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Shale Volumetrics

A plug-in of Terra 3E for Assessing Hydrocarbons in Place for Gas and Liquid-rich Shales and their Associated Uncertainties

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Outline

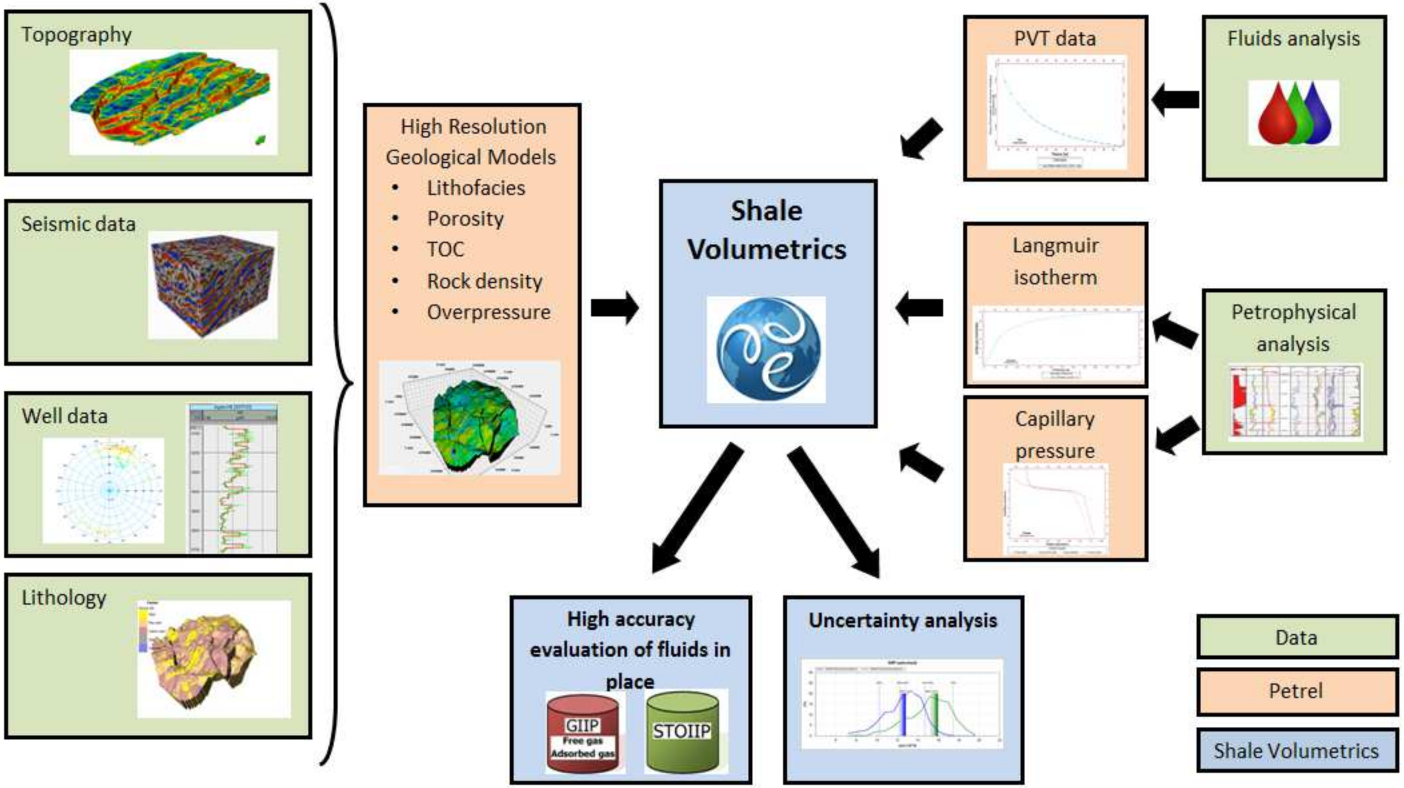
- Shale Volumetrics Method
- Shale Volumetrics Process
- Requested data
  - High resolution geological model
  - Thermodynamic data
  - Capillary pressure curves and adsorption functions
- Shale Volumetrics : STOIIP & GIIP
  - Free oil and gas calculations
  - Adsorbed gas calculation
- Case study
- Integrated workflow
- Conclusions

Shale Volumetrics Method

- Calculations rather than estimations of fluids (oil, gas and water) in place
  - Using right physics of the phenomena
  - On high resolution geological models
  - Before losing resolution due to upscaling
  - Gravity forces and capillary forces in porous media
  - Adsorption of gas in matrix

