FracScope

(An exploration plugin for unconventional shale)

User Manual

(Initial Draft)

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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

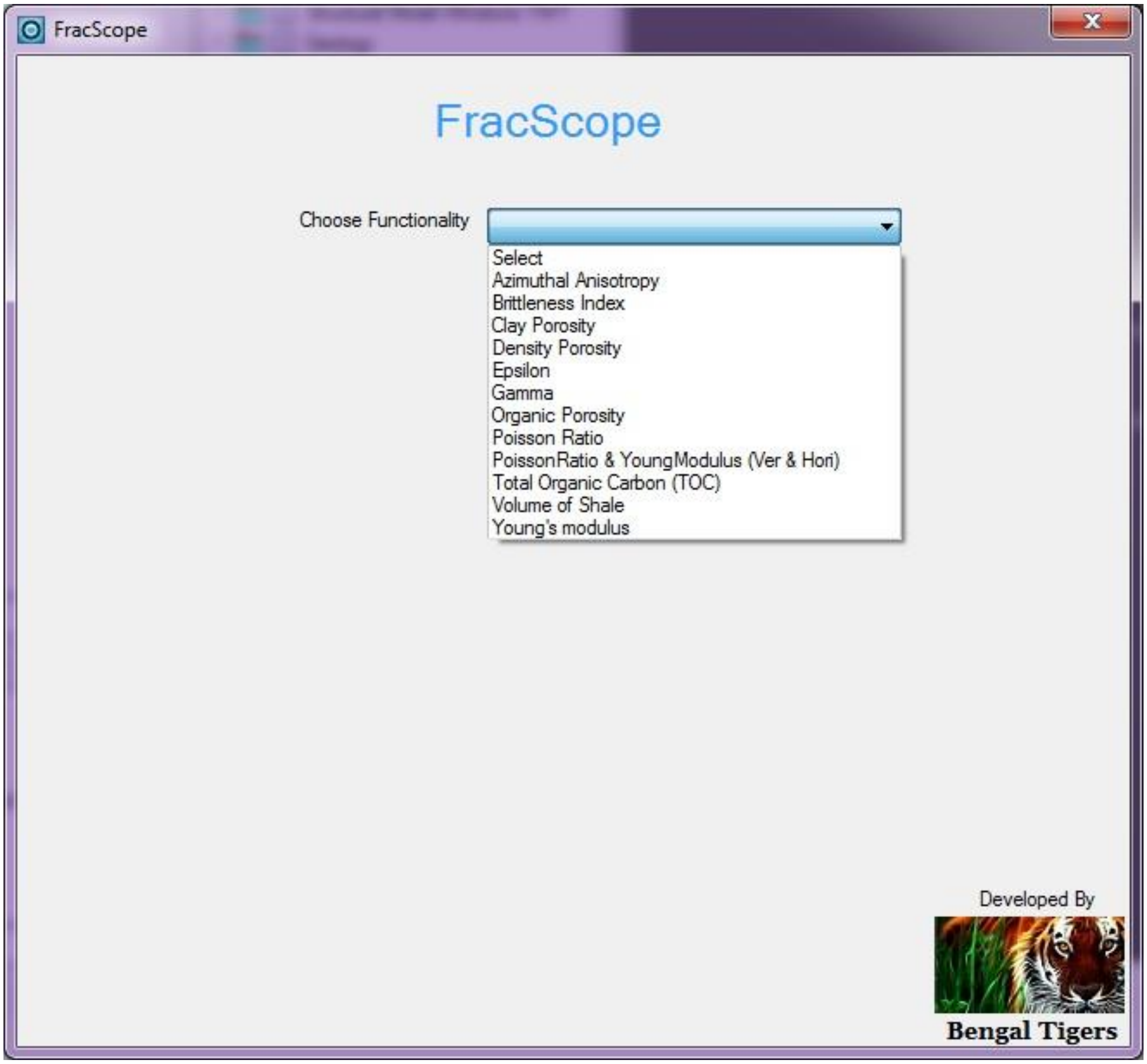

Figure 1: FracScope user interface showing all presently available functions

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.

