Stress Visualizer

User Guide and Technical Documentation

Table of Contents

List of Figures

List of Equations

I. User Guide

1. Open **StressVisualizer.exe** to launch the program

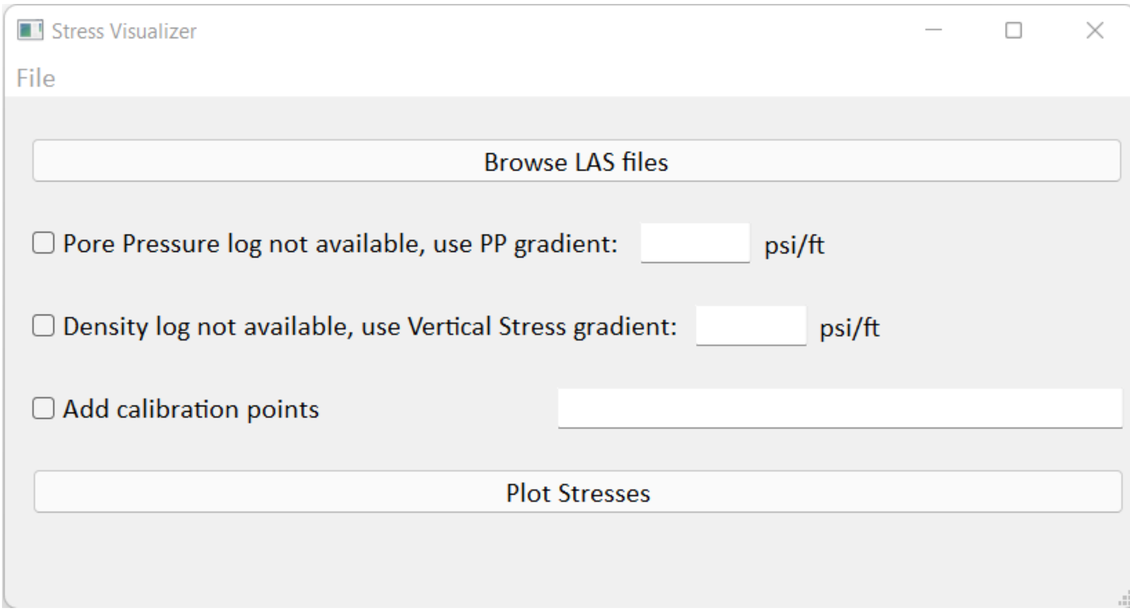

Figure 1. Main Window.

2. Click on **Browse LAS files** to choose which logs you want to visualize. Only *.las files are supported.

3. If Pore Pressure log is not available, click on the check box and input your desired pore pressure gradient in *psi/ft*.