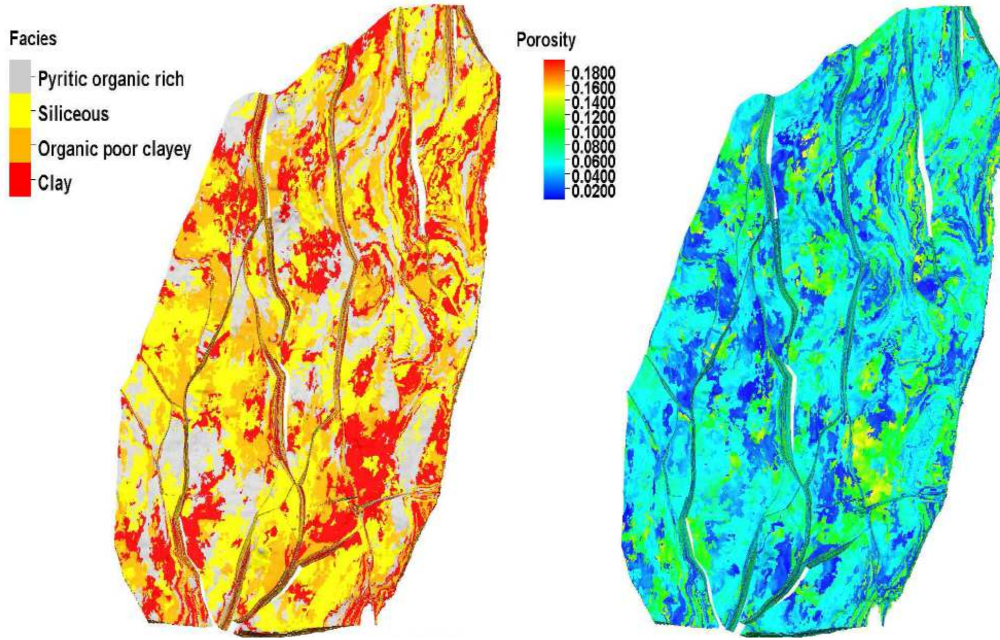
- Hydrocarbon volumes depends on
  - Rocks properties
  - Fluid properties
  - Rocks fluids interactions

Shale Volumetrics Process



Requested Data - High Resolution Geological Model

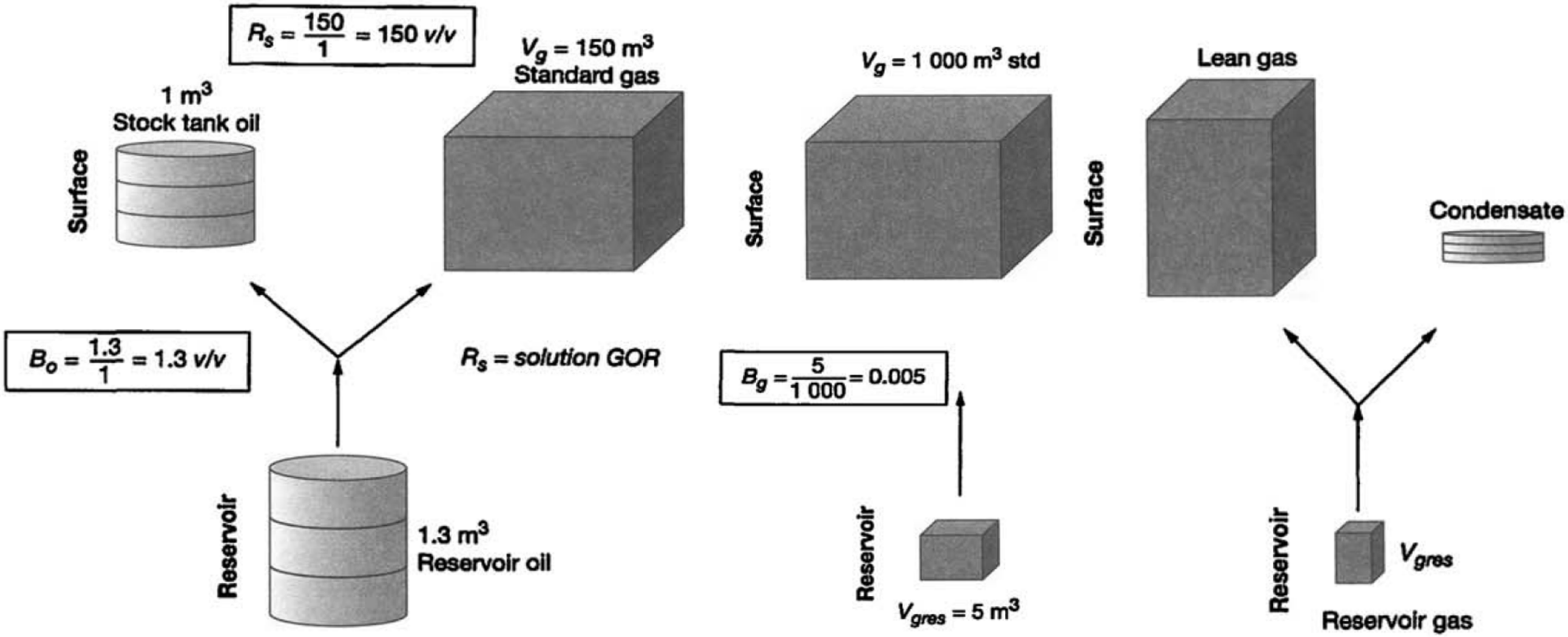
- 3D geological model described in
  - Lithofacies
  - Porosity
  - Density
  - Total Organic Content (TOC)
  - Net-to-gross (optional)
  - Overpressure (optional)



Requested Data - Thermodynamic Data

- Densities, volume factors and solution ratios of existing phases (Oil, Gas and Water)
  - ρg, ρo, ρw
  - Bg, Bo, Bw
  - Rs : Solution gas-oil ratio
  - Rv: Vaporized oil-gas ratio

