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Structural Sandbox Simulation of the Fault-Fracture Development in the Compression Deformation: A Case Study from the Sichuan Basin

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Abstract

Structural fractures are widely developed in compression deformation areas such as the foreland fault-fold belt. Complex structural deformation and weak response in seismic data are crucial challenges in fracture prediction, reserve appraisal, and economical production. We utilize structural sandbox simulation and seismic attributes to reveal the law of fault-fracture development under the structural compression, thereby supporting fracture-related target evaluation and well design.

This study designs five groups of sandbox models with different conditions with the same simulated materials and layer thicknesses. A thin layer of silica gel is laid at the bottom of the model to simulate the detachment strata of gypsum rock. A thin layer of corundum is laid on it to simulate the carbonate strata. The top layer consists of a type of mixed material suitable for fracture development. Through the previous material test, we select the mixed material of kaolin and corundum with a ratio of 1:1 to simulate the tight sandstone, in which the simulated fault-fracture will develop. With the high-resolution camera and industrial CT, the distribution and evolution process of fault-fractures under different compression deformations are observed. In the application from the Sichuan Basin, seismic attributes are used to further clarify the fracture development and evolution. The prediction results are verified by seismic and well interpolation, contributing to new understanding of regional fracture development.

Sandbox experiments exhibit that the density of fault-fractures is controlled by the thrust strength of the fault, not the previously considered fault shape. The fault throw can be used to predict the density of fault-fractures. The lateral width of the fracture zone is controlled by fault length and fault throw. In addition, multiple faults with short fault throw can also generate a wide fracture zone. The crossed fracture zone is developed by fault transition or fault turning, and there are property differences on both sides of the zone. The experiments also show the proportion of tensile fractures and shear fractures under different compression conditions.

We employed the simulation results in a case study of fracture prediction in Tongjiang area of the Sichuan Basin, southwestern China. More detailed fracture characteristics in the survey are supplemented by seismic attributes sensitive to the fracture density and strength. The prediction results are consistent with the seismic and well data. Thus, the prediction results are applied to the exploration of the Tongjiang area, and the daily output of production well has broken the record.

Our study utilizes sandbox models under different compression conditions to reveal the law of fault-fracture development and predict fractures quantitatively. The seismic attributes sensitive to the fractures are also applied to further clarify the fracture development and evolution. The prediction results help us to perform fracture-related target evaluation and well design with lower risk, which provides a basis for production well breakthrough.