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

Where, N_{ϕ}= Neutron Porosity

D_{ϕ}= 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.

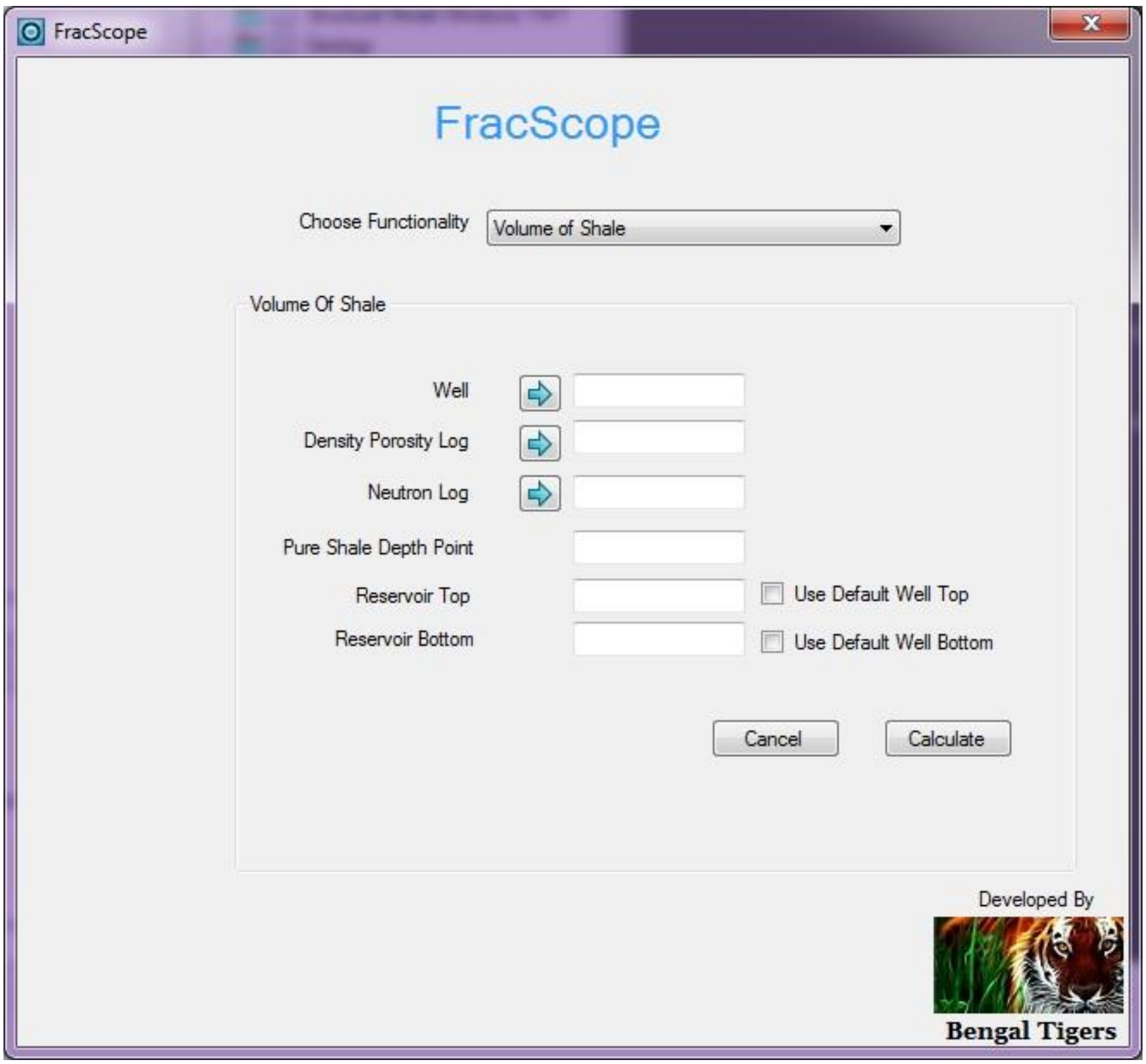

Figure 2: Volume of shale function of FracScope

3.2 **Uranium to Thorium Ratio**

3.3 **Density Porosity**

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

Default ρ_{matrix} =2.65 or 2.71 gm/cc, ρ_f =1 gm/cc user should be able to input it also.

