Thermodynamic Analysis of Wellbore Stability in Ultra-Deep Formations: Postprint

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Abstract

Wellbore stability is crucial for ultra-deep wells under high temperature and high stress conditions. To analyze the effects of thermal shock and horizontal stress on wellbore stability, a series of true triaxial compression experiments and wellbore stability experiments were conducted on dolomite specimens under high temperature and high triaxial stress conditions. In the true triaxial compression experiments, the peak strength of the specimens exhibited a nonlinear increasing trend with increasing horizontal stress. As the intermediate principal stress increased, the peak strength of the specimens first increased and then decreased, and the failure mode transitioned from shear failure to mixed tensile-shear failure. Thermal shock stimulates the generation of microfractures within the specimens, thereby reducing their peak strength, cohesion, and internal friction angle. In the wellbore stability experiments, the maximum horizontal principal stress causing wellbore instability showed a nonlinear increasing trend with increasing minimum horizontal principal stress. Under the same minimum horizontal principal stress conditions, the maximum horizontal principal stress causing wellbore instability was lower for thermally shocked specimens. Based on the experimental results, M-C and MG-C criteria incorporating thermal shock effects were established to evaluate wellbore stability. Compared with the M-C criterion, the MG-C criterion considers the effect of intermediate principal stress and can therefore more accurately predict wellbore stability in ultra-deep wells. This study enhances understanding of wellbore instability mechanisms and provides valuable insights for addressing stability challenges in ultra-deep well environments.

Full Text

Preamble

Thermo-mechanical Analysis of Wellbore Stability in Ultra-deep Formations

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Abstract

Wellbore stability is critical for ultra-deep wells under high temperature and high stress conditions. To analyze the effects of thermal shock and horizontal stress on wellbore stability, we conducted a series of true triaxial compression experiments and wellbore stability experiments on dolomite specimens under high temperature and high triaxial stress conditions. In the true triaxial compression experiments, specimen peak strength exhibited a nonlinear increase as horizontal stress increased. As the intermediate principal stress increased, peak strength initially increased then decreased, with the failure mode transitioning from shear failure to mixed tensile-shear failure. Thermal shock induced microcrack generation within specimens, thereby reducing their peak strength, cohesion, and internal friction angle.

In the wellbore stability experiments, the maximum horizontal principal stress causing wellbore instability exhibited a nonlinear increase with increasing minimum horizontal principal stress. Under identical minimum horizontal principal stress conditions, the maximum horizontal principal stress causing wellbore instability was reduced in thermally-shocked specimens. Based on the experimental results, we established M-C and MG-C criteria incorporating thermal shock effects to evaluate wellbore stability. Compared with the M-C criterion, the MG-C criterion accounts for intermediate principal stress influence, enabling more accurate prediction of wellbore stability in ultra-deep wells. This study enhances understanding of wellbore instability mechanisms and provides valuable insights for addressing stability challenges in ultra-deep well environments.

Keywords: high temperature and high stress; ultra-deep wellbore stability; thermal shock; MG-C criterion; M-C criterion; deep Earth science

Note: Figure translations are in progress. See original paper for figures.