

# **FracScope**

**(An exploration plugin for unconventional shale)**

## **User Manual**

**(Initial Draft)**

Mohammad Tanvir Rahman

Sharif M Morshed

Ismot Jahan

Md. Abdullah Shahneous Bari Sayket



Bengal Tigers  
University of Houston

## Contents

1. FracScope Summary
2. Brief description of FracScope functions
3. Geology and Petrophysics functions
  - 3.1 Clay Volume
  - 3.2 Uranium to Thorium Ratio
  - 3.3 Density Porosity
  - 3.4. TOC and Kerogen Porosity
  - 3.5 Clay Porosity
  - 3.6 Fracture Porosity
  - 3.7 Sand Porosity
4. Geophysical and Engineering functions
  - 4.1 Isotropic Parameters
    - 4.1.1 Young's Modulus
    - 4.1.2 Poisson's Ratio
    - 4.1.3 Brittleness Index
    - 4.1.4. Lamda and Mu
  - 4.2 Transverse Anisotropy Parameter
    - 4.2.1 Vertical and Horizontal Poissons Ratio
    - 4.2.2 Vertical and Horizontal Young's Modulus
    - 4.2.3 Epsilon and Gamma
5. Useful Demo Templates for Shale Gas Exploration
6. References



## **1. FracScope Summary**

FracScope is an exploration plugin for Schlumberger Petrel software. FracScope is based on latest technology to provide critical insights to the best zone for hydraulic fracturing. It provides quantitative and qualitative tools from wireline logging data. The user will be able to calculate relevant geological and petrophysical properties such as shale volume, Uranium to Thorium ratio and pore fractions (density porosity, total organic carbon, kerogen porosity, fracture porosity, clay porosity, and sand porosity). The plugin also provides elastic and engineering properties for isotropic and transversely isotropic (TI anisotropy) cases to choose the best fracture-able zones. The elastic and engineering properties include Young's modulus, horizontal Young's modulus, vertical Young's modulus, Poisson's ratio, vertical Poisson's ratio, horizontal Poisson's ratio, Brittleness index, Lamda, Shear moduli, azimuthal shear anisotropy and Thomsen (1986) TI parameter (Epsilon and Gamma). The plugin will also provide calculations of pore pressure, vertical stress, minimum horizontal stress and maximum horizontal stress. Two or three methods will be given for some calculations such as TOC, TI parameters and engineering parameters. Finally, few demo templates of plots and cross-plots will be provided for some useful applications of this plugin to explore shale gas.

