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

## Prepared For PowerLog User Group Meeting

**Prepared By** 

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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**

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Core data is imported using PowerLog's ASCII importer

Tops are imported using PowerLog's ASCII top importer

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- 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

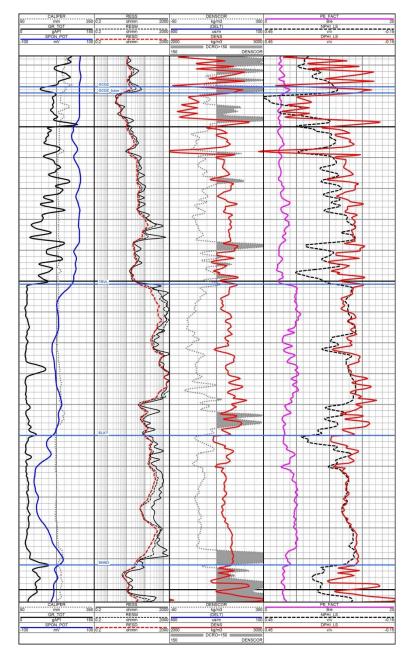
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	XRDclay_volfrac	XRDclay_volfrac	XRDclay_volfrac
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#### **XRD SCAL Data**

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

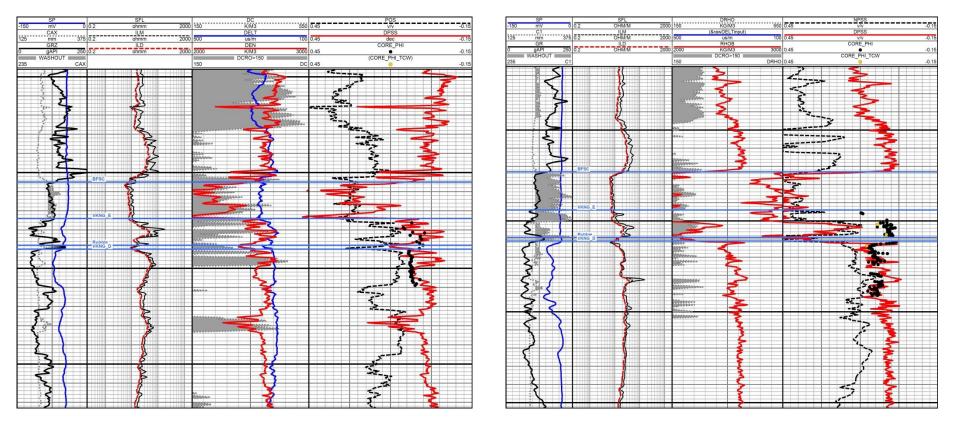
#### Curve alias table is used to define input logs

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#### Visually check all key input logs

 clastic over carbonate with some coal intervals



#### 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

			Тор			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			
	1.123		12	1111	1		1122	

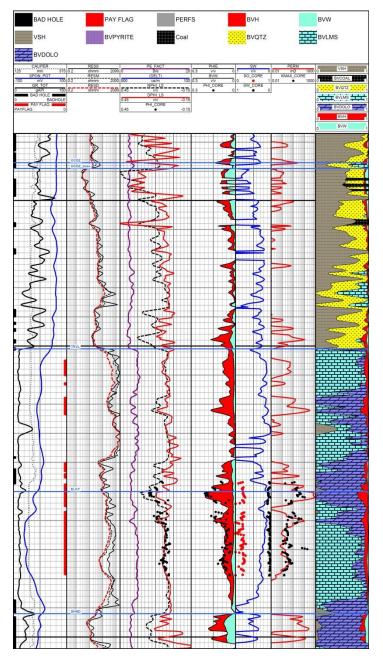
#### Zone Parameter Editor used to define parameters for calculation sequence

Well	Zone	Start	End	Depths	\$GRWmax	\$GR\//min	\$LITHMODE
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	Entire/v/ell	WellTop	WellBottom	281.6 to 1833.2	110	20	12

