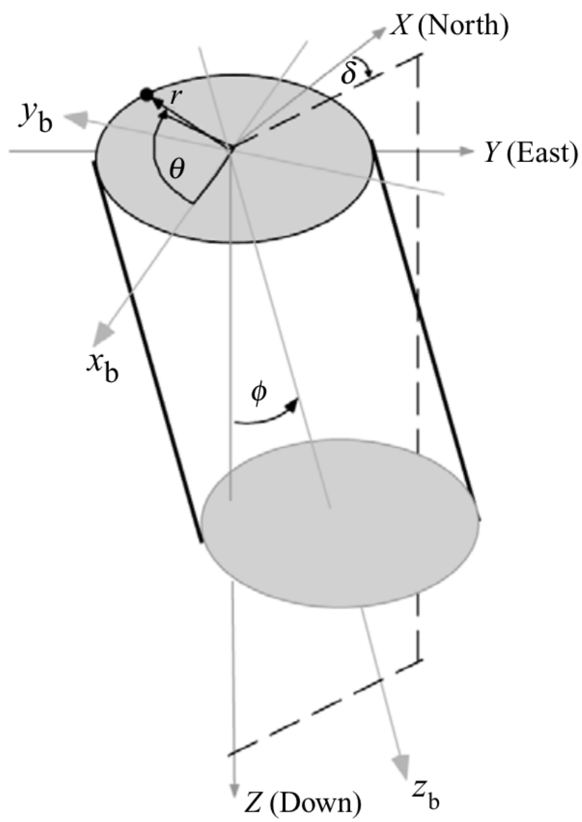
State of stress surrounding an arbitrarily deviated well



© Cambridge University Press Zoback, *Reservoir Geomechanics* (Fig. 8.1b, pp. 237)

Stresses in the wellbore coordinate system

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

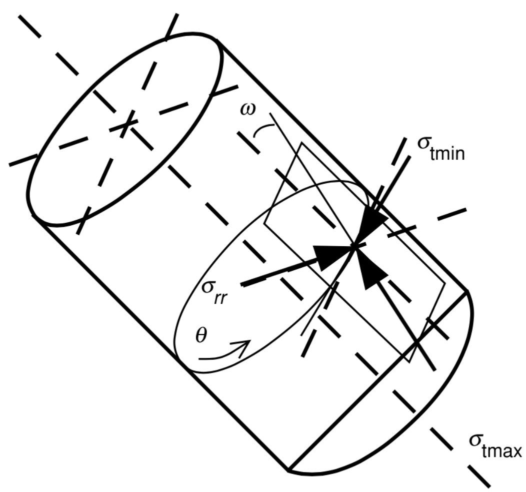
$$\mathbf{S}_B = \mathbf{R}_B\mathbf{S}_G\mathbf{R}_B^T$$

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

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



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

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

 Zoback, *Reservoir Geomechanics* (Fig. 8.1a, pp. 237)

Example: Reverse faulting

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

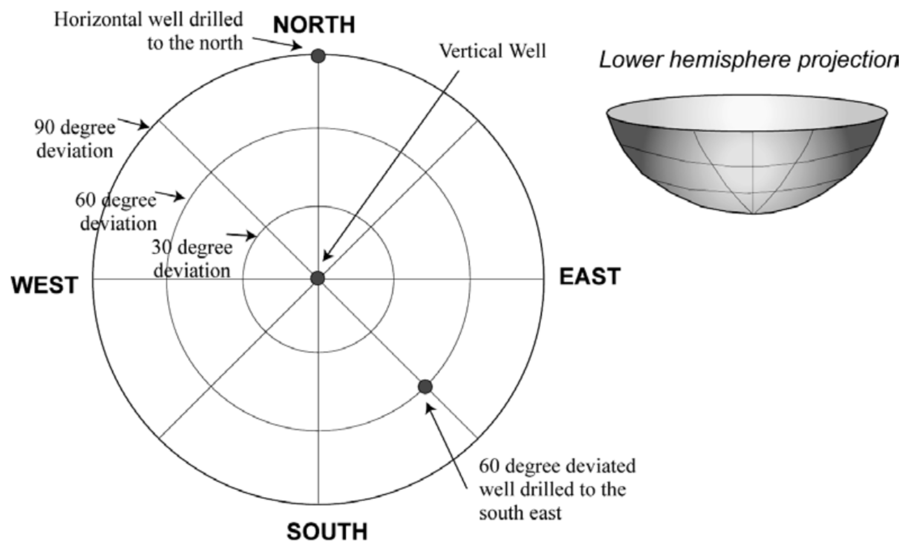
$$\alpha = 90^\circ \quad \text{Azimuth of } S_{Hmax}$$

$$\beta = 0^\circ \quad S_1 = S_{Hmax}$$

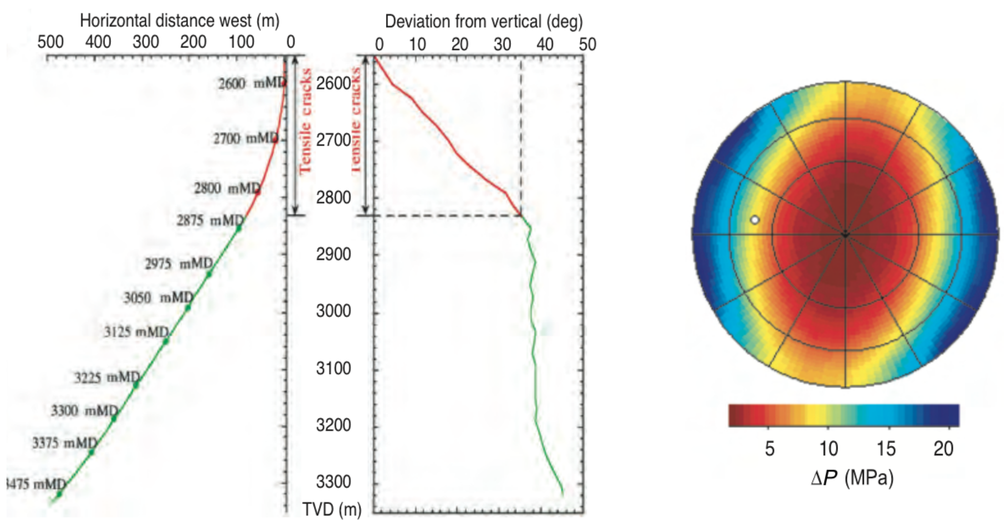
$$\gamma = 0^\circ \quad S_2 = S_{hmin}$$

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 and a Poisson ration of 0.2.

Lower hemisphere projection



Example


Horizontal distance west (m)
500 400 300 200 100 0
2600 mMD
2700 mMD
2800 mMD
2875 mMD
2975 mMD
3050 mMD
3125 mMD
3225 mMD
3300 mMD
3375 mMD
3475 mMD
Tensile cracks
2600
2700
2800
2900
3000
3100
3200
3300
TVD (m)
Deviation from vertical (deg)
0 10 20 30 40 50
Tensile cracks
5 10 15 20
ΔP (MPa)