## **2. Brief description of FracScope functions**



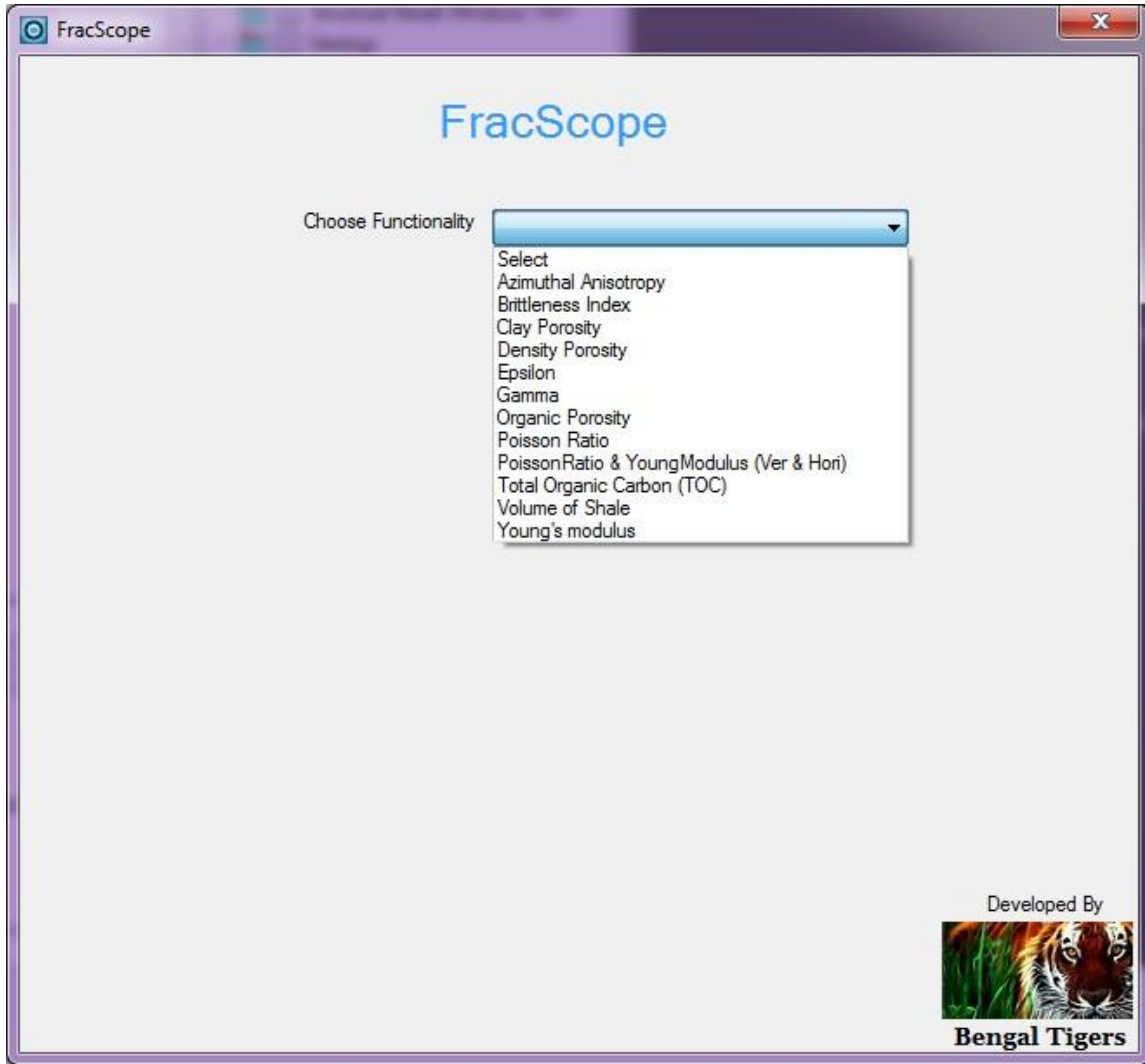


Figure 1: FracScope user interface showing all presently available functions

### 3. Geology and Petrophysics functions

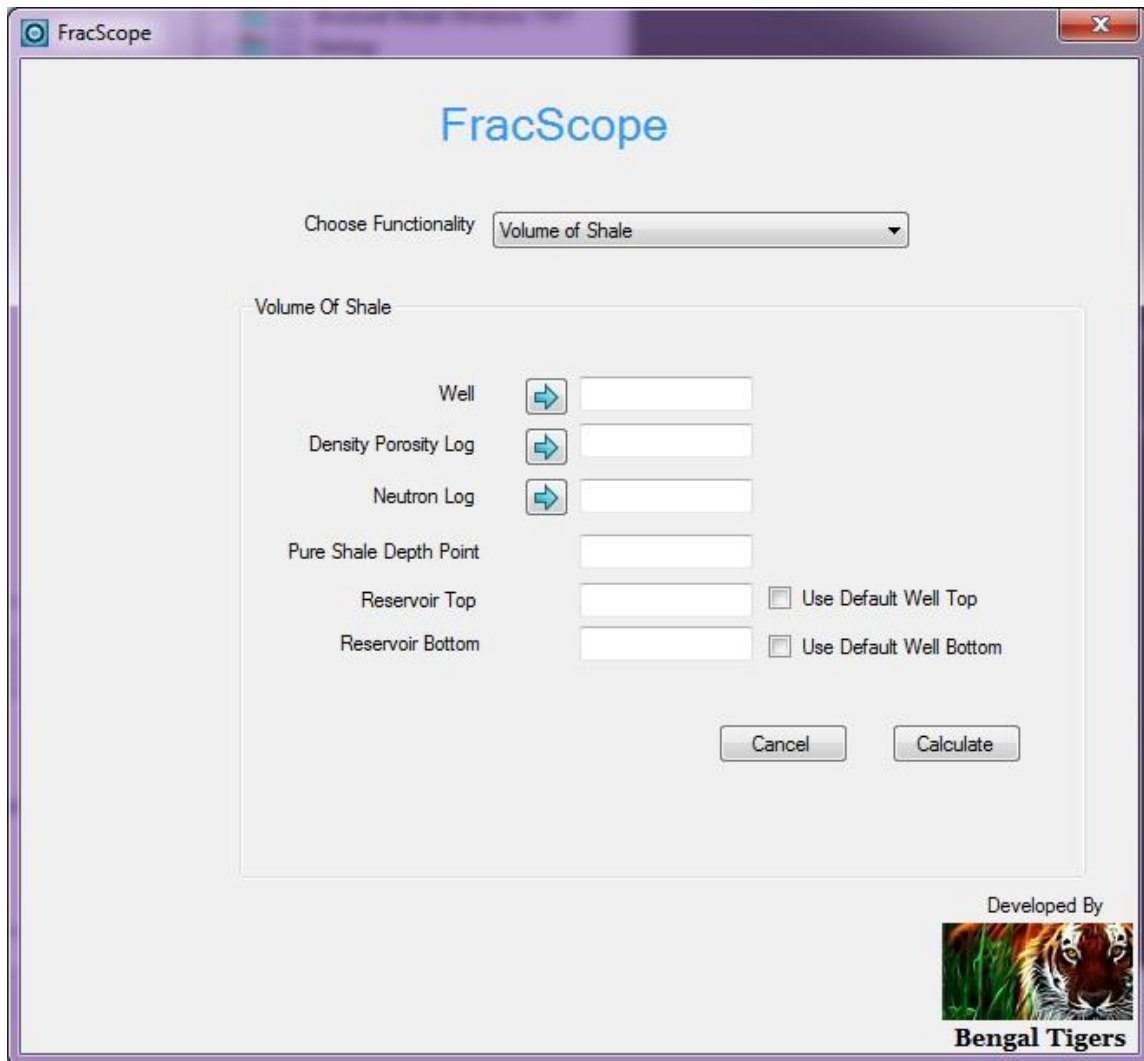
#### 3.1 Clay Volume

Clay volume is also known as shale volume or clay content. There are several methods in the literature to calculate clay volume. Here we used one method using neutron porosity and density porosity logs (Katahara, 2008). Basically neutron log sees clays as well as fluids in the formation as pores whereas density log sees only the fluids as pores. The equation for clay volume is given below.

$$\text{Clay volume } V_{\text{clay}} = (N_{\phi} - D_{\phi}) / (N_{\phi(sh)} - D_{\phi(sh)})$$

Where,  $N_\phi$  = Neutron Porosity  
 $D_\phi$  = Density Porosity  
 $N_{\phi(sh)}$  = Neutron Porosity at pure Shale  
 $D_{\phi(sh)}$  = Density Porosity at pure Shale

The user need to provide the well name, density porosity log, neutron porosity log, pure shale depth point and reservoir top and bottom. The pure shale depth point should be reliable enough to get the best result.