## **Run Base Calculation Sequence**

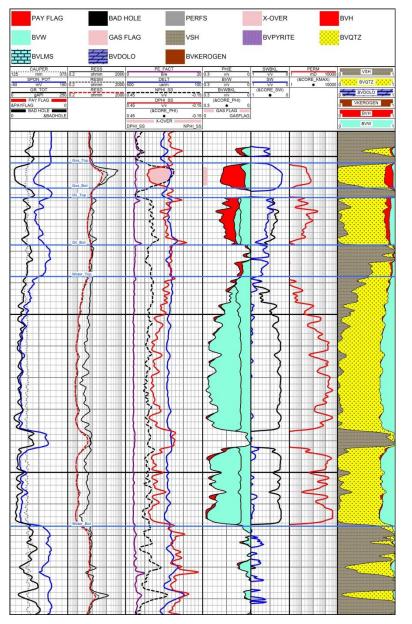
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- Petrophysicist's shale volume (clay minerals and clay bound water)
  - VSHGR (linear and non linear models)
  - Spectral GR models
  - VSHXND, VSHSP, VSHRESD
  - Porosity models
    - PHIXND, PHIXNS, PHIS, PHIDcustom, PHIE(VSH)
    - bad hole flag
    - 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



### Clastic and Carbonate Example

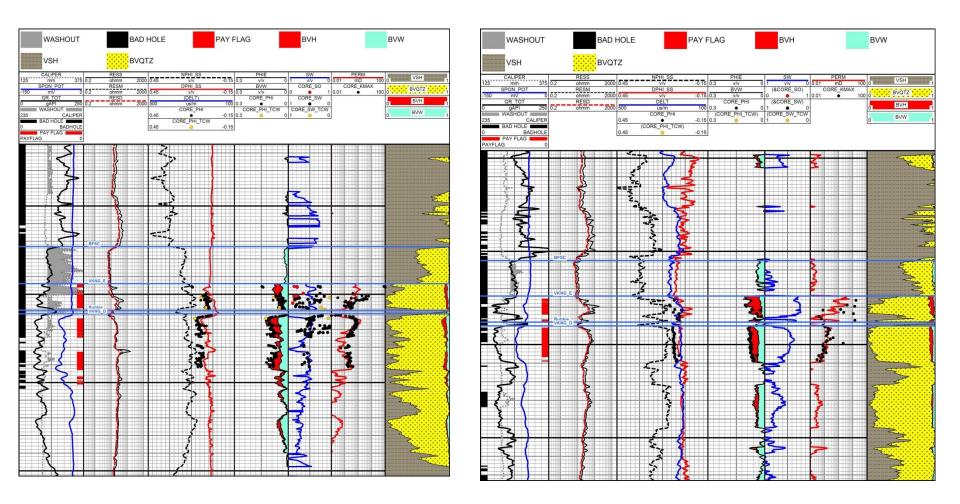
- Custom calculation sequence, along with zonation parameters used to calculate reservoir parameters for clastic and carbonate intervals.
- Results used as input to reconstruct density and sonic logs
- Reconstructed logs then used to calculate mechanical rock properties



#### Gas Over Oil Over Water Example

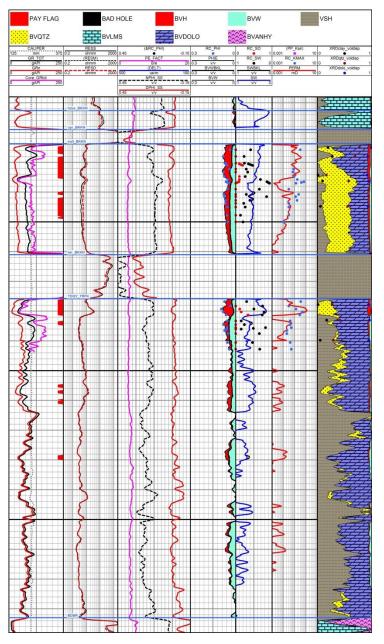
 Custom calculation sequence used to define this conventional reservoir interval