3.4. **TOC and Kerogen Porosity**

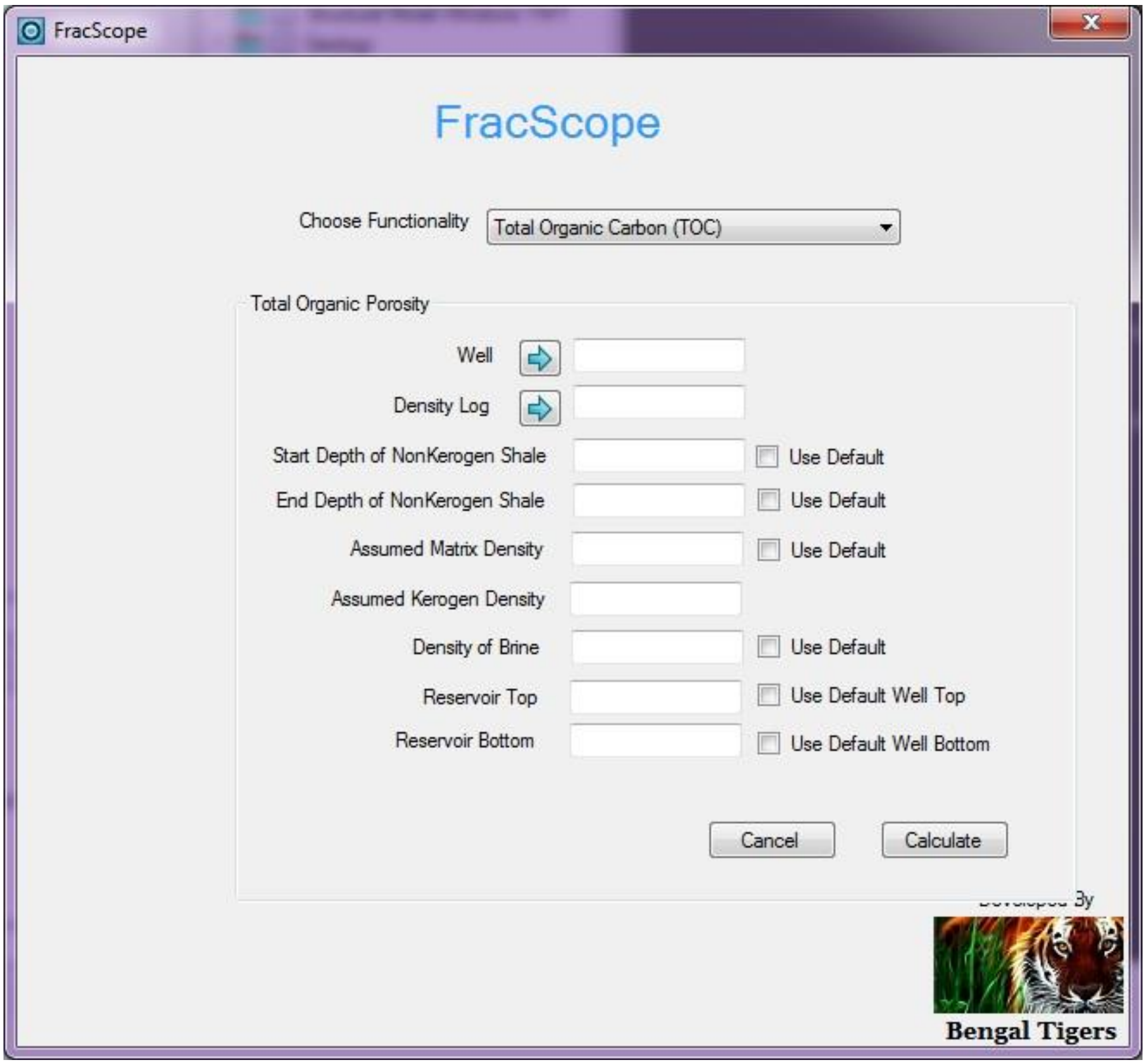

Figure 3: TOC function of FracScope

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 form density log by the following equations,

