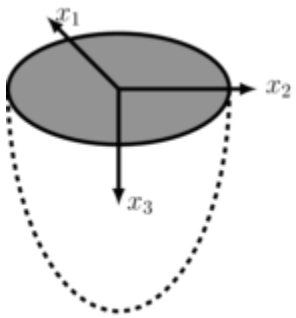
Principle stresses and directions in the earth

Idealized half-space



$$\rho\frac{\partial^2 u_1}{\partial t^2} = \frac{\partial S_{11}}{\partial x_1} + \frac{\partial S_{12}}{\partial x_2} + \frac{\partial S_{13}}{\partial x_3} + \rho b_1$$

$$\rho\frac{\partial^2 u_2}{\partial t^2} = \frac{\partial S_{12}}{\partial x_1} + \frac{\partial S_{22}}{\partial x_2} + \frac{\partial S_{23}}{\partial x_3} + \rho b_2$$

$$\rho\frac{\partial^2 u_3}{\partial t^2} = \frac{\partial S_{13}}{\partial x_1} + \frac{\partial S_{23}}{\partial x_2} + \frac{\partial S_{33}}{\partial x_3} + \rho b_3$$

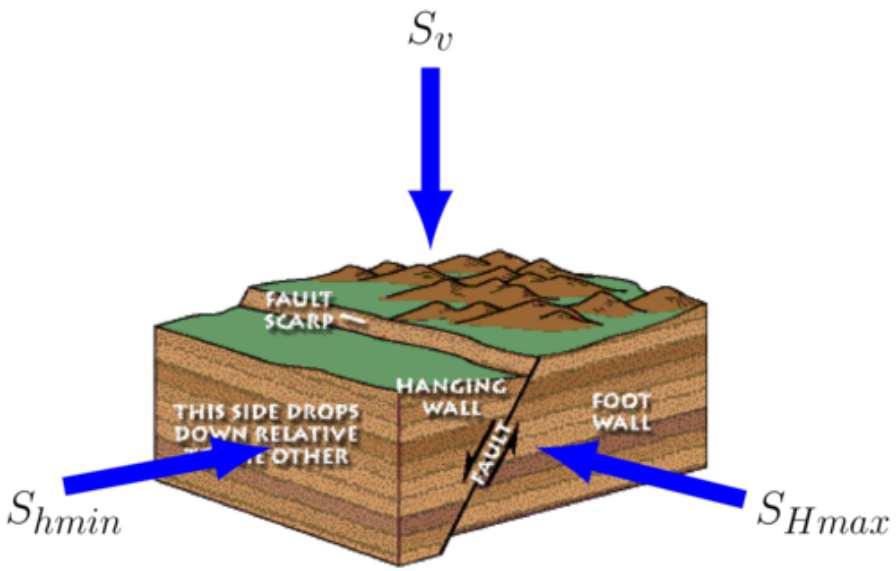
$S_{33} = S_v$ must be a principle stress!

Four parameters needed to describe state-of-stress in the earth

- S_V - vertical stress magnitude
- S_{Hmax} - maximum horizontal principle stress magnitude
- S_{hmin} - minimum horizontal principle stress magnitude
- One horizontal principle direction, usually the direction associated with S_{Hmax}

