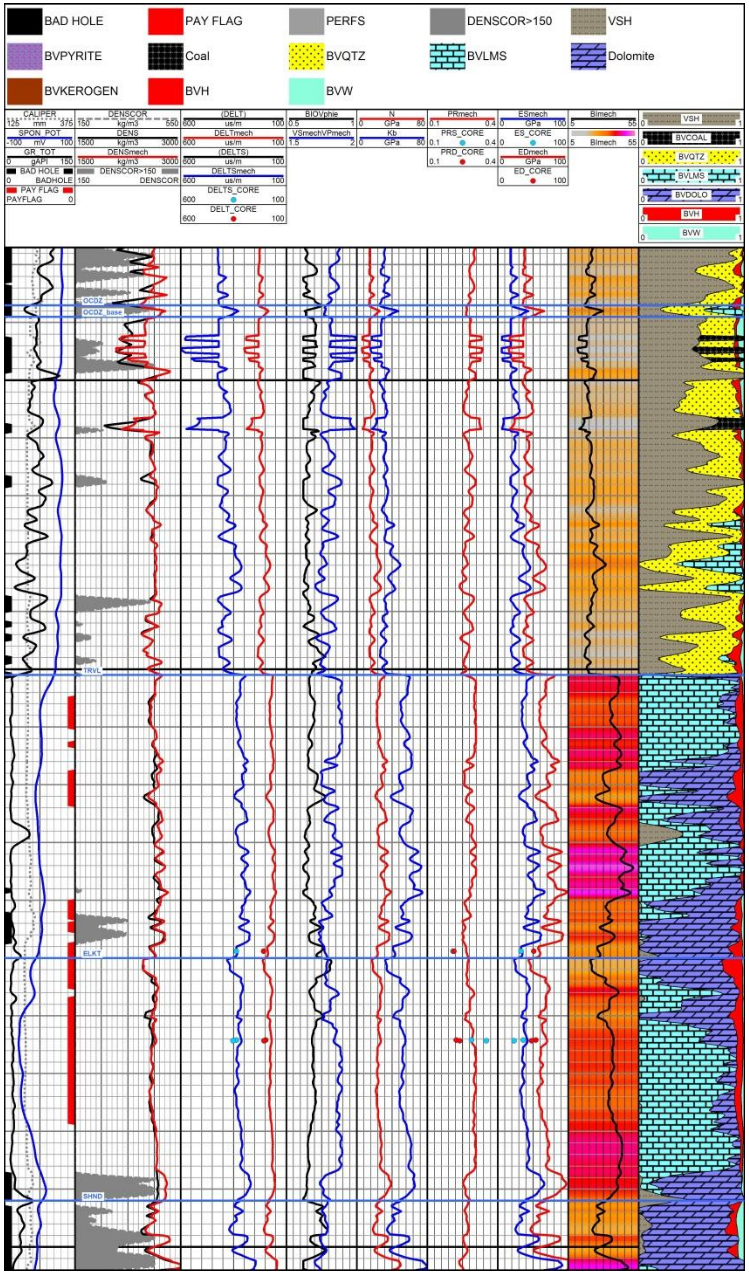
- Poisson's ratio
- Young's dynamic and static moduli
- bulk modulus
- shear modulus
- brittleness index

Effective porosity from the quantitative analysis is used to calculate:

- vertical Biot's poroelastic parameter

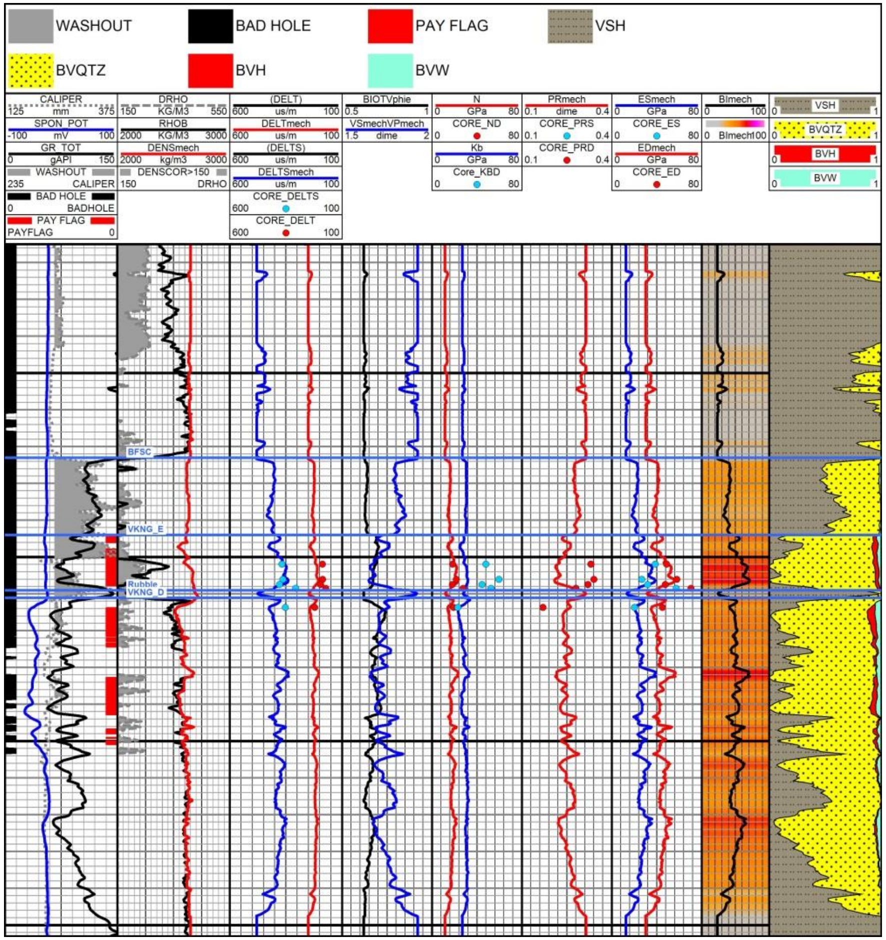
Closure stress is also calculated and must be calibrated to local field conditions with a strain or stress correction factor.