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

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

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

ρ_s =Density reading at the productive interval

ρ_{ma} =2.71 gm/cc , assumed matrix density

ρ_k =1.3 gm/cc , assumed kerogen density

ρ_{fl} =1.05 gm/cc, density of brine

ϕ_{fl} =Water filled porosity

ϕ_k=Kerogen filled porosity

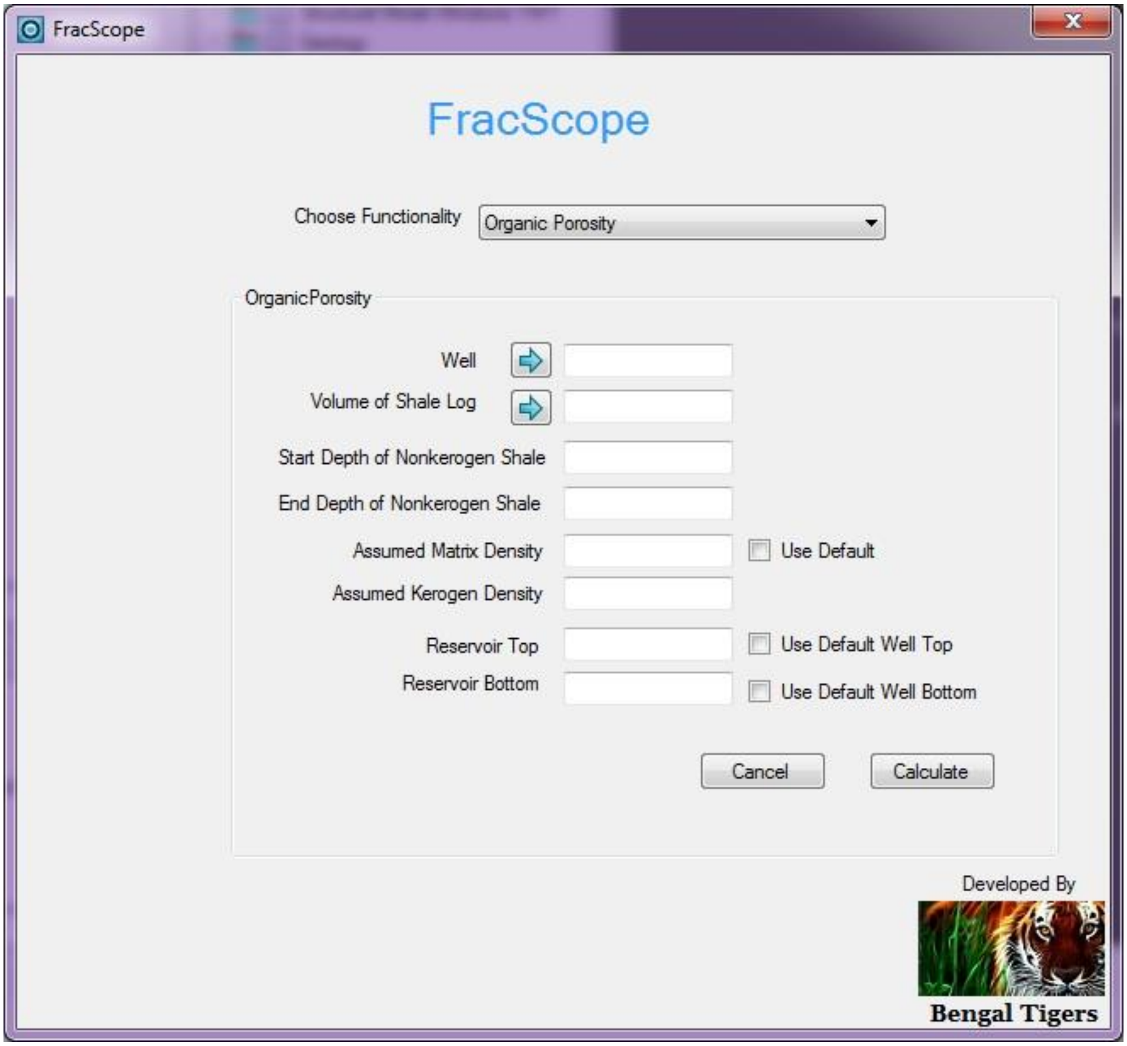

Figure 4: Organic porosity function of FracScope

3.5 **Clay Porosity**

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

Here, Vsh is the volume of clay

Φ_t is total porosity from density porosity log

3.6 **Fracture Porosity**

Fracture porosity = Fracture density from borehole image log * 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

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

Here, ρ 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.