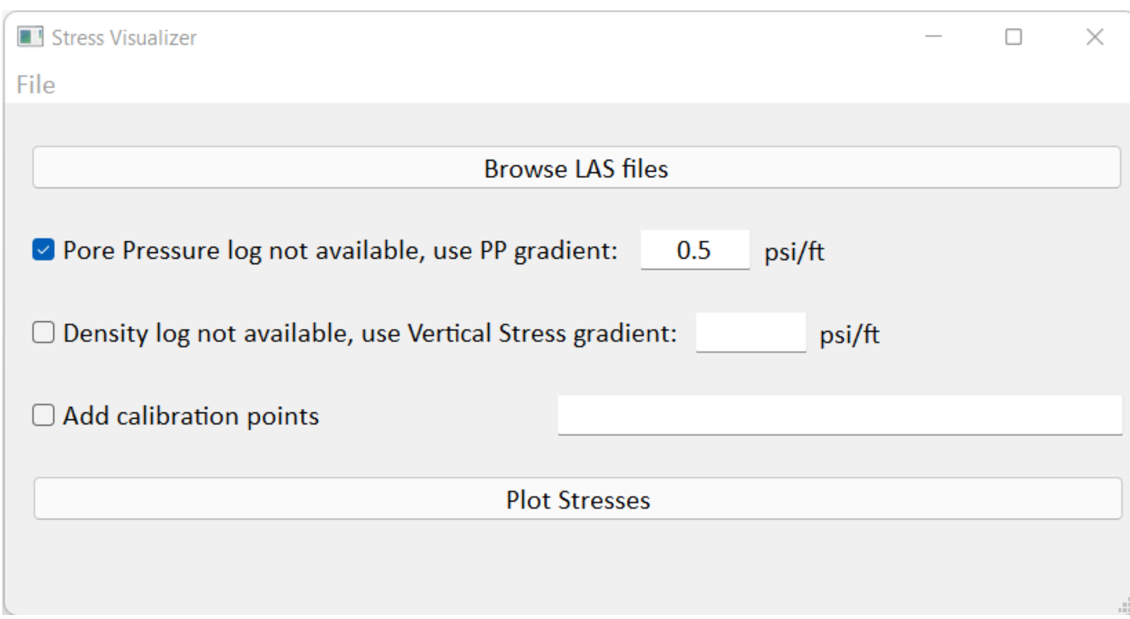

Figure 2. Pore Pressure check.

4. If Density log is not available, click on the check box and input your desired vertical stress (overburden) gradient in *psi/ft*.

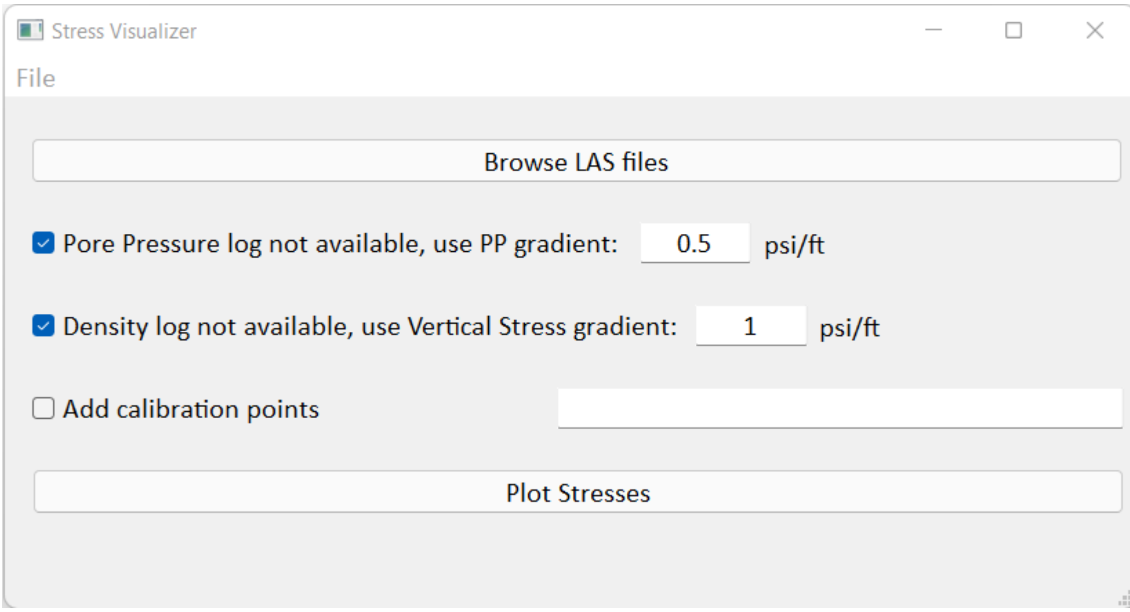

Figure 3. Density check.

5. To add calibration points, click on the check box and input the points in the following format: (depth1, stress1) (depth2, stress2) ...