The screenshot shows the FracScope software window. At the top, the title bar says 'FracScope'. Below it, the main title 'FracScope' is displayed in blue. A dropdown menu labeled 'Choose Functionality' is set to 'Volume of Shale'. Below this, a section titled 'Volume Of Shale' contains several input fields and checkboxes:

- 'Well' with a right-pointing arrow icon and an empty text box.
- 'Density Porosity Log' with a right-pointing arrow icon and an empty text box.
- 'Neutron Log' with a right-pointing arrow icon and an empty text box.
- 'Pure Shale Depth Point' with an empty text box.
- 'Reservoir Top' with an empty text box and a checkbox labeled 'Use Default Well Top'.
- 'Reservoir Bottom' with an empty text box and a checkbox labeled 'Use Default Well Bottom'.

At the bottom right of the 'Volume Of Shale' section are 'Cancel' and 'Calculate' buttons. In the bottom right corner of the main window, it says 'Developed By' above a tiger logo and the text 'Bengal Tigers'.

Figure 2: Volume of shale function of FracScope

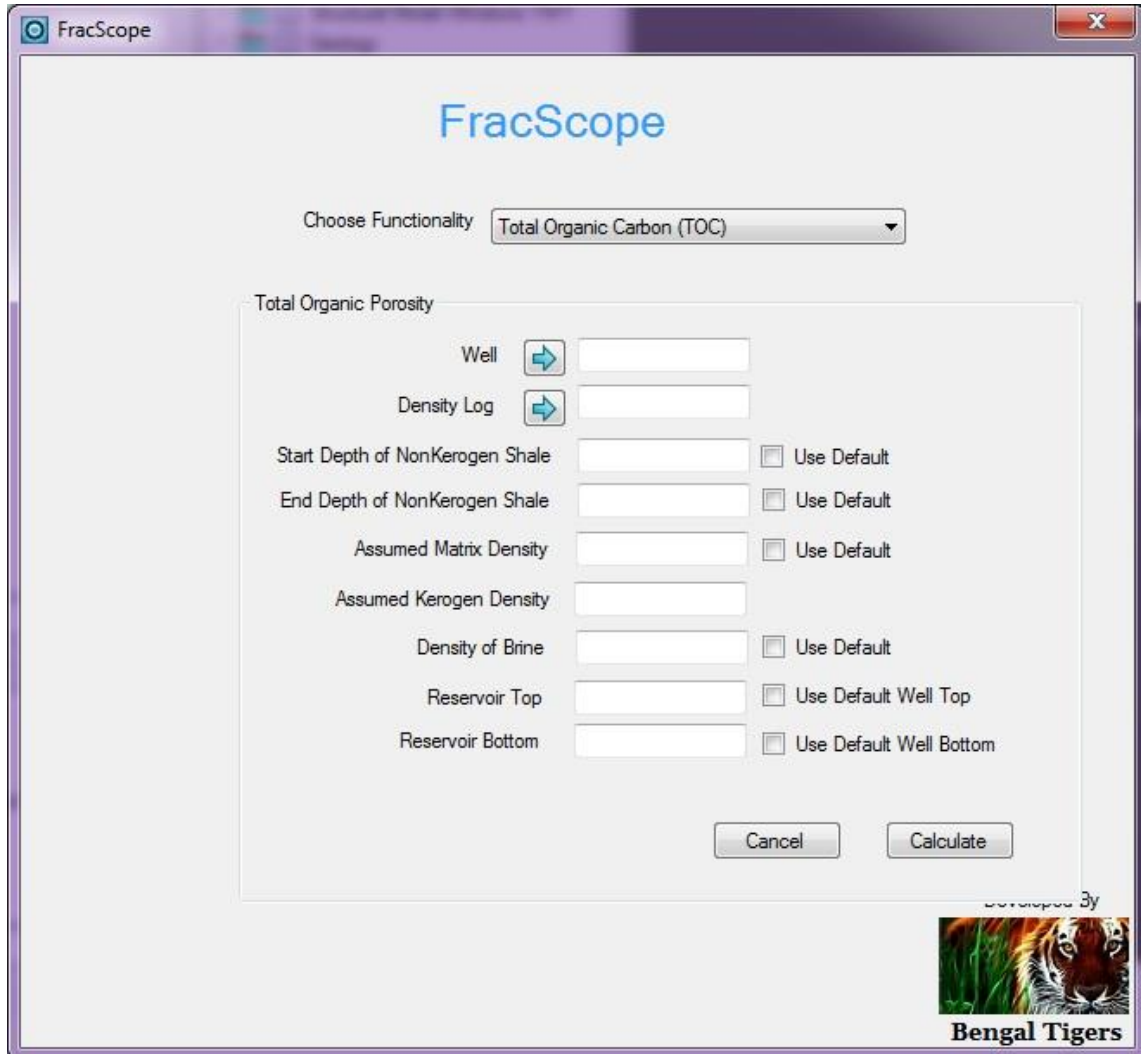
### 3.2 Uranium to Thorium Ratio

### 3.3 Density Porosity

$$\text{Total porosity} = D_{\phi} = (\rho_{\text{matrix}} - \rho_{\text{log}}) / (\rho_{\text{matrix}} - \rho_f)$$

Default  $\rho_{\text{matrix}} = 2.65$  or  $2.71$  gm/cc,  $\rho_f = 1$  gm/cc user should be able to input it also.