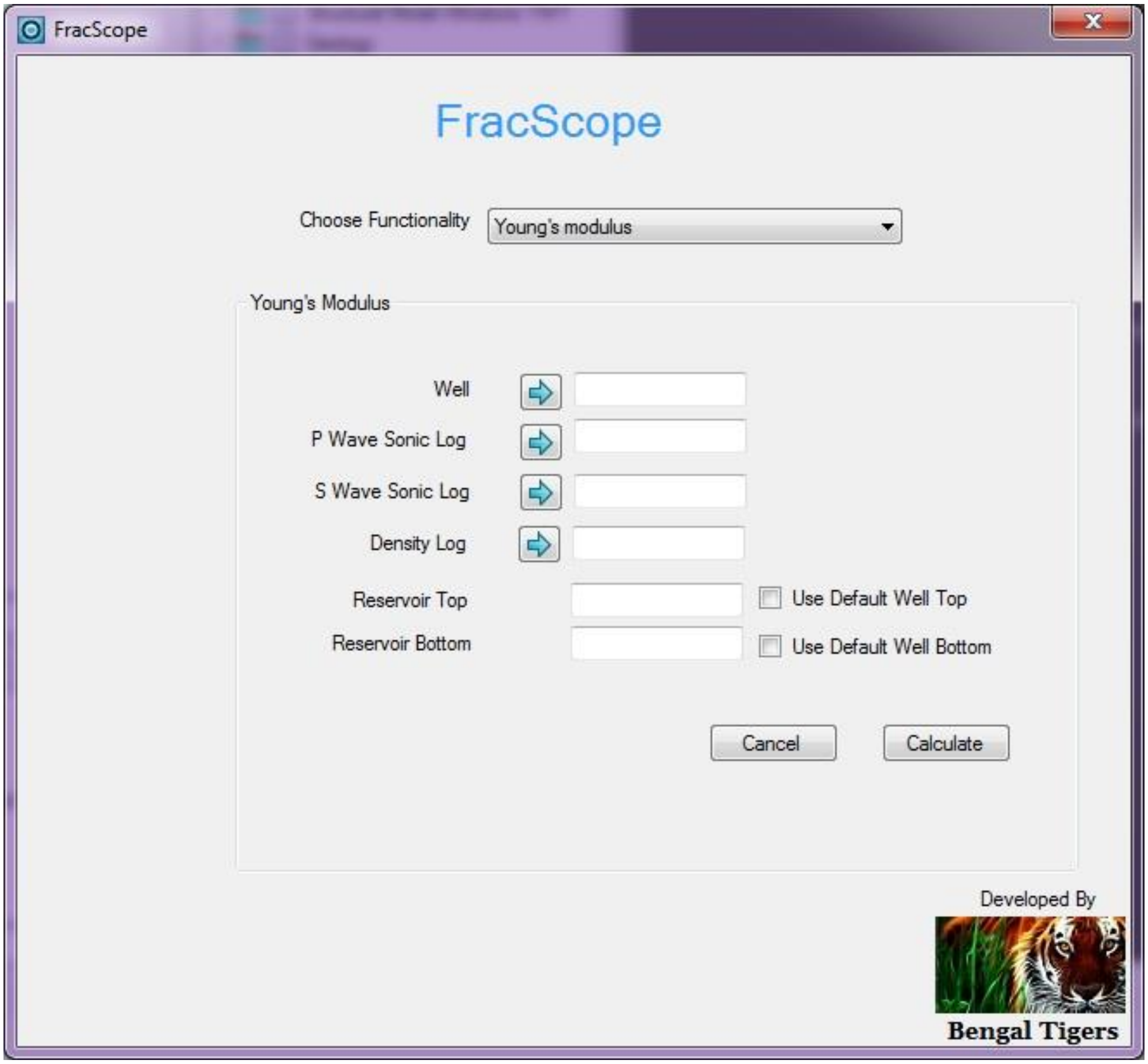

Figure 5: Young's modulus function of FracScope

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.

