Stochastic optimization using MATLAB code for the determination of in situ horizontal stress magnitudes from wellbore logging data

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We report a MATLAB code for the stochastic optimization of in situ horizontal stress magnitudes from wellbore wall image and sonic logging data in a vertical borehole. In undeformed sedimentary formations, one of the principal stresses is commonly assumed to be vertical, and its magnitude ($\sigma_v$) is simply related to the gravitational overburden. The two horizontal far-field principal stresses ($\sigma_h$ and $\sigma_h$) are then theoretically constrained by the relationship between the breakout width (or angular span) and rock compressive strength at a given depth. However, the deterministic relationship yields indeterminate solutions for the two unknown stresses. Instead of using the deterministic relationship between their average values in an interval of borehole, we introduce probabilistic distributions of rock strength and breakout width in the interval. This method optimizes the complete set of in situ principal stresses ($\sigma_v$, $\sigma_h$, and $\sigma_h$) by minimizing the objective function. For the rock failure model, we use a true triaxial failure criterion referred to as the modified Wiebols and Cook criterion that incorporates all three principal stresses. This criterion is expressed in the form of an implicit function with two equation parameters; the uniaxial compressive strength UCS and the internal friction coefficient $\mu$. The Weibull distribution model of UCS in a borehole section (~30 m interval) is obtained from the wellbore sonic logging data using the relation between UCS and P-wave velocity. The value of $\mu$ is assumed to be constant at 0.6 based on a previous experimental study. The breakout model is established based on the probabilistic distribution of rock strength at the margins of the breakout for a uniform set of far-field stresses. The inverse problem is solved with a MATLAB algorithm for the optimization by choosing the best-fit set of far-field stresses in a stress polygon. This process also enables one to evaluate the statistical reliability in terms of sensitivity and uncertainty. The stochastic optimization process is demonstrated using borehole images and sonic logging data obtained from the Integrated Ocean Drilling Program (IODP) Hole C0002A, a vertical hole near the seaward margin of the Kumano basin offshore from the Kii Peninsula, southwest Japan.