### 3.4. TOC and Kerogen Porosity



The screenshot shows the FracScope software window. At the top, the title bar says "FracScope". Below it, the main title "FracScope" is displayed in blue. A dropdown menu labeled "Choose Functionality" is set to "Total Organic Carbon (TOC)". Below this, a section titled "Total Organic Porosity" contains several input fields and checkboxes. The fields are: "Well" (with a right arrow icon), "Density Log" (with a right arrow icon), "Start Depth of NonKerogen Shale", "End Depth of NonKerogen Shale", "Assumed Matrix Density", "Assumed Kerogen Density", "Density of Brine", "Reservoir Top", and "Reservoir Bottom". Each field has a corresponding "Use Default" checkbox. At the bottom right of the input section are "Cancel" and "Calculate" buttons. In the bottom right corner of the window, there is a logo for "Bengal Tigers" featuring a tiger's face and the text "Developed By Bengal Tigers".

Figure 3: TOC function of FracScope

There are several methods proposed in the literature for estimation of TOC utilizing spectral GR (i.e Th/U ratio), density porosity, resistivity, sonic porosity and PE data. However, density is one of the most common log, and we used the method that Myers and Jenkyns (1992) proposed to estimate TOC from density log by the following equations,

$$TOC (\%) = \frac{0.85 * \rho_k * \phi_{fl}}{\rho_k * \phi_{fl} + \rho_{ma} * (1 - \phi_{fl} - \phi_k)} \quad (3)$$

$$\text{Where, } \phi_{fl} = \frac{\rho_{ns} - \rho_{ma}}{\rho_{fl} - \rho_{ma}}, \phi_k = \frac{\rho_s - \rho_{ns}}{\rho_k - \rho_{ma}}$$

Where,  $\rho_{ns}$  = Density reading at the vertically adjacent shale interval which doesn't contain kerogen (averaged a value from the log)

