choose to not select any breakouts where this happens.

Theoretical Breakout Directions in Arbitrary Stress Fields

Here we discuss how the theoretical breakout direction is calculated, given an arbitrary borehole orientation and far-field stress state. First, the far-field tectonic stress is transformed or rotated into the coordinate system associated with the borehole, as the stress tensor

$$\mathbf{S}_{IJK} = \begin{pmatrix} S_{ii} & S_{ij} & S_{ki} \\ S_{ij} & S_{jj} & S_{jk} \\ S_{ki} & S_{jk} & S_{kk} \end{pmatrix} \tag{3}$$

with compressional stress positive.

Hiramatsu and Oka [1962] and *Fairhurst* [1968] derived the relationship between far-field stresses and stresses on the wall of a cylindrical hole, assuming that the medium is isotropic, homogeneous, and linearly elastic with constant fluid pressure in the borehole. The stresses on the borehole wall are given by

$$\begin{aligned} \sigma_{kk} &= S_{kk} - 2\nu(S_{ii} - S_{jj})\cos 2\alpha \\ &\quad -4\nu S_{ij}\sin 2\alpha && (4) \\ \sigma_{\alpha\alpha} &= S_{ii} + S_{jj} - 2(S_{ii} - S_{jj})\cos 2\alpha \\ &\quad -4S_{ij}\sin 2\alpha - \Delta P && (5) \\ \tau_{k\alpha} &= 2(S_{jk}\cos\alpha - S_{ki}\sin\alpha) && (6) \\ \sigma_1 &= \frac{1}{2}(\sigma_{kk} + \sigma_{\alpha\alpha}) \\ &\quad +\frac{1}{2}\sqrt{(\sigma_{kk} - \sigma_{\alpha\alpha})^2 + 4\tau_{k\alpha}^2} && (7) \end{aligned}$$

Here, σ_1 is the greatest compressive stress on the borehole wall at a particular position, and ΔP is the difference between the borehole fluid pressure and the in situ pore pressure. Throughout this work we take ΔP to be 0. The angle α is measured from the **I** axis toward the **J** axis (Figure 5). Here, ν is Poisson's ratio of the rock and is taken to be 0.25. To find the position at which the breakouts should form on the borehole wall, we maximize σ_1 with respect to the angle α.

Inversion of Borehole Breakout Data

In this section we describe the steps taken after a dipmeter data set is gathered to determine the stress state that best describes the data. Briefly, the steps are as follows:

1. Calculate the **IJK** elongation angle for all wells at 0.125 m depth spacing.

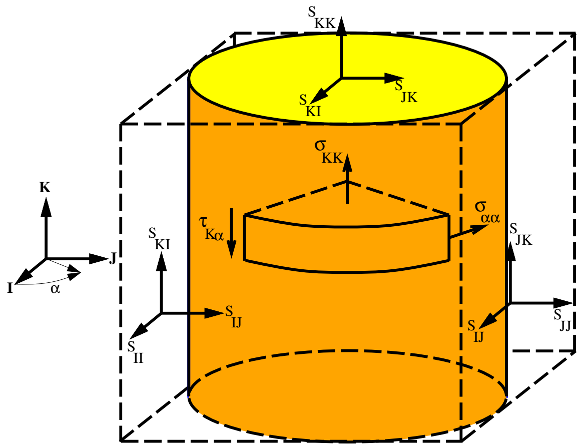

Figure 5. View of the borehole and the components of the stress tensor in the borehole coordinate system. The angle α is used in finding the cylindrical components of the stress tensor on the borehole wall. After *Qian and Pedersen* [1991].

2. Use the breakout selection criteria listed above to identify breakouts.

3. Optionally bin the breakouts into bins of **XYZ** borehole azimuth and borehole deviation. We calculate a weighted average breakout direction and a weighted standard deviation of the breakout angles [*Mardia*, 1972]. We weight individual breakouts linearly with their length and inversely with the standard deviation of the breakout angle over the breakout's length.

4. Use a genetic algorithm (GA) to identify the region of the stress state solution space that most likely contains the minimum weighted one-norm misfit between a stress state and the, possibly binned, breakout data.

5. Run a N-dimensional optimizer with the results from the GA to find the minimum misfit.

6. Calculate error bounds on the best fitting stress state.

Calculation of Borehole Elongation Directions

Each data point used in the inversion consists of three values: the **XYZ** borehole azimuth, the borehole deviation, and **IJK** elongation angle. The **IJK** elongation angle is used in preference to the **XYZ** elongation azimuth, because at large borehole deviations, **XYZ** elongation azimuths will lie predominantly 90° away from the borehole azimuth. The relationship between the **IJK** elongation angle and the **XYZ** elongation azimuth is not linear, so calculation of the misfit