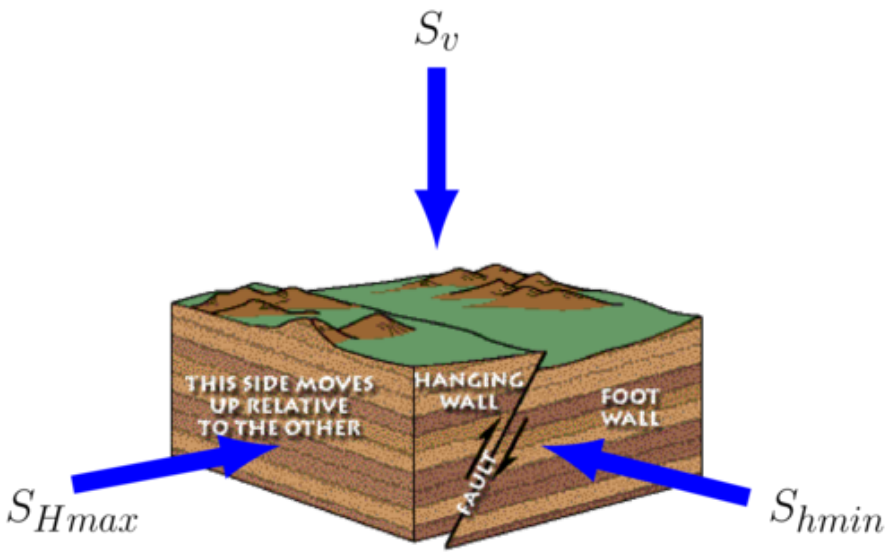
Anderson fault classification

Normal fault



$$S_v > S_{Hmax} > S_{hmin}$$

Reverse fault



$$S_{Hmax} > S_{hmin} > S_v$$

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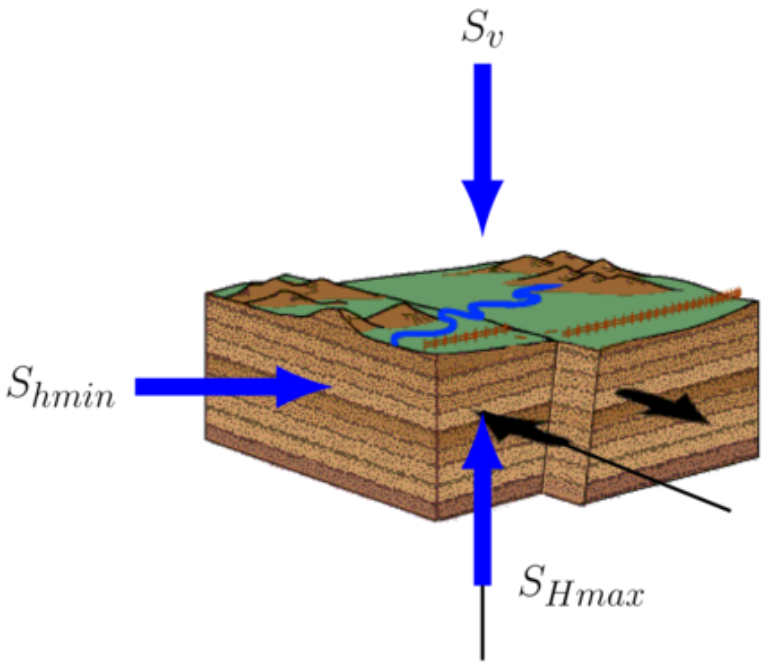
Strike-slip



$$S_{Hmax} > S_v > S_{hmin}$$

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Summary

Regime	**S_1**	**S_2**	**S_3**
Normal	S_v	S_{Hmax}	S_{hmin}
Strike-slip	S_{Hmax}	S_v	S_{hmin}
Reverse	S_{Hmax}	S_{hmin}	S_v