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

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

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

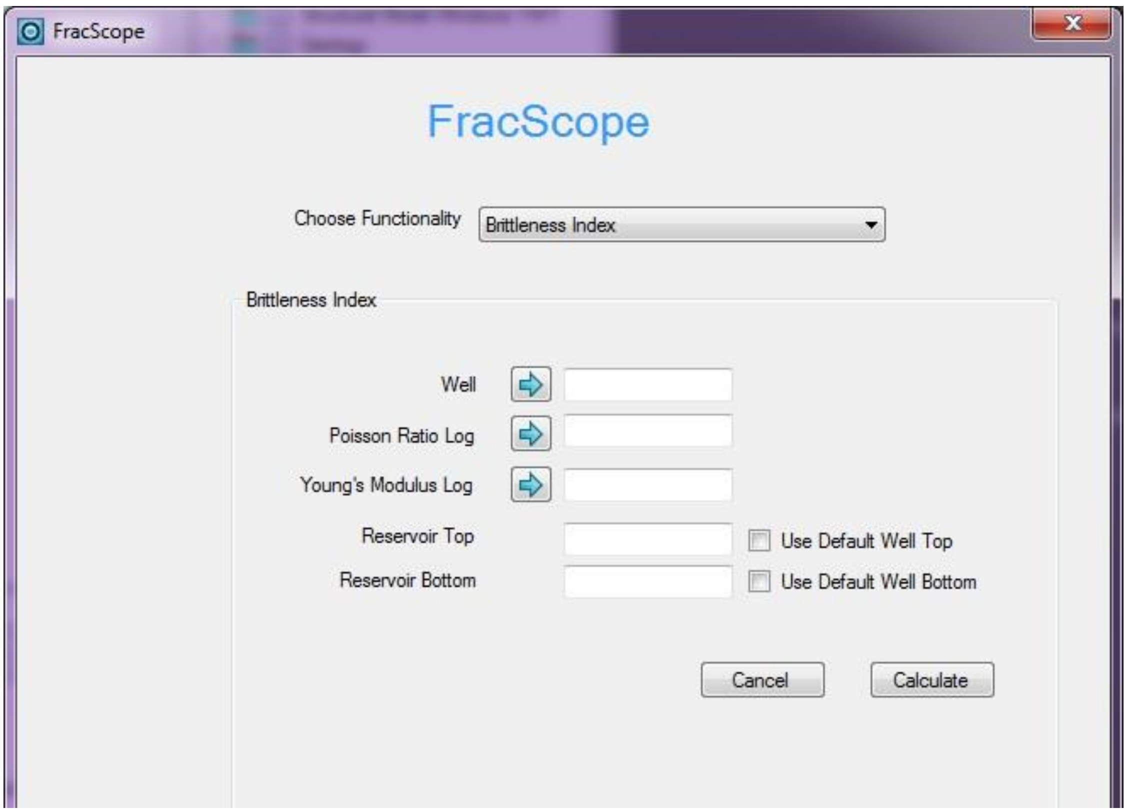

Figure 6: Brittleness Index function of FracScope

4.1.4. Lamda and Mu

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

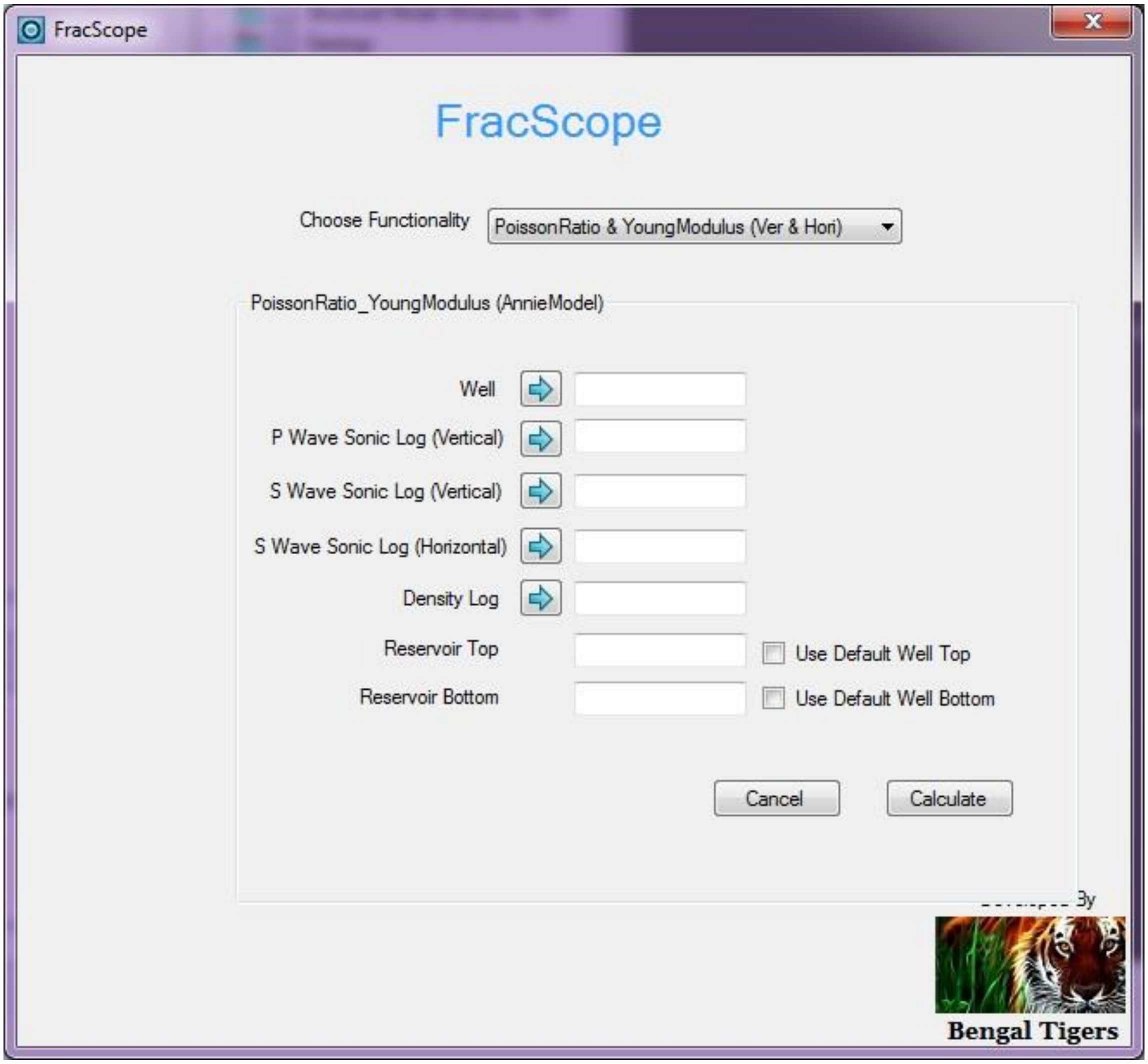

Figure 7: Horizontal and vertical Young’s modulus and Poisson’s ratio function with ANNIE approximation in FracScope

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 ρ 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:

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

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

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:

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

4.2.3 Epsilon and Gamma

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

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

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

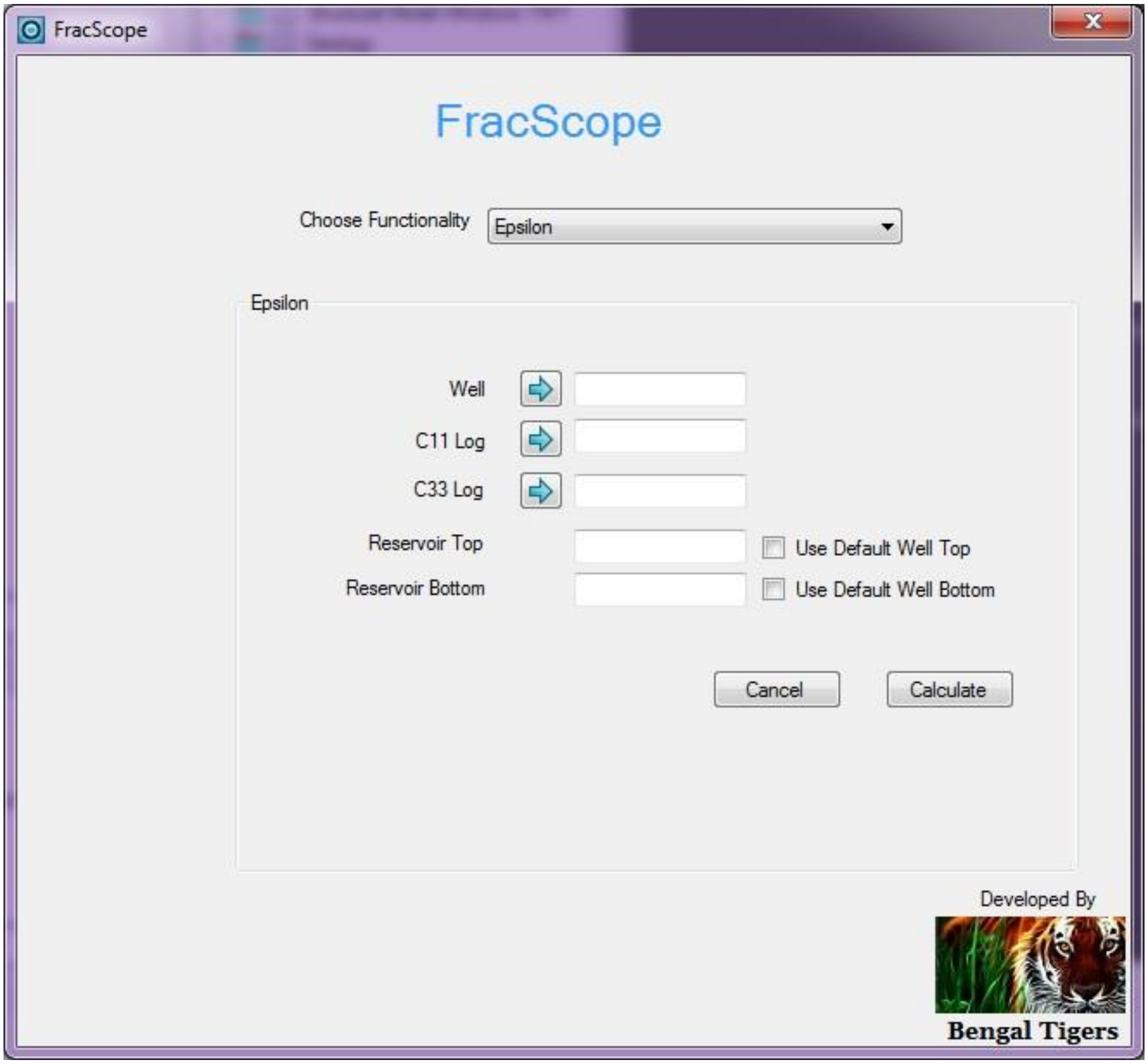

Figure 8: Epsilon function of FracScope

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.