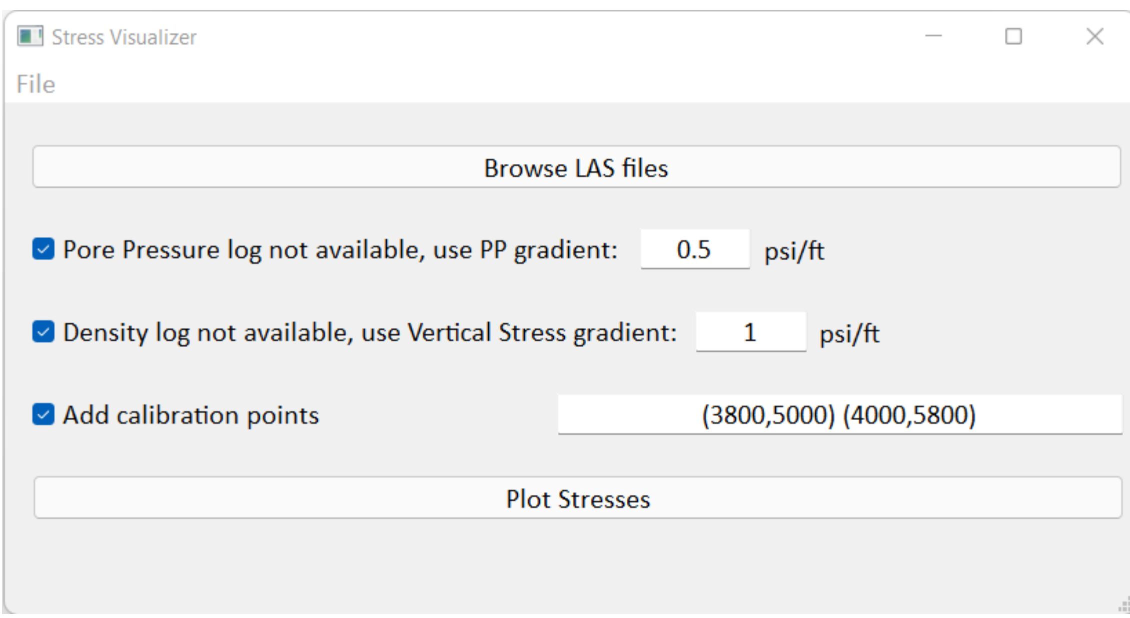

Figure 4. Calibration points.

6. Click on **Plot Stresses** to visualize the isotropic and anisotropic stresses.

II. Technical Documentation

StressVisualizer calculates and plots isotropic and anisotropic stresses based on the given log file. The following sections detail those calculations.

1. Isotropic Stress

a. Isotropic Poisson's ratio:

$$\nu = \frac{V_p^2 - 2V_s^2}{2(V_p^2 - V_s^2)}$$

Equation 1. Isotropic Poisson's ratio

b. Isotropic Young's Modulus:

$$E = \frac{\rho V_s^2 (3V_p^2 - 4V_s^2)}{V_p^2 - V_s^2} = 2\rho V_s^2 (1 + \nu)$$

Equation 2. Isotropic Young's Modulus

c. Minimum horizontal stress assuming isotropic medium:

$$\sigma_h^{min} = \frac{\nu}{1-\nu}(\sigma_v - \alpha P_p) + \alpha P_p + \left(\frac{E}{1-\nu}\right)\varepsilon_h + \left(\frac{E}{1-\nu}\right)\varepsilon_H$$

$$\sigma_v = \text{Vertical/Overburden stress}$$

$$\alpha = \text{Biot's coefficient}$$

$$P_p = \text{Pore pressure}$$

$$\varepsilon_h = \text{Minimum horizontal stress}$$

$$\varepsilon_H = \text{Maximum horizontal stress}$$

Equation 3. Minimum isotropic stress

2. Anisotropic Stress

Vertically transverse isotropy (VTI) assumes a vertical axis of rotational symmetry and properties are the same horizontally.