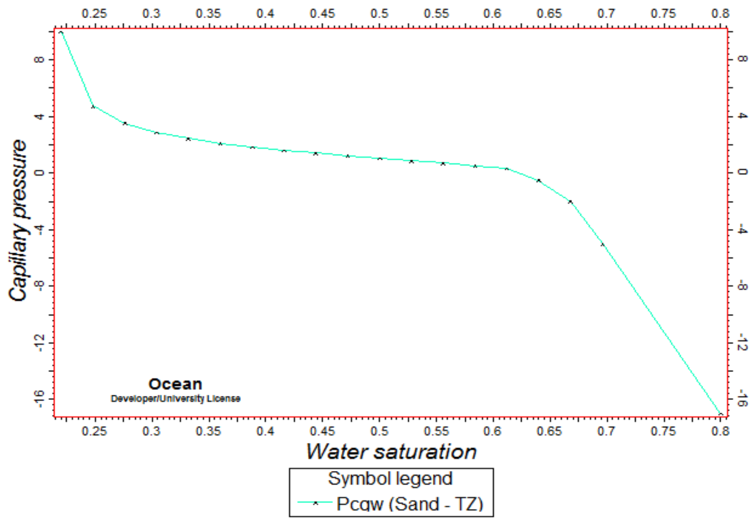
Requested Data - Thermodynamic Data



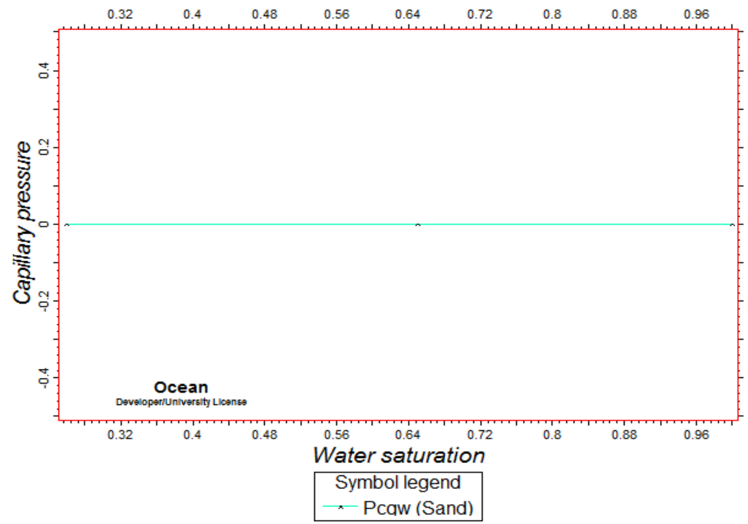
Fluids relationship (Donnez, 2007)

Requested Data - Capillary Pressure Curves

- Capillary pressure: $$P_{cgw} = P_g - P_w$$ $$P_{cow} = P_o - P_w$$ $$P_{cgo} = P_g - P_o$$



