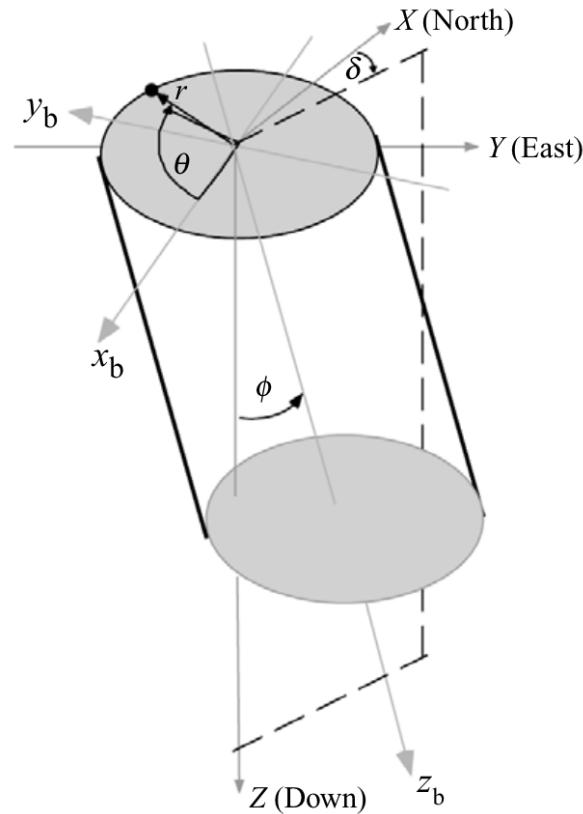


Recall: State of stress surrounding an arbitrarily deviated well



Stresses in the wellbore coordinate system

$$\mathbf{R}_B = \begin{bmatrix} \cos \delta \cos \phi & \sin \delta \cos \phi & -\sin \phi \\ -\sin \delta & \cos \delta & 0 \\ \cos \delta \sin \phi & \sin \delta \sin \phi & \cos \phi \end{bmatrix}$$

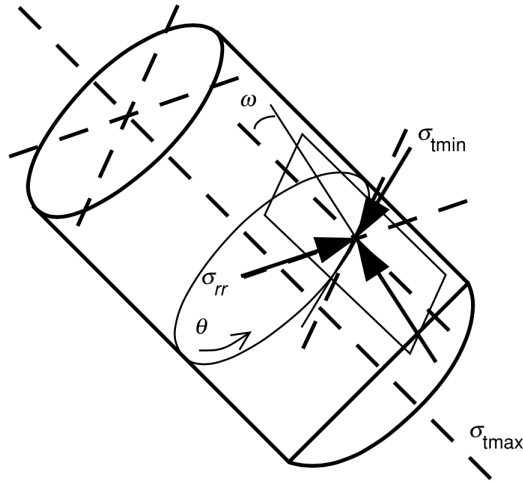
$$\mathbf{S}_B = \mathbf{R}_B \mathbf{S}_G \mathbf{R}_B^T$$

$$\mathbf{S}_B = \mathbf{R}_B (\mathbf{R}_G^T \mathbf{S}_G \mathbf{R}_G) \mathbf{R}_B^T$$

Stress at wellbore wall

$$\begin{aligned}\sigma_{zz} &= \sigma_{33} - 2\nu(\sigma_{11} - \sigma_{22}) \cos 2\theta - 4\nu\sigma_{12} \sin 2\theta \\ \sigma_{\theta\theta} &= \sigma_{11} + \sigma_{22} - 2(\sigma_{11} - \sigma_{22}) \cos 2\theta - 4\sigma_{12} \sin 2\theta - \Delta P \\ \tau_{\theta z} &= 2(\sigma_{23} \cos \theta - \sigma_{13} \sin \theta) \\ \sigma_{rr} &= \Delta P\end{aligned}$$