$\rho_s$  = Density reading at the productive interval

$\rho_{ma}$  = 2.71 gm/cc , assumed matrix density

$\rho_k$  = 1.3 gm/cc , assumed kerogen density

$\rho_{fl}$  = 1.05 gm/cc, density of brine

$\phi_{fl}$  = Water filled porosity

$\phi_k$  = Kerogen filled porosity



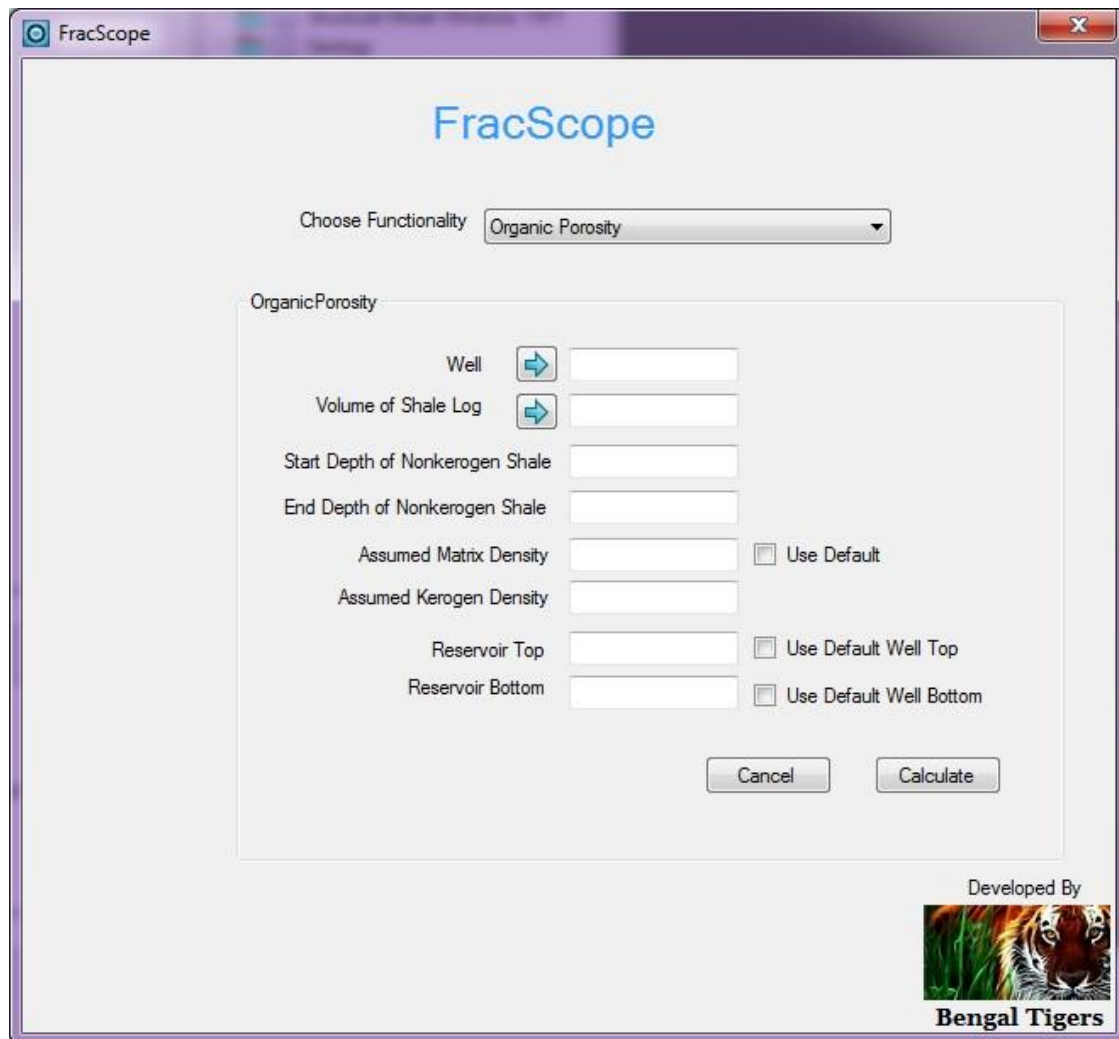


Figure 4: Organic porosity function of FracScope

### 3.5 Clay Porosity

$$\text{Clay porosity} = V_{sh} * \Phi_t$$

Here,  $V_{sh}$  is the volume of clay

$\Phi_t$  is total porosity from density porosity log

### 3.6 Fracture Porosity

$$\text{Fracture porosity} = \text{Fracture density from borehole image log} * \text{empirical constant}$$



### 3.7 Sand Porosity

## 4. Geophysical and Engineering functions

### 4.1 Isotropic Parameters

#### 4.1.1 Young's Modulus

The equation of Young's Modulus for isotropic case is

$$E(\text{psi}) = 1.34e10 * \frac{\rho}{DT_s^2} * \left( \frac{3DT_s^2 - 4DT_c^2}{DT_s^2 - DT_c^2} \right)$$

Here,  $\rho$  is density log

DTs is the shear wave slowness log

DTc is the compressional or P-wave slowness log

The user need to provide the well name, P-wave slowness log, S-wave slowness log and density log.