Case with transition zone



Case without transition zone

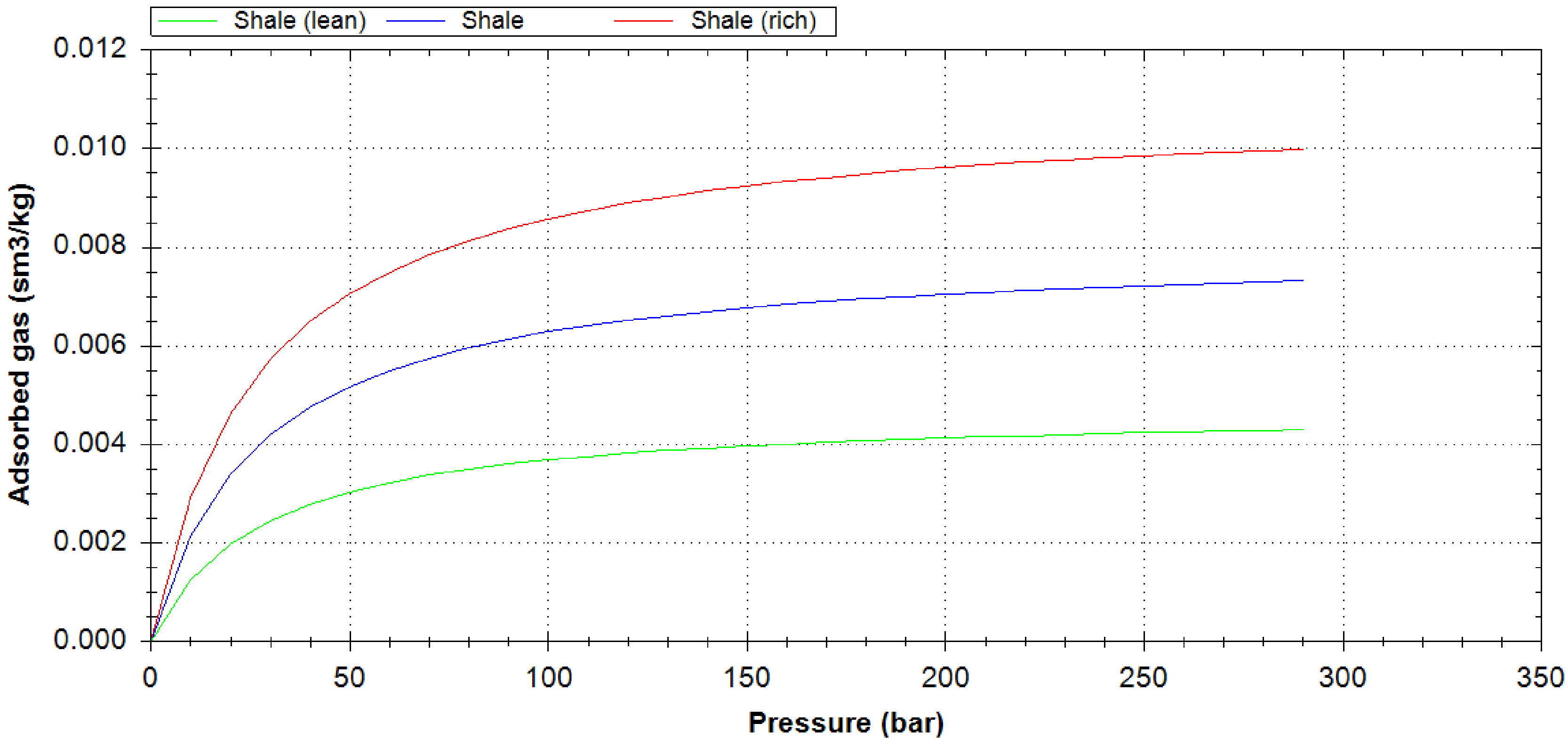
Requested Data - Adsorption Functions

- Adsorption represented by Langmuir isotherm

$$V = \frac{V_L\, p}{P_L + p}$$

- V = amount of gas adsorbed at pressure p
- V_L = Langmuir volume constant
  - maximum adsorption capacity at a given temperature
- P_L = Langmuir pressure constant
  - pressure at which the adsorbed gas content is equal to $V_L/2$

Requested Data - Adsorption Functions



Requested Data - Langmuir Volume vs. TOC

- Organic material is referred to as TOC (Total Organic Carbon)
- TOC measured as a percentage of the rock weight
- The amount of gas that can be stored by adsorption within the rock depends on the amount of organic carbon present

Requested Data - Langmuir Volume vs. TOC

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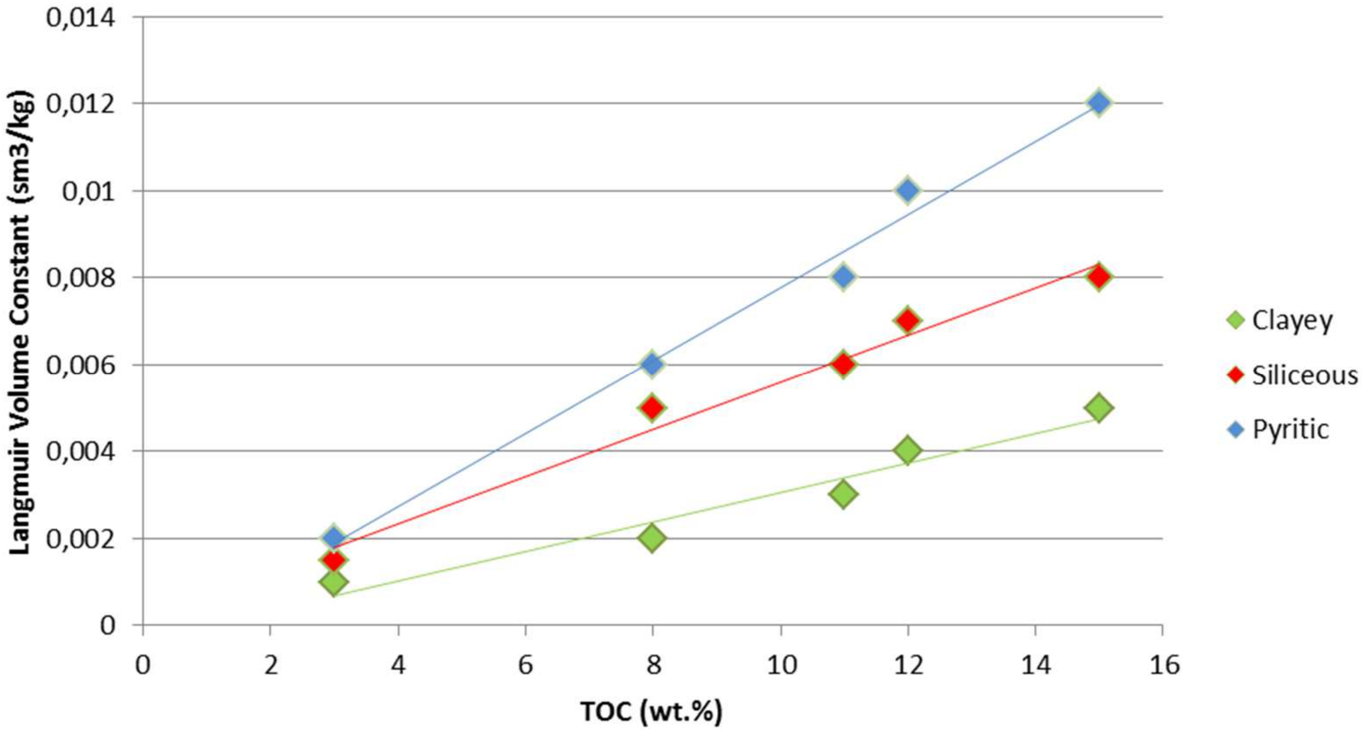
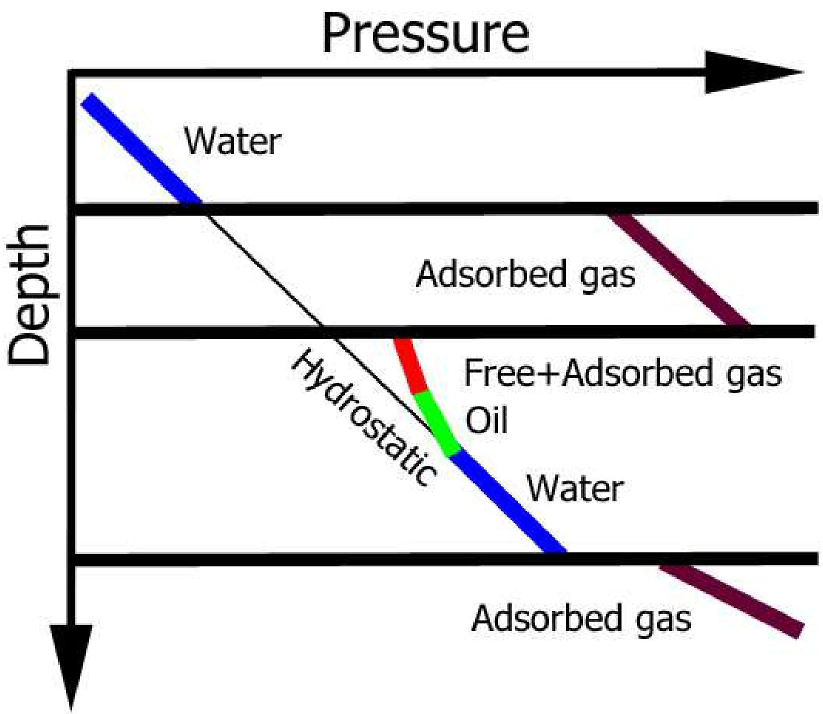