#### **Reservoir Results**



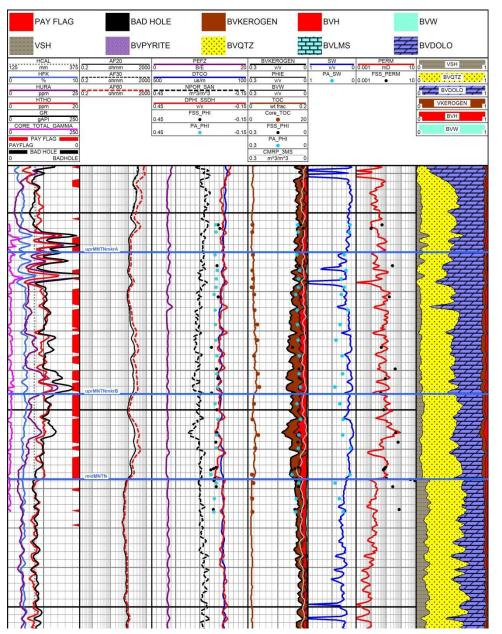
#### Clastic Example with Rough Bore Hole

- 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

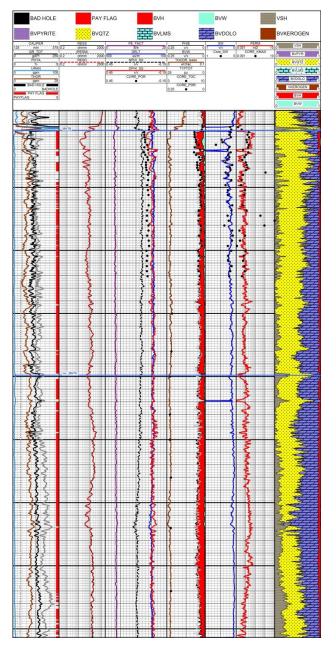


#### Tight Oil Example

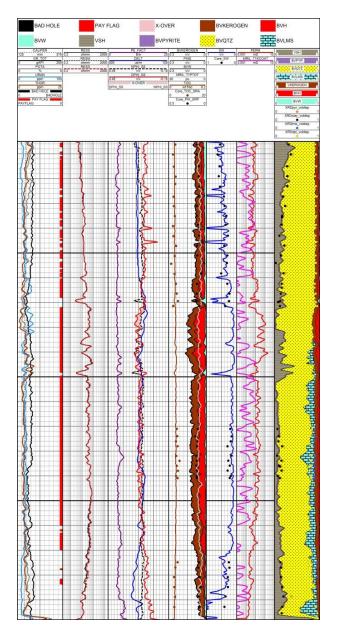
 Results from custom calculation sequence match RCAL and SCAL data quite well, considering the laminated nature of the reservoir



Unconventional gas example with a kerogen correction applied



Unconventional gas example without a kerogen correction applied



# 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**

5 Outputs							
Suppested Value	Input Value						
BADHOLE	BADHOLE	BADHOLE: Bad hole flag	(0=Off, 1=On)				
1	1		constant (generally set equal to 1)				
-999	-999		ot's pore elastic from custom method				
BVANHY	BVANHY	BVANHY' Bulk volume an					
BVCOAL	BVCOAL	BVCOAL: Bulk volume co					
BVDOLO VKEROGEN	BVDOLO VKEROGEN	BVDOLO: Bulk volume do					
BVLMS	BVLMS	BVKEROGEN: Bulk volum BVLMS: Bulk volume calc					
BVPYR	BVPYR	BVPYR: Bulk volume pyrit					
BVQTZ	BVQTZ	BVQTZ: Bulk volume gue					
BVH	BVH	BVH: Bulk volume hydroc					
B/W	BWW	BVW: Bulk volume water (					
&CALinput	&CALinput	CAL: Caliper log for qualit					
&DELTinput	8DELTinput	DELT: Compressional sor					
325	325		DELTCOAL Compressional slowness coal (us/m) - Anthracite=344, Bituminous=394, Lignite=525				
500	500	DELTSCOAL: Shear slow	ness coal (us/m)				
350	350 DELTKERIDGEN: Compressional slowness kerogen (us/m)						
550	550	DELTSKEROGEN: Shear					
1	1		ctor used to adjust synthetic compressional sonic (				
1	1		factor used to adjust synthetic shear sonic (DELTS)				
0	0	DELTsynOFF: Offset value used to adjust synthetic compressional sonic (DELTsyn=DEL Syn=Syn=Syn=Syn=Syn=Syn=Syn=Syn=Syn=Syn=					
0	0	DELTSeynOFF: Offset value used to adjust synthetic shear sonic (DELTSeyn-DELTSeynSCAL'DELTSeyn-DELTSeynO					
&DELTSSLOWinput	&DELTSSLOW/input	DELTS: Shear sonic input - use slow shear if available (us/m)					
300 480	300 480	DELTSH: Compressional slowness for shale (us/m)					
650	550	DELTSSH: Shear slowness for shale (us/m) DELTHYDRO: Compressional slowness hydrocarbon (us/m)					
1200	1200		winess hydrocarbon (us/m)				
615	616	DELTW: Compressional s					
		1					
		Intervals		Zone for			
Jse S	kart (7)	Stop (7)	Zone	Parameters			
7		1					
		122					
net Static Variables Even Interval C Well C		e [999					
mpling Grd	1						

