arm is always as large as the bit size and no larger than 1.1 times the bit size. The minimum breakout length of criterion 4 was increased to 3 m to find longer, more consistent breakout intervals. Criterion 5 of Plumb and Hickman discards breakouts that fit all other selection criteria but are parallel to the high and low sides of the hole. We keep such data initially, since the theoretical breakout patterns for most stress regimes (Figure 2) show that in certain borehole orientations the breakouts are expected to be aligned with the high and low side of the hole. After initial data analysis, if we determine that some of these elongation directions are probably due to key seats, we remove them manually from the data set. We also note that *Qian and Pedersen* [1991] performed an inversion of a set of breakouts measured with four-arm dipmeter data containing radial breakouts (Figure 7). Finally, we add one more criterion, which discards breakouts with very large spalled regions, since other processes, such as wholesale failure along fault zones, might account for large spalled regions.

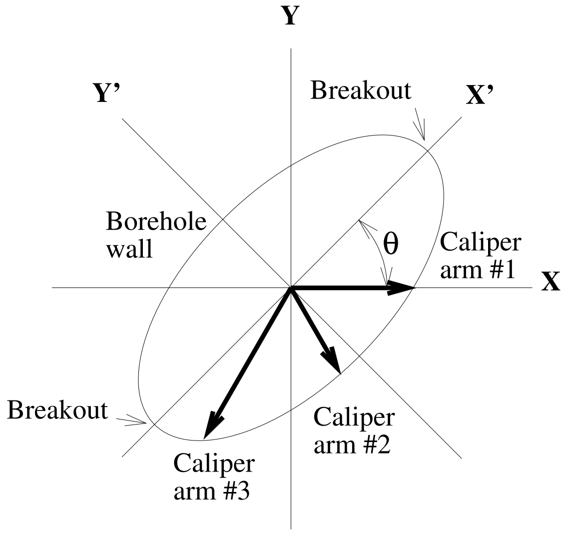

Figure 4. Geometry of the caliper arms in the six-arm dipmeter looking down onto the tool and ellipse used to find the breakout orientation.

Calculation of Elongation Azimuths

Calculation of the elongation direction for a four-arm dipmeter is straightforward. We assume that the center of the dipmeter is located at the center of the borehole, so the elongation direction is parallel to the direction of the longer caliper arm. We also make the assumption that the borehole is symmetric about 180°, so that all elongation orientations lie between 0° and 180° without any loss of generality.

The six-arm dipmeter is similar to the four-arm dipmeter except that it has two extra arms and all of the arms are separated by 60° intervals. Calculation of the borehole elongation direction from a six-arm dipmeter is more complicated, since it is not as obvious that any one set of caliper arms will be aligned with the breakout. In addition, the extra two pads on the borehole wall may change the threshold of detection of breakouts, because the increased friction on the borehole wall requires less ellipticity to counteract tool torque. We are not aware of any study in which the breakout directions calculated from a six-arm dipmeter have been compared to those found either from a borehole televiewer tool or from a four-arm dipmeter.

Here we describe two methods of calculating the elongation direction from six-arm dipmeter data. The first method uses the orientation of the longest caliper arm as the elongation direction. However, the longest caliper arm may not track the breakout, so the second method, which we use on our data, fits an ellipse to the caliper arm data and takes the orientation of the semimajor axis as the elongation direction.

We briefly describe the second method here. The six-arm dipmeter measures three independent diameters that are separated by 60°. These three values define three vectors, which originate at the origin of a suitable coordinate system and are separated by 60° intervals. We assume that the three vectors constrain an ellipse centered at the origin of the coordinate system. We parameterize the orientation of this ellipse, using θ, the angle between the semimajor axis of the ellipse, and the direction of caliper arm 1 (Figure 4). To determine θ, we write three equations describing the ellipse, inserting the vector positions of the endpoints of the caliper arms. The three equations are then written in matrix form. As in many linear algebra problems, for a solution to exist the determinant of the matrix must be zero. Here the matrix will have zero determinant when the angle of rotation of the ellipse is found. Once this angle of rotation is found, the lengths of the semimajor and semiminor axes are easily calculated. Using this information with the rotation angle allows calculation of the elongation direction with respect to azimuth of pad 1.

One potential problem with this method is that the three caliper arm vectors might be fitted by a hyperbola instead of an ellipse. We have observed this problem with some of the data from Point Pedernales, and we