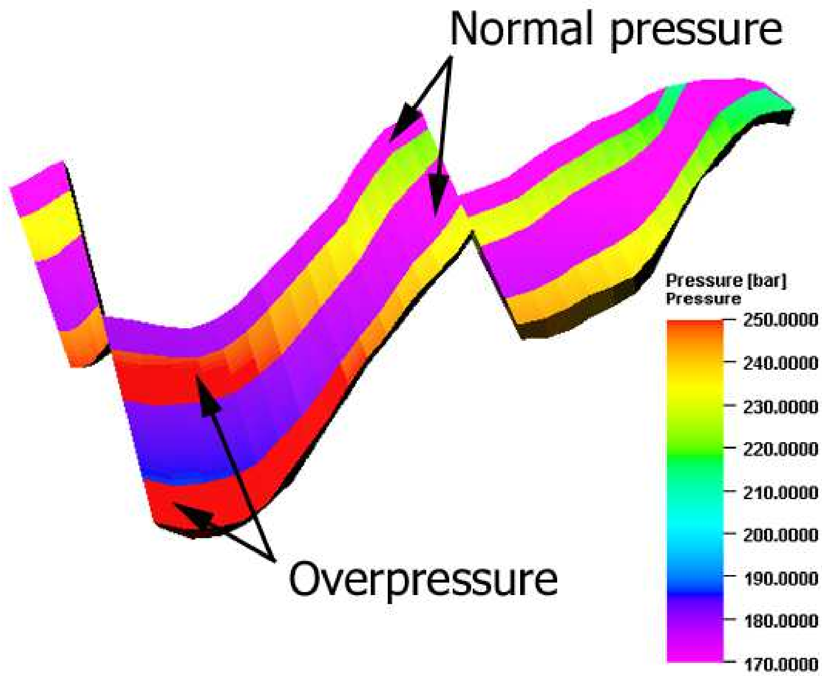
Shale Volumetrics : STOIIP & GIIP

- From PVT data and an initial condition (a pressure at a given depth)
  - Initial equilibrium is computed
  - Fluids present in the reservoir tend to stratify according to their density

- Fluids in shale reservoirs are not always at equilibrium state
  - Overpressured zones could be generated due to the history of reservoir formation

Shale Volumetrics : STOIIP & GIIP





Shale Volumetrics : Free Oil and Gas Calculations

- Compute the pressure of each phase
  - $\frac{dP_o}{dh} = \rho_o(P_o, R_s) \times g, \quad \frac{dP_g}{dh} = \rho_g(P_o, R_v) \times g, \quad \frac{dP_w}{dh} = \rho_w(P_o) \times g,$

- Compute saturation from capillary pressure between phases
  - $P_{cog} = P_g - P_o, \quad P_{cow} = P_o - P_w, \quad P_{cgw} = P_g - P_w$