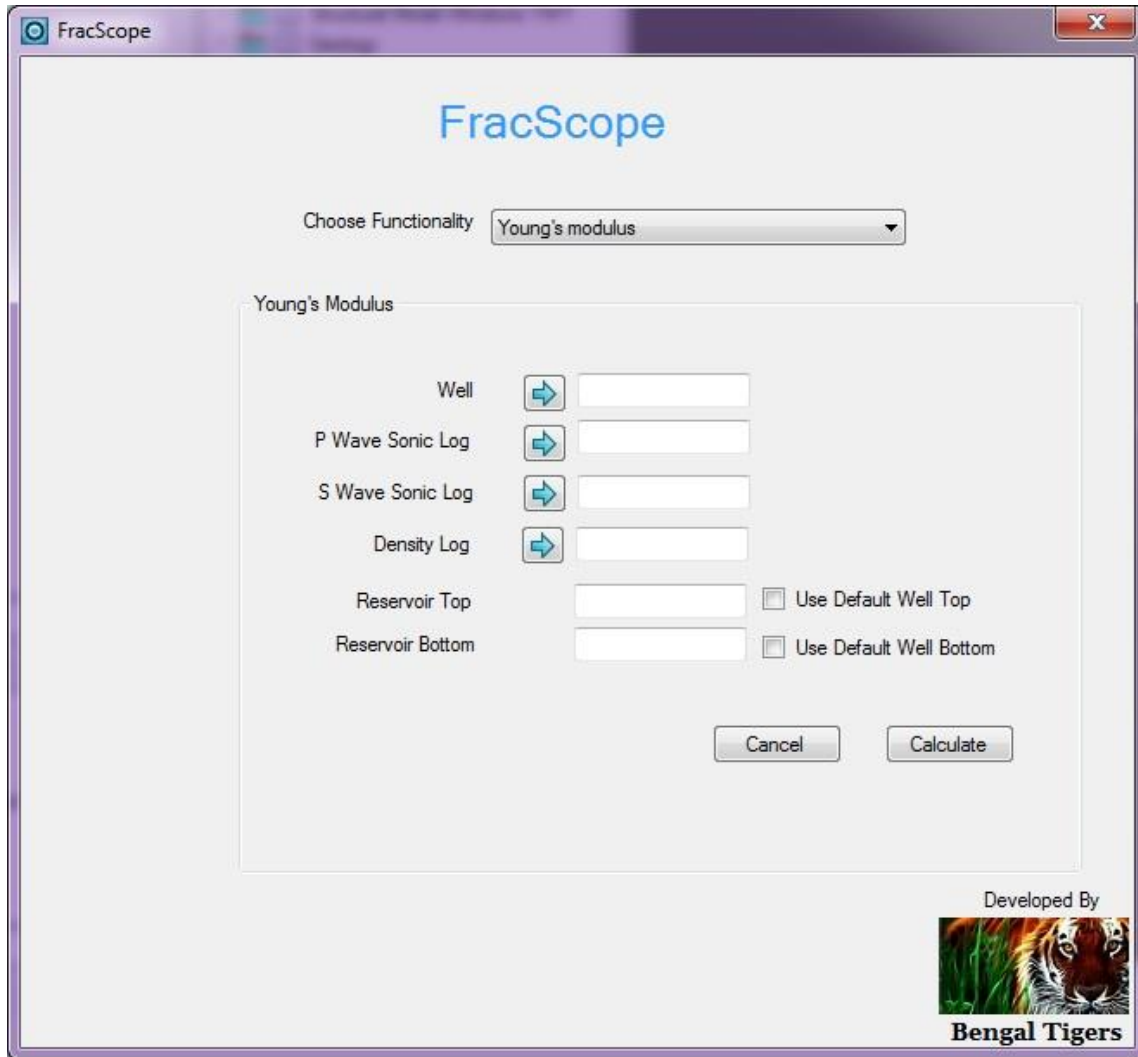


Figure 5: Young's modulus function of FracScope

#### 4.1.2 Poisson's Ratio

The equation of Poisson's Ratio for isotropic case is

$$PR = \frac{1}{2} * \left( \frac{DTs^2 - 2DTc^2}{DTs^2 - DTc^2} \right)$$

Here, DTs is the shear wave slowness log

DTc is the compressional or P-wave slowness log

The user need to provide the well name, P-wave slowness log and S-wave slowness log.

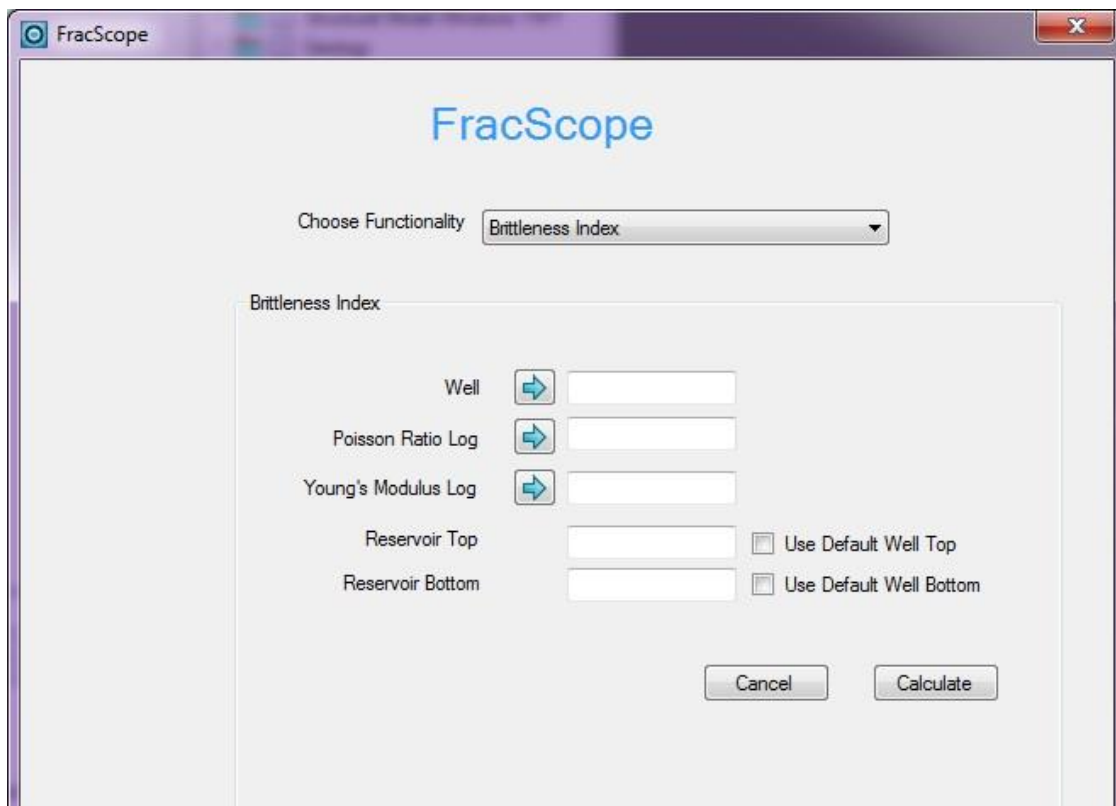
#### 4.1.3 Brittleness Index

We use two method for calculating the brittleness index for isotropic assumption. In this stage we provide method as given below. The second method will be included in the next stage of this competition.

$$E_{Norm} = 100 * \frac{(E - E_{min})}{E_{max} - E_{min}} \quad PR_{Norm} = 100 * \frac{(PR - PR_{max})}{E_{min} - E_{max}}$$

$$\Rightarrow Brit.Index = \frac{(E_{Norm} + PR_{Norm})}{2}$$

The user need to provide the well name, Young's modulus log and Poisson's ratio log.



The screenshot shows the FracScope software window. At the top, the title bar says "FracScope". Below it, the main window has a blue header with the text "FracScope". Underneath, there is a "Choose Functionality" dropdown menu set to "Brittleness Index". Below this, there is a section titled "Brittleness Index" containing several input fields and buttons:

- "Well" with a blue arrow button and an empty text box.
- "Poisson Ratio Log" with a blue arrow button and an empty text box.
- "Young's Modulus Log" with a blue arrow button and an empty text box.
- "Reservoir Top" with an empty text box and a checkbox labeled "Use Default Well Top".
- "Reservoir Bottom" with an empty text box and a checkbox labeled "Use Default Well Bottom".

