between **XYZ** elongation azimuths would not be representative of the real difference between **IJK** elongation angles.

Typically, calculating the **IJK** elongation angle involves several different steps depending on the types of available data. Different dipmeters measure different angular quantities recording the orientation of the dipmeter's caliper arms, either the relative bearing or the pad 1 azimuth. If the relative bearing is measured, then we subtract the relative bearing from 90° to get the **IJK** elongation angle, since the relative bearing is measured with respect to the **J** axis. However, if the pad 1 azimuth is measured, we calculate the **IJK** angle that expresses the same vector direction as the pad 1 azimuth for the caliper arm. Depending on the age of the logging tool and the type of tool used to log the hole, we might need to make a magnetic declination correction for all geographic azimuths that the tool measures, such as the pad 1 azimuth and the borehole azimuth.

Binning of Breakout Data

After identification of the breakouts from a set of wells, lower hemisphere stereographic projection plots of the breakouts may show a large degree of scatter in the breakout angle. In this case, to simplify the subsequent inversion, we may bin the data into equal-area borehole azimuth versus borehole deviation bins. We use the technique of *Mardia* [1972] to calculate a weighted average and a weighted standard deviation of a set of breakout angles. We weight the data linearly with the breakout's length and inversely with the standard deviation of the **IJK** breakout angles over the length of an individual breakout.

Stress State Parameterization

A stress tensor can be described in a number of ways. We would like a parameterization of the stress tensor that separates the magnitudes of the principal stresses from the orientation of the principal stress directions.

We choose to parameterize the stress state with four parameters: three Euler angles and the stress state ratio ϕ (equation (1)). Euler angles are three angles that describe three successive rotations about various coordinate axes and are a natural representation often used to completely describe the orientation of a set of axes attached to a body in space [*Goldstein*, 1950]. We use this formalism to describe the orientation of the eigenvectors of a stress tensor.

Since the stress tensor is completely described by six parameters and three of the parameters describe the stress state orientation, the two parameters we are not parameterizing describe the magnitudes of the principal stresses. We can parameterize the magnitudes of the principal stress directions as

$$S_1 = a(b+1) \quad (8)$$

$$S_2 = a(b+\phi) \quad (9)$$

$$S_3 = a(b) \quad (10)$$

Examination of equations (4) through (7) shows that the location of the greatest compressive stress, σ_1, is unaffected by the constant multiplicative factor a in equations (8)-(10). Therefore the only parameter that we choose to ignore in our parameterization is b, which we set to 1.

Calculation of the Misfit

In optimization of a problem a misfit scheme must be chosen that describes how well a particular model fits the data. Following *Parker and McNutt* [1980] and *Gephart and Forsyth* [1984], we use a one-norm measure of the misfit,

$$m = \sum_{j=1}^{n} \frac{|\theta_j - o_j|}{\sigma_j}, \quad (11)$$

where θ_j is a theoretical value for an observation o_j and σ_j is the measure of error in the observation. We use the least absolute values (L_1 norm) measure instead of the more familiar least squares (L_2 norm) approach, because our data show a propensity of observations that are quite a distance away from the predicted orientations from the best fitting model. In other words, the distribution of angular differences about the best fitting model is not Gaussian, and we do not wish to weight those particular measurements as heavily as a least squares or χ^2 misfit would do. It should be noted that the individual observations, o_j, and standard deviations, σ_j, appearing in equation (11) would be either the standard deviation of the **IJK** elongation angle over the breakout or from the statistics of the binned breakouts.

Fitting the Breakout Data

Since the determination of the best fitting stress state for a set of borehole breakout data is inherently nonlinear, we choose to use forward modeling instead of any inverse technique. Inversions have been used by others [e.g., *Qian and Pedersen*, 1991]. We use a two-step approach. First, a genetic algorithm [*Holland*, 1975; *Davis*, 1987; *Goldberg*, 1989] is applied to the problem to find an approximate best fitting stress state, using