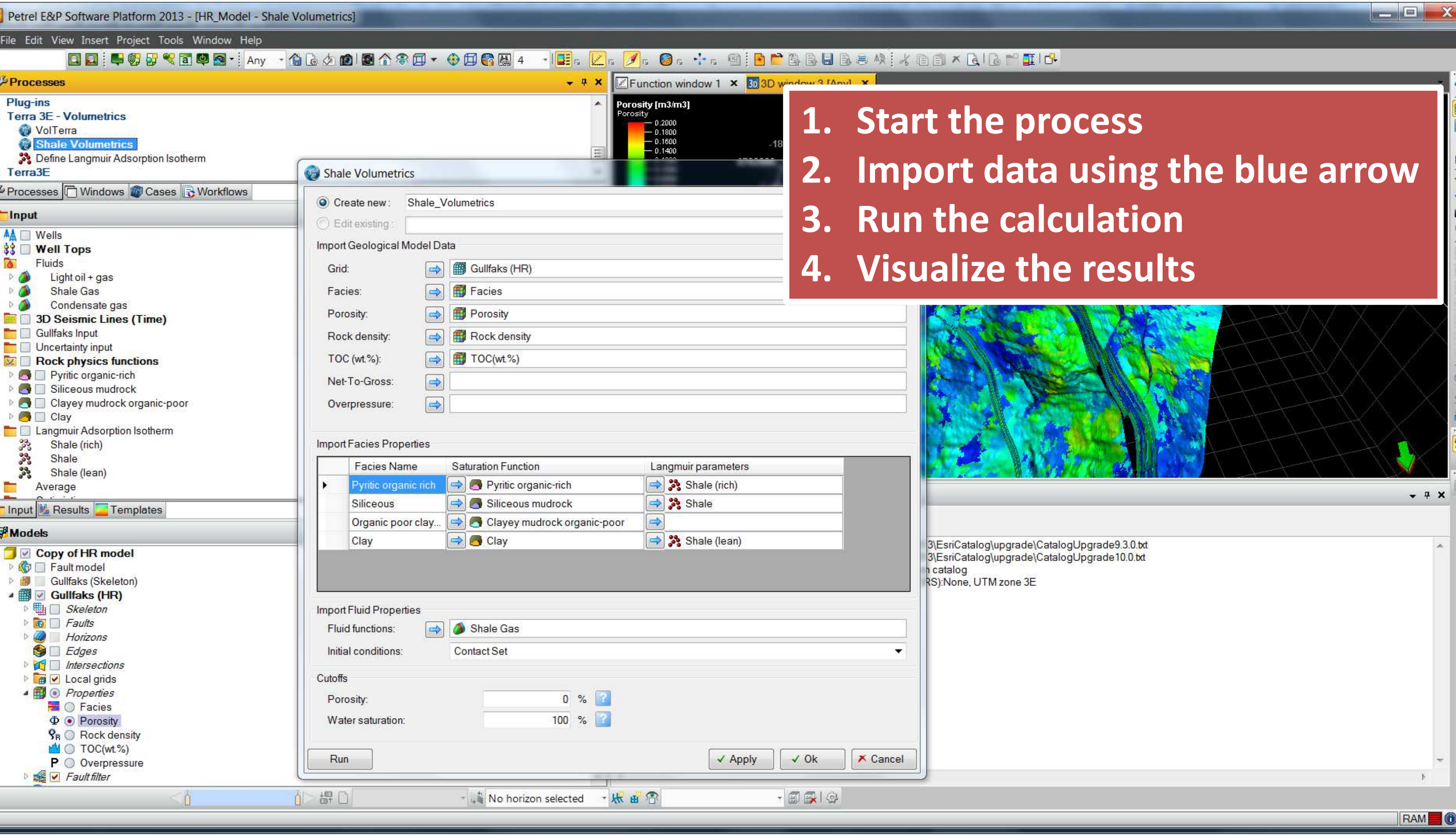
- Volume of free oil and gas in this cell is
  - $STOIIP^i = \frac{S_o^i V_i \varphi_i}{B_o^i}$
  - $GIIP_{free}^i = \frac{S_g^i V_i \varphi_i}{B_g^i}$

Shale Volumetrics : Adsorbed Gas Calculations

- For each grid cell, the Langmuir volume constant is evaluated through TOC curves of the facies corresponding to the cell: V_L versus TOC

- The amount of gas adsorbed V_{gc} is evaluated through the Langmuir isotherm formulation using the pressure of the cell and the Langmuir pressure constant of the facies corresponding to the cell
  - $V_{gc} = \frac{V_L p}{P_L + p}$

- Volume of adsorbed gas in this cell is computed using
  - $\mathrm{G}IIP^{i}_{adsorbed} = S^{i}_{g}\ V_{i}\ V^{i}_{gc}\ \rho^{i}_{rock}$