At the bottom right of the "Brittleness Index" section, there are two buttons: "Cancel" and "Calculate".

Figure 6: Brittleness Index function of FracScope

#### 4.1.4. Lamda and Mu

This feature will be given in the next stage of the competition.

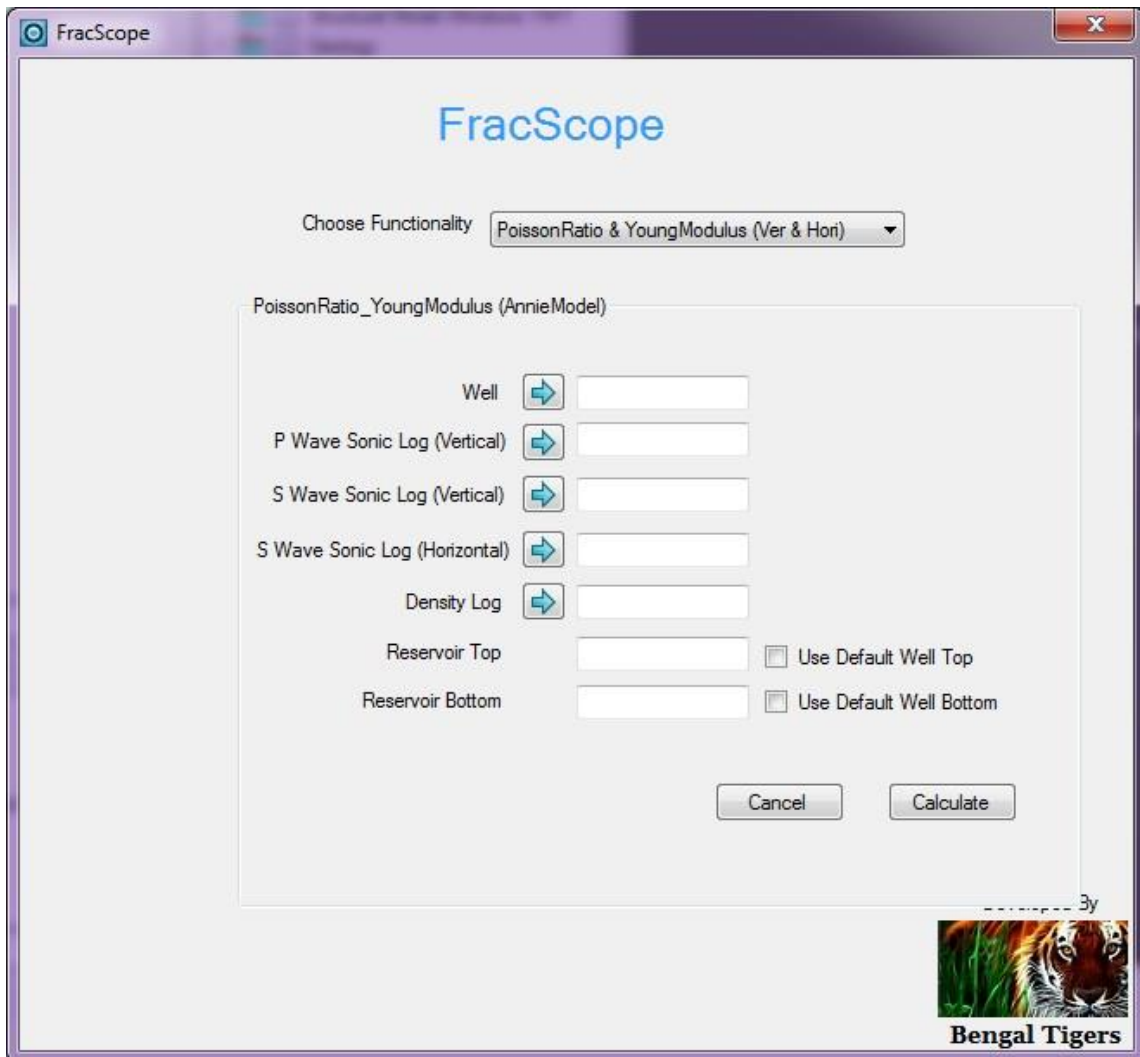


Figure 7: Horizontal and vertical Young's modulus and Poisson's ratio function with ANNIE approximation in FracScope

## 4.2 Transverse Anisotropy Parameter

Transverse isotropy (TI) is often a common case for subsurface formations. TI anisotropy may happen because of cracks, laminated sequence or oriented clay minerals. In this stage we provide the TI parameters for a vertical borehole. Denoting  $V_{ij}$  as the elastic wave velocity propagating along  $i$ -axis and polarized along  $j$ -axis and  $\rho$  as density, the velocities in different direction can be given as,

$$V_{11} = V_{22} = \sqrt{\frac{C_{11}}{\rho}}, V_{33} = \sqrt{\frac{C_{33}}{\rho}}, \quad V_{31} = V_{13} = V_{23} = V_{32} = \sqrt{\frac{C_{44}}{\rho}} V_{12} = V_{21} = \sqrt{\frac{C_{66}}{\rho}}$$