Hooke's Law:

$$\begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \sigma_4 \\ \sigma_5 \\ \sigma_6 \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & 0 & 0 & 0 \\ C_{12} & C_{11} & C_{13} & 0 & 0 & 0 \\ C_{13} & C_{13} & C_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{44} & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{66} \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \end{bmatrix}$$

$$\sigma_1, \sigma_2, \sigma_3 = \text{Normal stresses}$$

$$\sigma_4, \sigma_5, \sigma_6 = \text{Shear stresses}$$

$$\varepsilon_1, \varepsilon_2, \varepsilon_3 = \text{Normal strains}$$

$$\varepsilon_4, \varepsilon_5, \varepsilon_6 = \text{Shear strains}$$

$$C_{ij} = \text{Stiffness coefficients}$$

Equation 4. Hooke's Law

There are six unknowns, but only 5 are independent because of symmetry:

$$C_{11} = \rho V_p^2(90°)$$

$$C_{33} = \rho V_p^2(0°)$$

$$C_{44} = \rho V_s^2(0°)$$

$$C_{66} = \rho V_s^2(90°) = \rho_f \frac{v_f^2 v_{Stoneley}^2}{v_f^2 - v_{Stoneley}^2} = \rho_f \frac{1}{\Delta t_{Stoneley}^2 - \Delta t_f^2}$$

$$C_{13} = \sqrt{4\rho^2 V_p^4(45°) - 2\rho V_p^2(45°)(C_{11} + C_{33} + 2C_{44}) + (C_{11} + C_{44})(C_{33} + C_{44})} - C_{44}$$

$$C_{12} = C_{11} - 2C_{66}$$

Equation 5. Stiffness coefficients

Assuming all of the above parameters are known, the vertical/horizontal mechanical properties of the rock can be determined.

a. Anisotropic Poisson's ratio:

$$\nu_v = \frac{C_{13}}{C_{11} + C_{12}}$$

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

Equation 6. Vertical and Horizontal Poisson's ratio

b. Anisotropic Young's Modulus:

$$E_v = C_{33} - \frac{2C_{13}^2}{C_{11} + C_{12}}$$

$$E_h = \frac{(C_{11} - C_{12})(C_{11}C_{13} - 2C_{13}^2 + C_{12}C_{33})}{C_{11}C_{33} - C_{13}^2}$$

Equation 7. Vertical and Horizontal Young's Modulus

c. Minimum horizontal stress assuming VTI medium:

$$\sigma_{h,VTI}^{min} = \frac{E_h}{E_v}\left(\frac{\nu_v}{1 - \nu_h}\right)(\sigma_v - \alpha_v P_p) + \alpha_h P_p + \left(\frac{E_h}{1 - \nu_h^2}\right)\varepsilon_h + \left(\frac{E_h \nu_h}{1 - \nu_h^2}\right)\varepsilon_H$$

Equation 8. Minimum anisotropic stress

Stoneley Wave stress model

$$C_{33} = \rho V_p^2(0°)$$

$$C_{44} = \rho V_s^2(0°)$$

$$C_{66} = \rho V_{sh}^2(90°) = \rho_f \frac{v_f^2 v_{Stoneley}^2}{v_f^2 - v_{Stoneley}^2} = \rho_f \frac{1}{\Delta t_{Stoneley}^2 - \Delta t_f^2} \qquad \Delta t_f = 190\, \mu s/ft$$

$$C_{11} = K_1 \left[C_{33} + 2(C_{66} - C_{44})\right] \qquad K_1 = 1.1$$

$$C_{12} = C_{11} - 2C_{66}$$

$$C_{13} = K_2 C_{12} \qquad K_2 = 0.8$$

Equation 9. Stoneley Wave stress model

Velocity Regression stress model

$$C_{33} = \rho V_p^2(0^\circ)$$

$$C_{44} = \rho V_s^2(0^\circ)$$

$$V_p(90^\circ) = 0.8615 V_p(0^\circ) + 1.3315$$

$$V_p(45^\circ) = 0.9189 V_p(0^\circ) + 0.6175$$

$$V_s(90^\circ) = 0.8467 V_s(0^\circ) + 0.8161$$

$$C_{11} = \rho V_p^2(90^\circ)$$

$$C_{66} = \rho V_s^2(90^\circ)$$

$$C_{13} = \sqrt{4\rho^2 V_p^4(45^\circ) - 2\rho V_p^2(45^\circ)(C_{11} + C_{33} + 2C_{44}) + (C_{11} + C_{44})(C_{33} + C_{44})} - C_{44}$$

$$C_{12} = C_{11} - 2C_{66}$$

Equation 10. Velocity Regression stress model