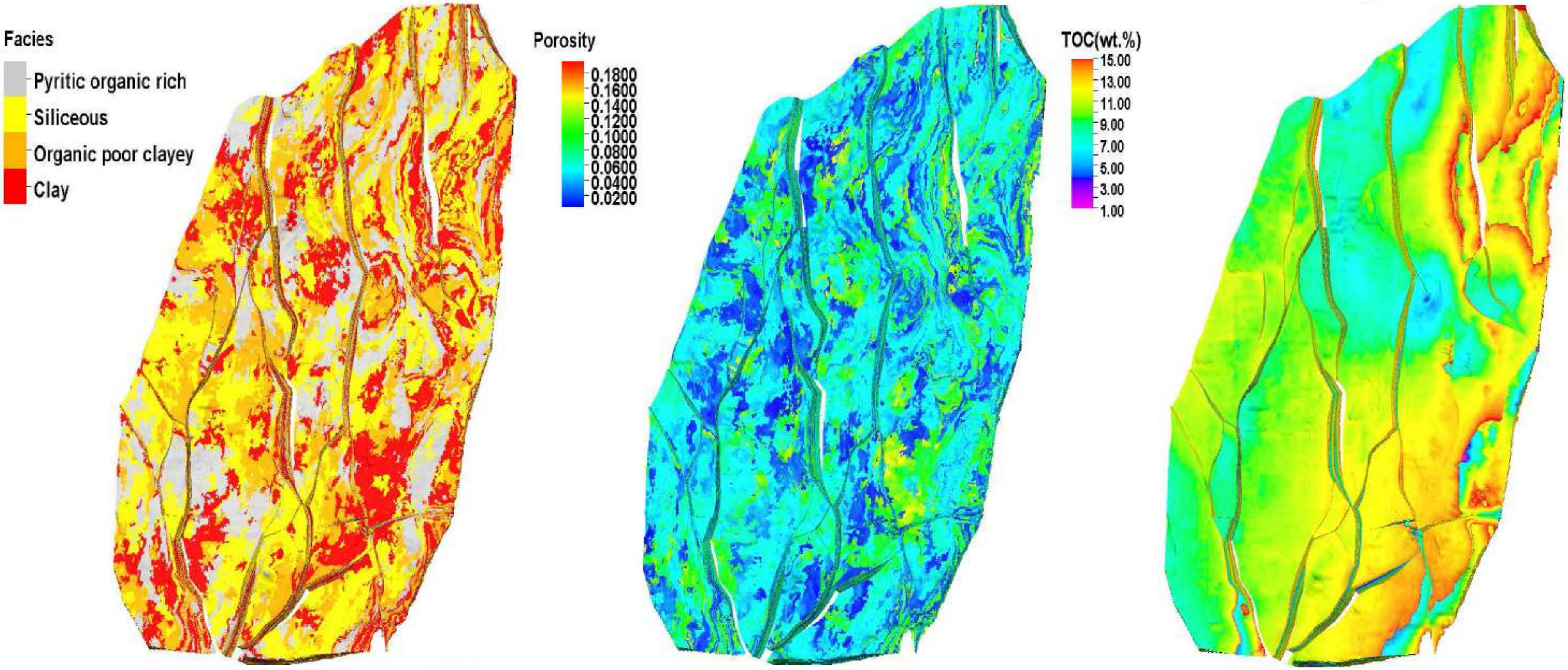


1. **Start the process**
2. **Import data using the blue arrow**
3. **Run the calculation**
4. **Visualize the results**

Case Study

- Synthetic geological model composed of 32.000.000 active cells
- Average cell dimension : 15m x 15m x 1.2m
- 315 layers
- 5 zones
  - 2 zones considered with an overpressure
  - Fluids in equilibrium within the three other zones
- 4 lithofacies
  - 3 are defined as “shale type”
- Porosity and rock density modeling conditioned to the 3D facies realization
- Fluid model : liquid-rich shale gas

Case Study


Facies
Pyritic organic rich
Siliceous
Organic poor clayey
Clay
Porosity
0.1800
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
TOC(wt.%)
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00

Case Study

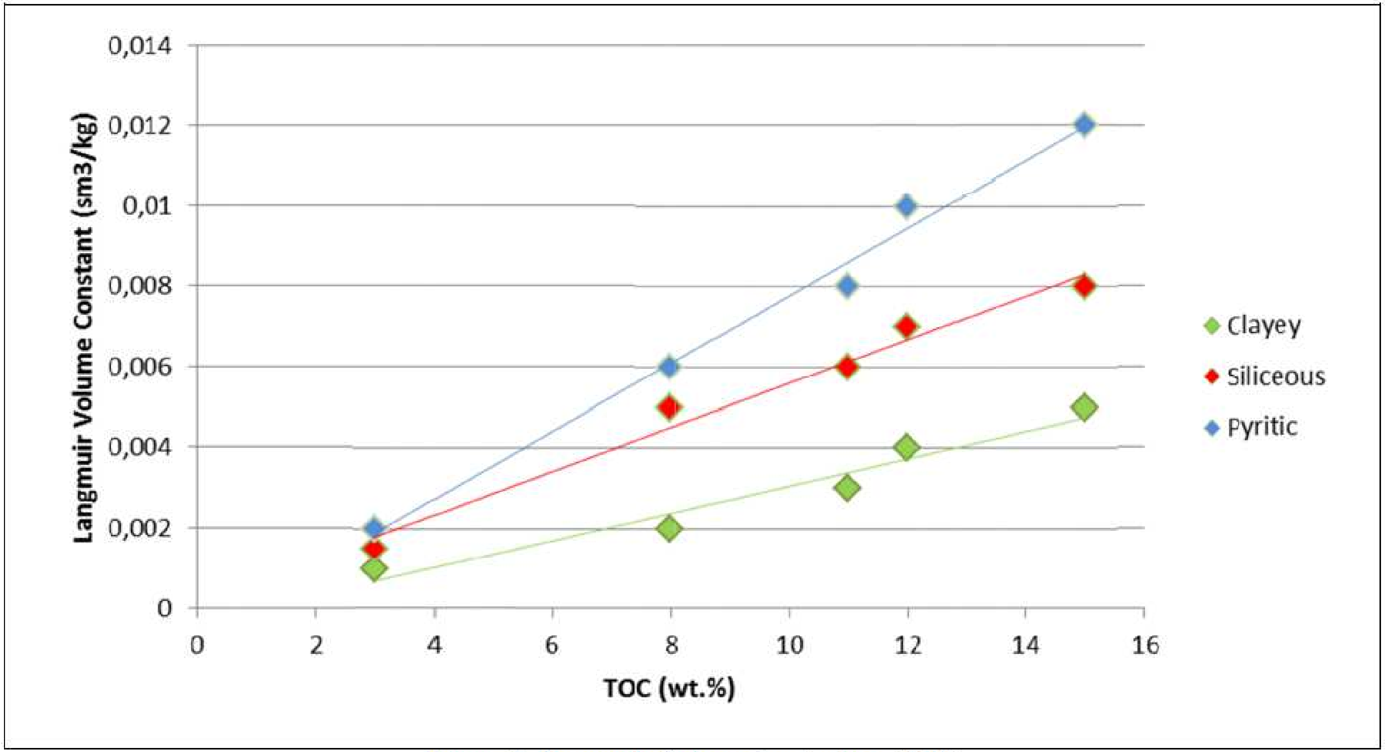
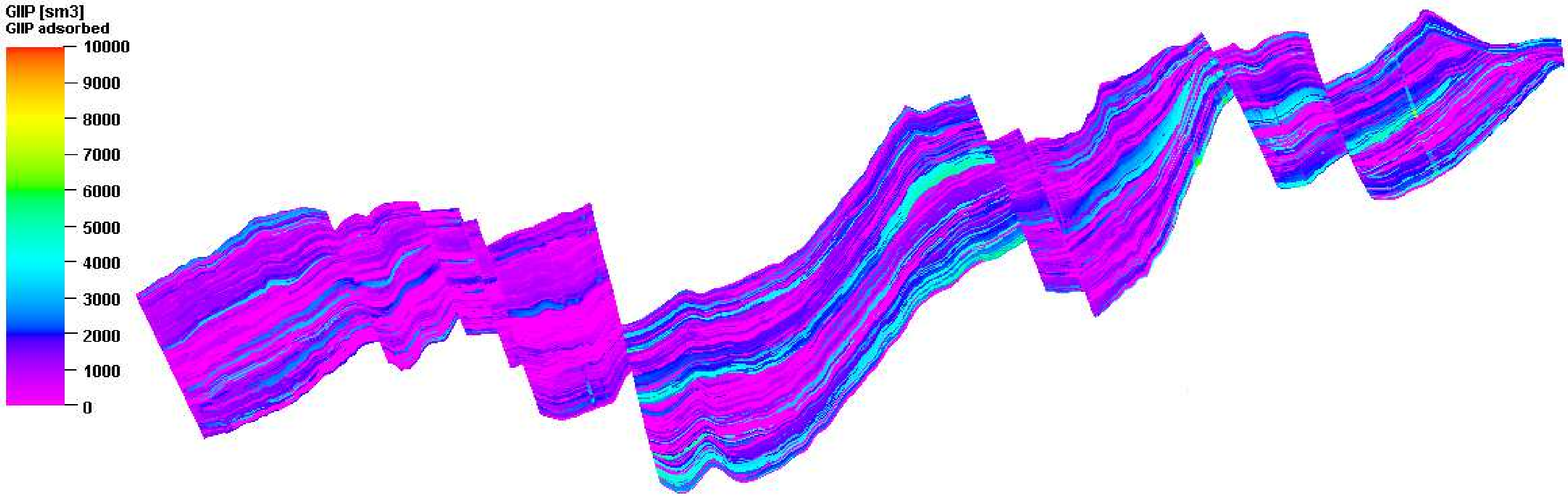