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

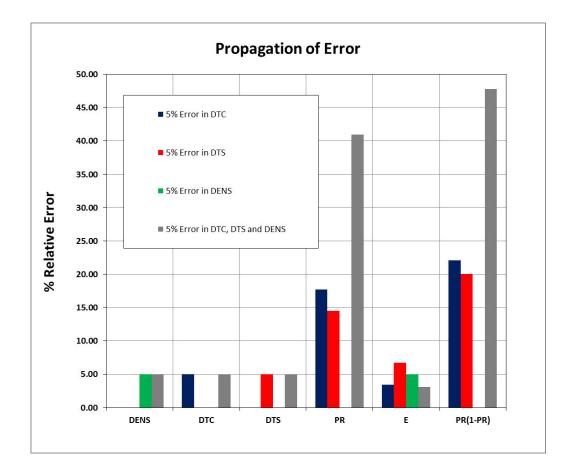
Since logs read the invaded zone, light hydrocarbons (light oil or gas) make the density log read too low and the sonic log read too high, compared to the water filled case.

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

$$P_{c} = \frac{v}{(1-v)} \Big[ D_{tv} \gamma_{ob} - \alpha_{v} \Big( D_{tv} \gamma_{p} + P_{off} \Big) \Big] + \alpha_{h} \Big( D_{tv} \gamma_{p} + P_{off} \Big) + \varepsilon_{x} E + \sigma_{t}$$

## **Mechanical Calculation Sequence**

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

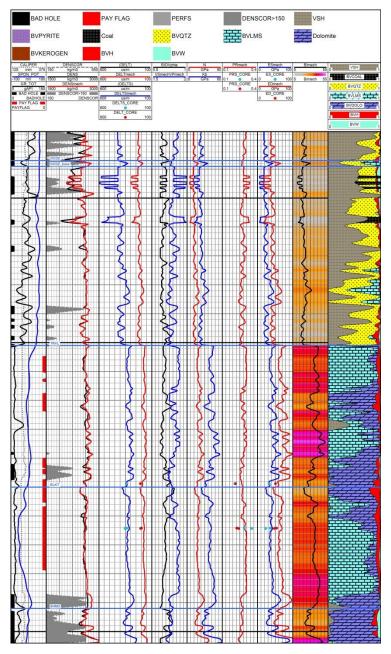
The reconstructed density and sonic logs are then used to calculate:

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

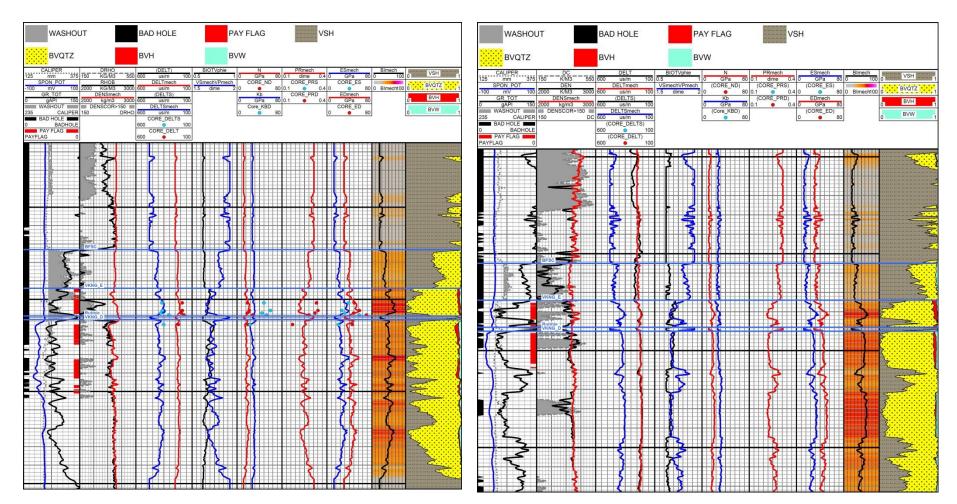
Effective porosity from the quantitative analysis is used to calculate:

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.

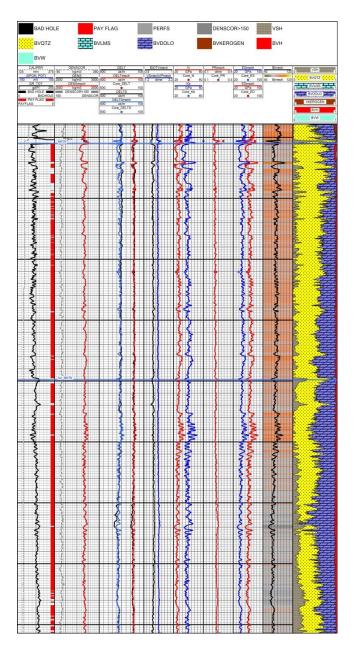


#### Clastic and Carbonate Example

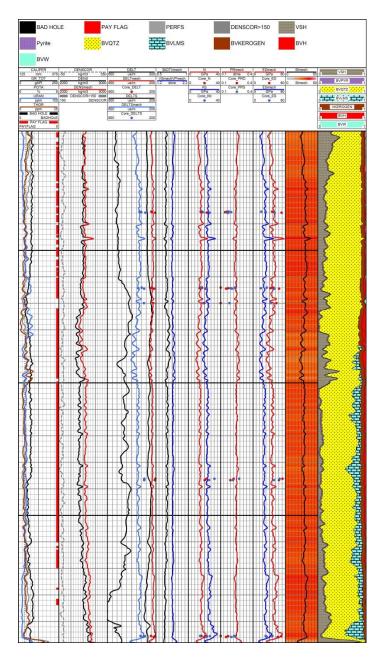


#### Clastic Example with Rough Bore Hole

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



Unconventional gas example without a kerogen correction applied



# 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 Hydroca							
	Log or Core Effective Porosity (PHIE)							
	Micro Porosity <	— Macro I	Porosity —	$\longrightarrow$				
	←	Connected Porosity						
NMR CBW	3 ms NMR Irreducible Water 3	3 ms ← ──	NMR Movea	ble Fluids $\longrightarrow$				

- 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**

$$P_{c} = \frac{\nu}{(1-\nu)} \Big[ D_{tv} \gamma_{ob} - \alpha_{v} \Big( D_{tv} \gamma_{p} + P_{off} \Big) \Big] + \alpha_{h} \Big( D_{tv} \gamma_{p} + P_{off} \Big) + \varepsilon_{x} E + \sigma_{t}$$

- $P_c$  = closure pressure, kPa
- v = Poisson's Ratio

 $\alpha_{\rm h}$ 

 $\mathcal{E}_{\mathbf{x}}$ 

E

 $\sigma_{t}$ 

 $\mathbf{P}_{\mathrm{off}}$ 

- $D_{tv}$  = 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
  - = horizontal Biot's poroelastic constant
  - = pore pressure offset, kPa
    - = regional horizontal strain, microstrains
    - = Young's Modulus, GPa
  - = regional horizontal tectonic stress, kPa

## **Biot's Poroelastic Parameter**