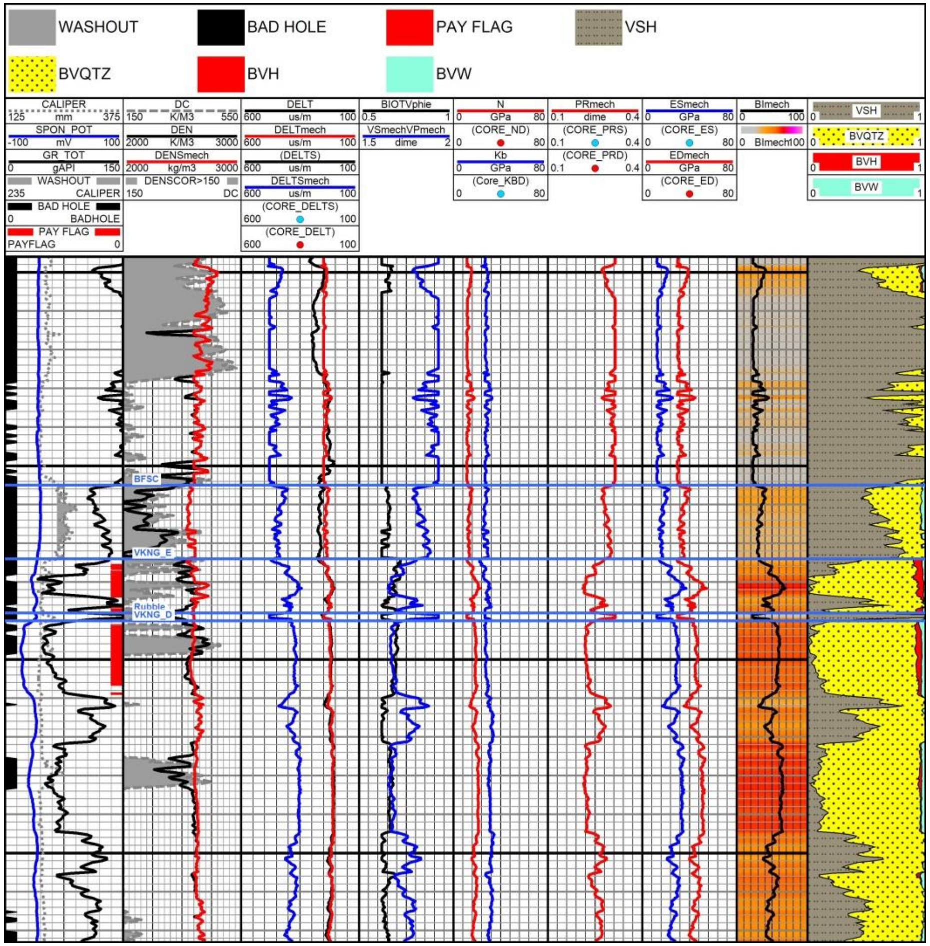
Review Mechanical Results



Clastic and Carbonate Example

Review Mechanical Results

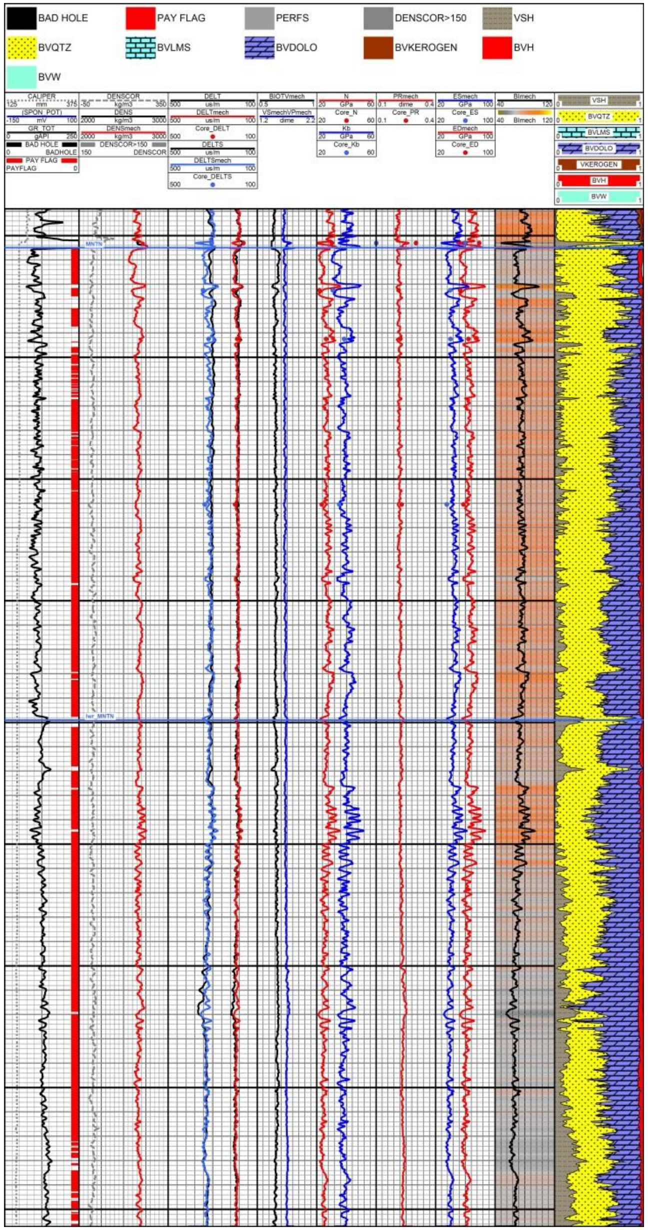




Clastic Example with Rough Bore Hole

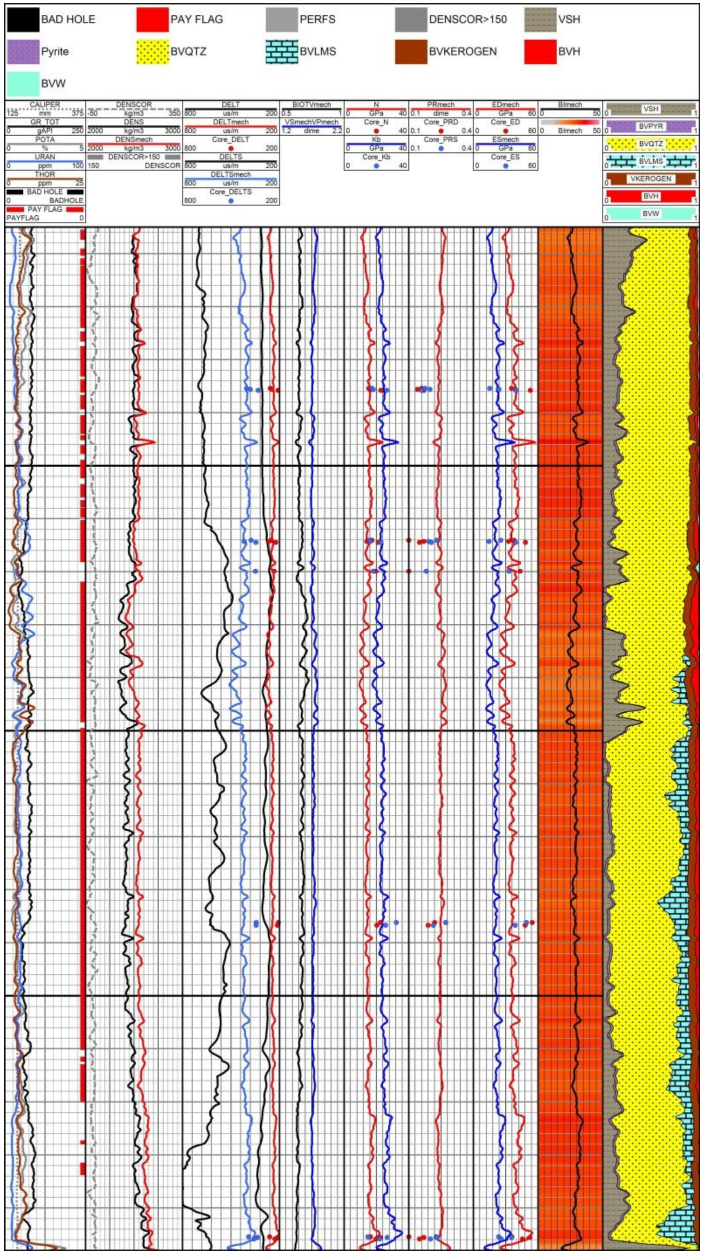
- Reconstructed density and sonic logs used to calculate mechanical rock properties

Review Mechanical Results



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)

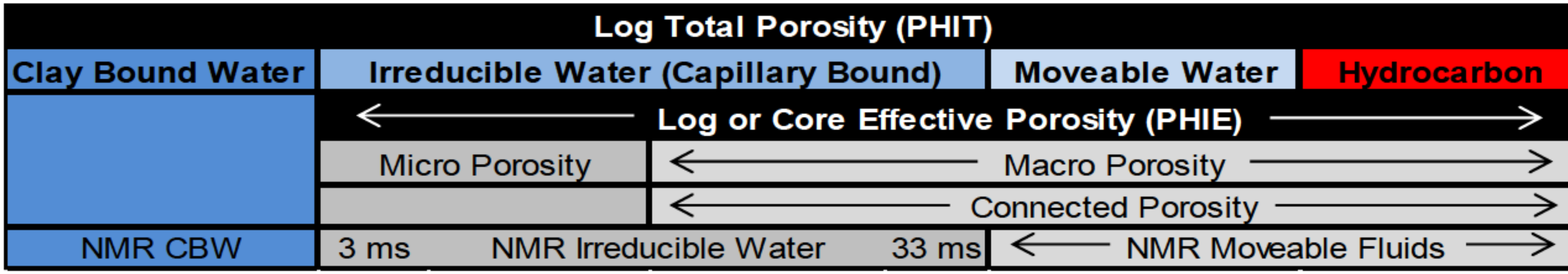
- LAS files are exported using PowerLog's LAS File or Batch LAS File export modules
  - templates are used to export log data sets to match the depth plots
    - RAW, ANS and MECH LAS files are created
  - LAS files are easily imported into other software packages

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



- 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

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

P_c = closure pressure, kPa
ν = Poisson's Ratio
D_{tv} = true vertical depth, m
γ_{ob} = overburden stress gradient, kPa/m
γ_p = pore fluid gradient, kPa/m
α_v = vertical Biot's poroelastic constant
α_h = horizontal Biot's poroelastic constant
P_{off} = pore pressure offset, kPa
ε_x = regional horizontal strain, microstrains
E = Young's Modulus, GPa
σ_t = regional horizontal tectonic stress, kPa

Biot's Poroelastic Parameter