Figure 7 - Langmuir Volume Constante vs. TOC

Case Study - Results

Fluids in place	
STOIIP	$58.9\ 10^6\ sm^3$
GIIP	$54.6\ 10^9\ sm^3$
- Free	$15.9\ 10^9\ sm^3$
- Adsorbed	$38.7\ 10^9\ sm^3$



Case Study – Uncertainty Analysis

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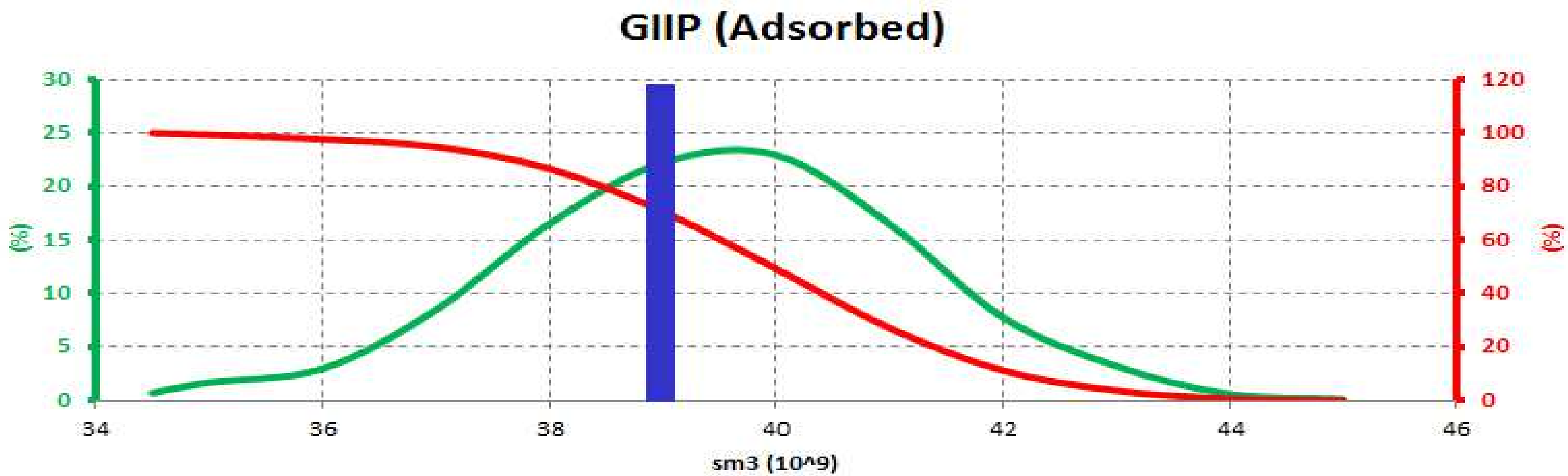
- 8 parameters
  - Seeds to generate lithofacies, porosity, rock density and TOC
  - A shift for each Langmuir Volume Constant vs. TOC curve
  - A shift on pressure gradient in over pressured zones.



Conclusions

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- Shale volumetrics method provides an exact calculation of initial fluids in place
  - On high resolution geological model
  - Without reservoir simulator
  - The calculation speed allows uncertainty estimations
    - 17 minutes for 32 millions cells (Intel Core i5 CPU 2.53GHz)
- Calculations are performed for Black-Oil model
  - With constant or variable bubble point and dew point
- Exact calculation of initial adsorbed gases are considered with :
  - Different qualities of shales
  - 3D TOC distribution
  - Overpressure zones
- A full Word report (Data and results) is provided on a click

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- www.ocean.slb.com

- Free evaluations (14 days)
- 15,000 $ (12 months)

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