Fine Prediction of Thin Dolomite Using Multi-Wave Joint Inversion

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Abstract

The Lower Permian Qixia Formation in Chuanzhong area of the Sichuan Basin is dominated by limestone with an average depth of 4500 m. 2-3 sets of dolomite thin reservoirs are developed with cumulative thickness less than 15 m, and the cause of dolomite is generally considered to be controlled by structural hydrothermal fluid, and the dolomite porosity is less than 5%. The drilling results show that when the dolomite thickness is greater than 5m, the industrial gas can be obtained, while its response in conventional PP wave seismic profile is not obvious, so the effective prediction for the thin layer dolomite is full of challenge. Logging curve analysis shows that the P-wave velocity of dolomite is lower than that of limestone, but the S-wave velocity and density are obviously higher than limestone. Therefore, in theory, multi-wave seismic data (PP and PS (converted shear wave)) have advantages in distinguishing between dolomite and limestone. By analysis of multi-wave seismic data, we found that the PP wave generally exhibits strong amplitude characteristics in the trough background when limestone develops, while due to strong attenuation of PS wave in deep formation, the resolution of PS wave is lower than that of PP wave, so it shows a weak amplitude. For better understanding the reflection difference between PP wave and PS wave, we carried seismic forward modeling and it turned out that the amplitude of PP is strong while that of PS is weak when dolomite develops, which is consistent with the actual seismic response. Based on the fine matching of PP and PS and the seismic calibration, the multi-wave joint inversion is carried out, and the S-impedance and S-wave velocity data with obviously higher stability and higher resolution than the conventional P-wave inversion are obtained as expected in theory. Further calculate the product of Lame constant with density (Lamd*Den), which has better effect on distinguishing between dolomite and

limestone by analysis of logging curve sensitivity. On the plan view of Lamd*Den, the lower value indicates favorable area of dolomite, and it can be seen that the dolomite distribution has good agreement with known wells, which is obviously better than the prediction result of single PP wave inversion, proving that the multi-wave seismic has significant advantages in identifying thin layer dolomite in limestone formations. Moreover, the paleo-geomorphic characteristics of the Qixia Formation were analyzed by the residual thickness method. The dolomite distribution area predicted by multi-wave inversion is mainly located in the high part, which represents the high-energy shallow water sedimentary environment and is conducive to the development of the sedimentary beach. And the dolomite distribution has a good correlation with the fracture distribution predicted by coherence, indicating that the development of cracks creates conditions for dolomitization.