#### 4.2.1 Vertical and Horizontal Poisson's Ratio

The equations for vertical and horizontal Poisson's ratio under ANNIE approximation (Schoenberg and Sayers 1996) are given below:

$$\nu_{vert} = \frac{C_{13}}{C_{11} + C_{12}}$$

$$\nu_{horz} = \frac{C_{33}C_{12} - C_{13}^2}{C_{33}C_{11} - C_{13}^2}$$

#### 4.2.2 Vertical and Horizontal Young's Modulus

The equations for vertical and horizontal Young's modulus under ANNIE approximation (Schoenberg and Sayers 1996) are given below:

$$E_{vert} = C_{33} - \frac{2C_{13}^2}{C_{11} + C_{12}} \quad E_{horz} = C_{11} + \frac{C_{13}^2(C_{12} - C_{11}) + C_{12}(C_{13}^2 - C_{12} * C_{33})}{C_{33} * C_{11} - C_{13}^2}$$

#### 4.2.3 Epsilon and Gamma

Thomsen (1986) weak anisotropy parameter for VTI case are:

$$\varepsilon = (C_{11} - C_{33})/2C_{33}$$

$$\gamma = (C_{55} - C_{44})/2C_{44}$$



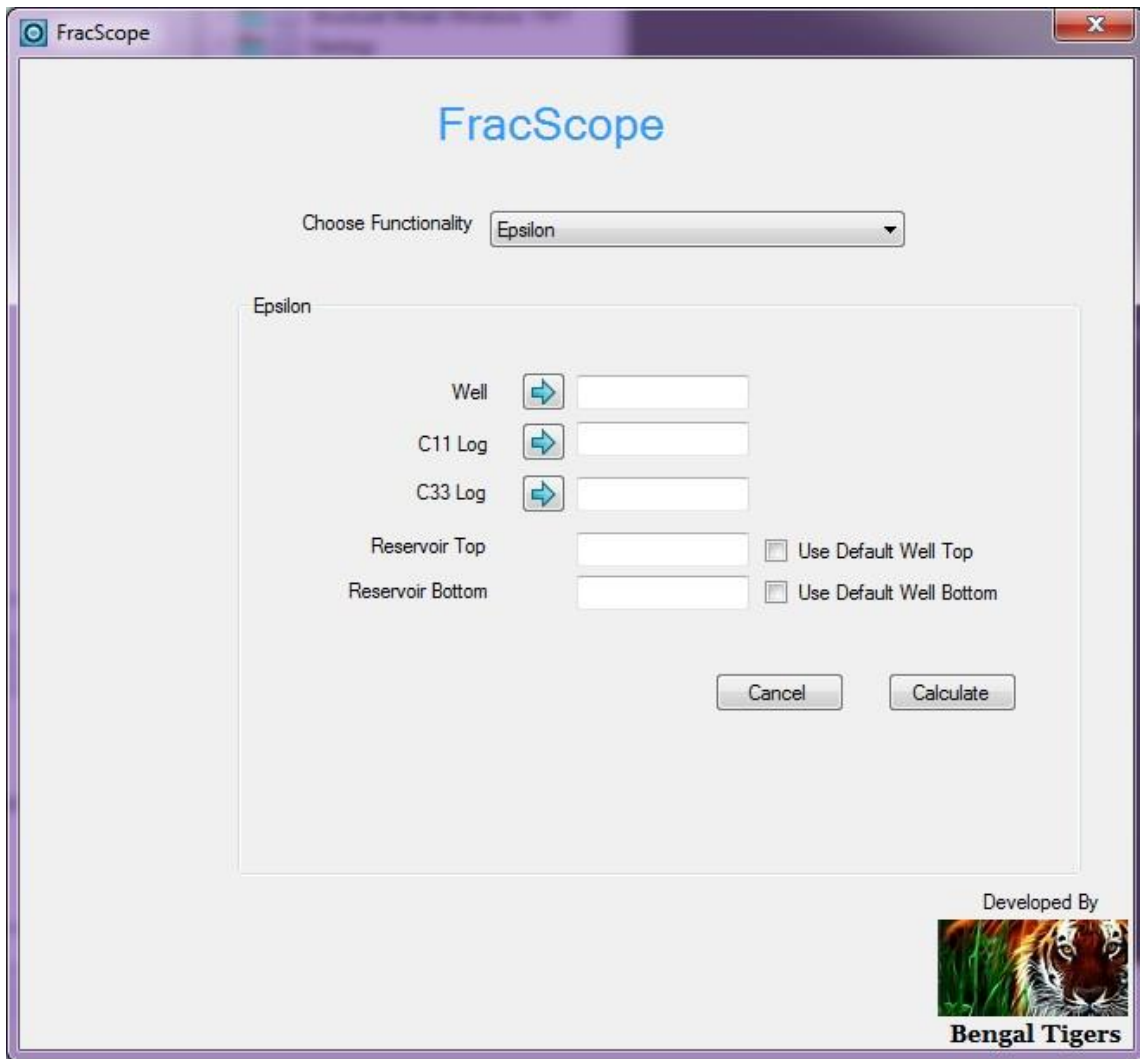


Figure 8: Epsilon function of FracScope

## 5. Useful Demo Templates for Shale Gas Exploration

## 6. References

- Katahara, K., 2008, What is shale to a petrophysicist?, *The Leading Edge*, 6, 738-741
- Schoenberg, M., Muir F., and Sayers, C. 1996. Introducing Annie: A simple three parameter anisotropic velocity model for shale: *Journal of Seismic Exploration*, 5:35-49
- Thomsen, L., 1986. Weak elastic anisotropy: *Geophysics*, 51, 1954-1966.