Principal effective stresses around the wellbore



$$\sigma_{tmax} = \frac{1}{2} \left(\sigma_{zz} + \sigma_{\theta\theta} + \sqrt{(\sigma_{zz} - \sigma_{\theta\theta})^2 + 4\tau_{\theta z}^2} \right)$$
$$\sigma_{tmin} = \frac{1}{2} \left(\sigma_{zz} + \sigma_{\theta\theta} - \sqrt{(\sigma_{zz} - \sigma_{\theta\theta})^2 + 4\tau_{\theta z}^2} \right)$$

Example: Reverse faulting

$$\mathbf{S} = \begin{bmatrix} 30 & 0 & 0 \\ 0 & 25 & 0 \\ 0 & 0 & 20 \end{bmatrix}$$

$$\alpha = 90^\circ$$

$$\beta = 0^\circ$$

$$\gamma = 0^\circ$$

Azimuth of S_{Hmax}

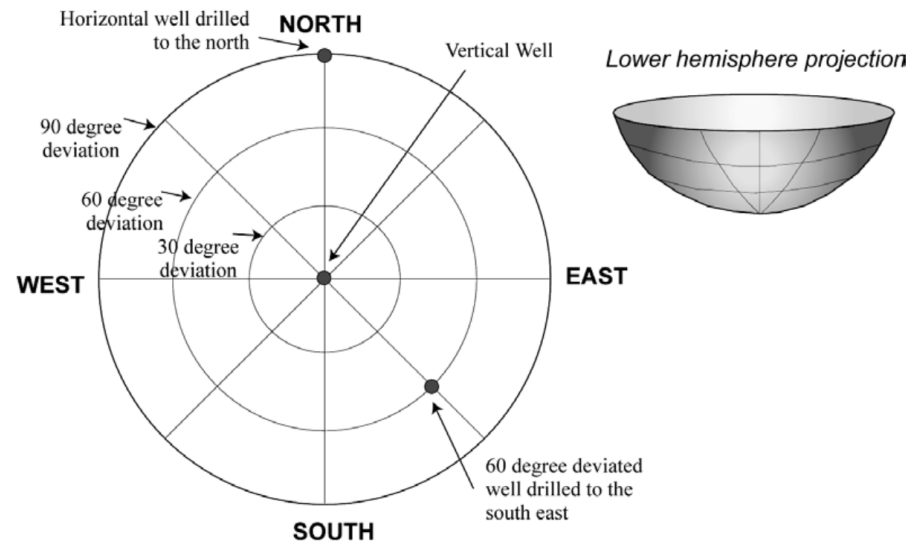
$$S_1 = S_{Hmax}$$

$$S_2 = S_{hmin}$$

Find the minimum and maximum tangential stress for an open hole well that is oriented 20° from North and deviated 20° from vertical at a depth of 2 km. Assume a hydrostatic pore pressure gradient, a Poisson ration of 0.2, and a balanced drilling operation.

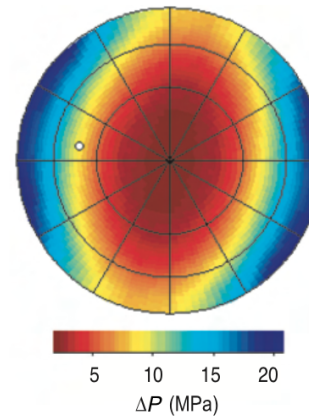
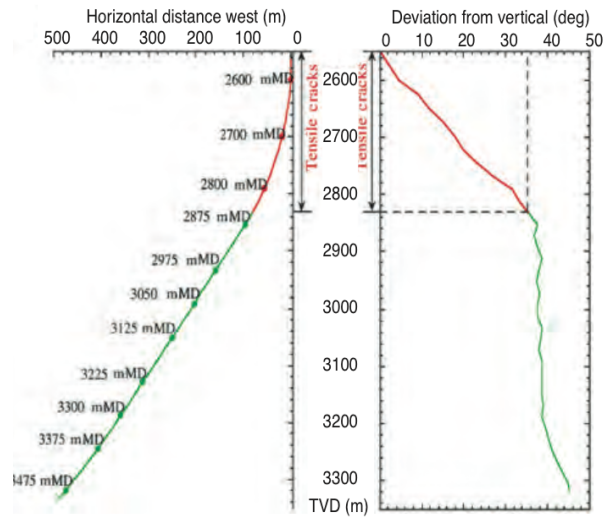
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Lower hemisphere projection