Vertical stress magnitude

$$S_v = \int_0^z \rho(z) g \mathrm{d}z$$

In offshore areas

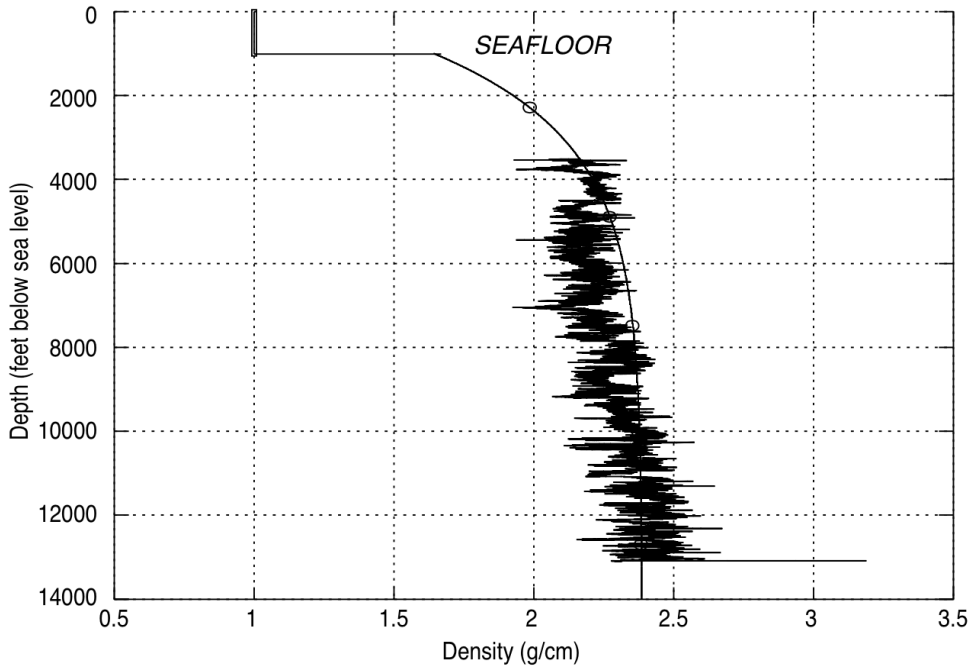
$$S_v = \rho_w g z_w + \int_{z_w}^{z} \rho(z) g \mathrm{d}z$$

Rules of thumb

- $\rho_w \approx 1 \text{g/cm}^3$
  - increases at a rate of 10 MPa/km (0.44 psi/ft)

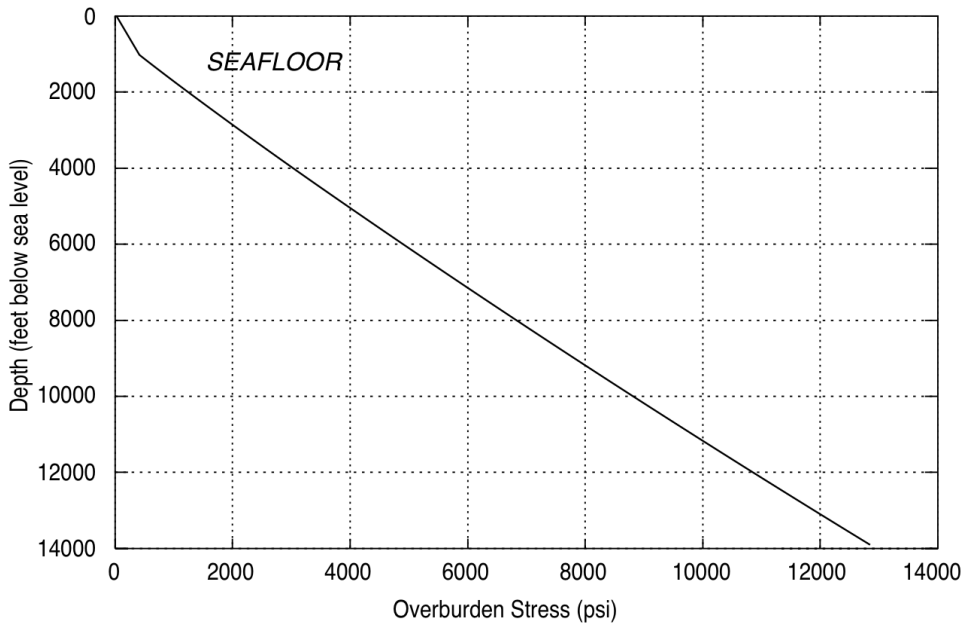
- $\rho_{\text{rock}} \approx 2.3 \text{g/cm}^3$
  - increaes at a rate of 23 MPa/km (1 psi/ft)

Density logs



 Zoback, *Reservoir Geomechanics* (Fig. 1.3, pp. 11)

Density log integration



 Zoback, *Reservoir Geomechanics* (Fig. 1.3, pp. 11)