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Fault analysis and fracture patterns in Moxi gas field, Sichuan Basin, China: Constraints on *in situ* stress research and numerical simulation method

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Fracture patterns and its relationship with faults are essential issues in Moxi gas field which is the typical carbonate fractured reservoirs. Giant single gas reservoir with great production potential has been found in its Sinian-Cambrian formation. We analyzed the planar characteristics of fault systems with coherent cube technique, curvature method and the inversion of seismic waveform difference to reveal that there are 5 regions divided by 6 main fault zones with N-S, NW-SE, NE-SW and E-W trends in Moxi gas field. Each fault zone consists of many small faults with similar trend and en-echelon arrangement. Spectral decomposition technology and precision angle estimation algorithm in frequency domain have been carried out to achieve fine resolution of seismic data in order to confirm the profile characteristics in Moxi gas field and we found that flower structures and normal faults with high angle are well-developed. They are formed under the tensile-sheer stress field from Caledonian to Hercynian circle. Considering planar and profile characteristics of main faults, we set proper parameters, run the automatic extraction technology system to extract faults in 3D space, and built fault model of Moxi gas field. We conducted forward modeling with finite element method on the basis of fault model and paleo-structural characteristics; so that we confirm the properties and periods of faults generation. Current in situ stress state can be regard as the main factor and key parameter. Current in situ stress was calculated automatically after defining the rock mechanics parameters and finite element analysis. The maximum horizontal principal stress is primarily oriented NE-SW in Moxi gas field, while because of the effect of fault zones; it is mainly oriented NW-SE in the northeast area. Moreover, the high stress value zones are distributed in the vicinity of faults, such as fault concentration, intersection, convergence and pinch-out area. Stress values are lower in the middle area of Moxi gas field, especially far from the fault zones. We made an assumption based on seismic interpretation achievement and internal characteristics of faults that the N-S trend fault (F1) developed in the rift extensional period and other 5 faults (F2 to F6) developed under the dextral stress. Then, the paleo-stress simulation was conducted and we recognized that there are 3 main periods of fault generation. Fault 1 (F1) is the pre-existing basement fault with tensile property. Fault 2 developed under the sinistral stress and Fault 6 was induced in the northeast of Fault 2 with sinistral property. Fault 3 developed under the dextral stress and Fault 5 was induced in the northeast of Fault 3 with dextral property. Patterns and characteristics of fractures have been descripted on the basis of fault analysis and in situ stress research. We compiled a suitable program to calculate parameters of fractures including length, density, aperture, porosity and permeability with the help of rock failure and fracture mechanics theory. Therefore, we concluded that every parameter of fracture declines when the distance to faults increases. With the increase of distance to middle area, linear density of fracture enlarges while physical property parameters including aperture, porosity and permeability decrease. Linear density of fracture increases while other parameters including length, aperture, porosity and permeability decrease with the drop of layer depth.

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