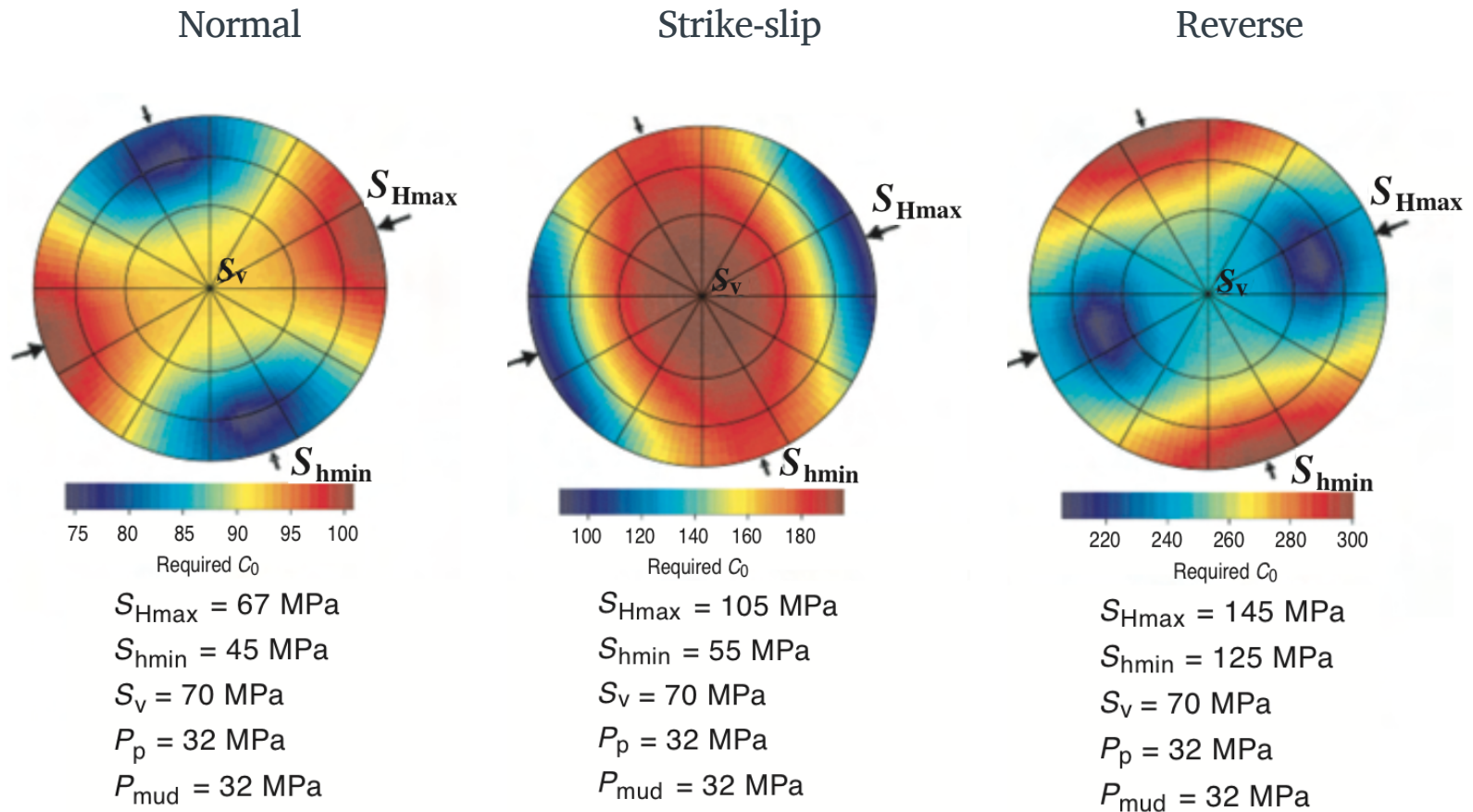


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Example



Examples: Breakout initiation



Examples: Drilling induced tensile fracture

