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A stochastic prediction of in situ stress magnitudes from the distributions of rock strength and breakout width at IODP Hole C0002A in Nankai accretionary prism, SW Japan

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Most continuum theories in rock mechanics are based on a postulate of existence of a representative elementary volume (REV), over which a single number is chosen as an effective rock property. Such deterministic prediction of rock property without clear account of microstructural randomness over the REV excludes a rational discussion on risk assessment and uncertainty analysis. If the rock property is scale-dependent or severely heterogeneous, its distribution may provide more valuable information than its average does. Borehole wall images and sonic logging data obtained from IODP Hole C0002A near the Nankai Trough show a wide distribution of breakout widths and rock strengths even at a short interval of depth. The small-scale but frequent variation in breakout width in a short section of borehole wall is due to heterogeneous rock strength rather than a correspondingly frequent change in far-field stress. In this paper we consider the distribution of rock strengths and breakout widths in a given length of wellbore, which is large enough to analyze the logging data in a statistical manner but small enough to make sure that the far-field stresses are to be uniform, in order to determine the magnitudes of the stresses. Assuming the normal distribution of uniaxial compressive strength (UCS), which is estimated empirically from sonic velocity logs (Chang et al., 2006, JPSE; 2010, G3), we calculated the probability distribution of breakout width for given sets of the maximum and the minimum horizontal principal stresses (S_{Hmax} and S_{hmin}, respectively) for every 20m depth interval. The same procedure was repeated for various combinations of the two horizontal principal stress magnitudes. Then the objective function with two variables, S_{Hmax} and S_{hmin}, was obtained from the total misfits between the observed and the calculated occurrence distributions of breakout width. Finally we were able to determine the best solution of S_{Hmax} and S_{hmin} with the minimum total misfit. The results from this new approach of stress estimation are comparable with previous other results (e.g., Chang et al., 2010, G3; Lee et al., 2013, MPG). This stochastic model is prominent because it gives not only both values of S_{Hmax} and S_{hmin} simultaneously but also information about statistical reliability of the determined values quantified by sensitivity and uncertainty. Our result shows that the two stress magnitudes in Nankai accretionary prism are not completely independent in terms of sensitivity, suggesting that other independent measure of one of the two stresses might be definitely useful (e.g., from leak-off test).