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Integrated petrophysical log characterization for tight carbonate reservoir effectiveness: A case study from the Longgang area, Sichuan Basin, China

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Abstract: Ultra-low porosity and permeability, inhomogeneous fracture distribution, and complex storage space together make the effectiveness evaluation of tight carbonate reservoirs difficult. Aiming at the carbonate reservoirs of the Da'anzhai Formation in the Longgang area of the Sichuan Basin, based on petrophysical experiments and logging response characteristics, we investigated the storage properties of matrix pores and the characteristics of fracture development to establish a method for the characterization of effectiveness of tight reservoirs. Mercury injection and nuclear magnetic resonance (NMR) experiments show that the conventional relationship between porosity and permeability cannot fully reflect the fluid flow behavior in tight matrix pores. Under reservoir conditions, the tight reservoirs still possess certain storage space and permeability, which are controlled by the characteristic structures of the matrix porosity. The degree of fracture development is crucial to the productivity and quality of tight reservoirs. By combining the fracture development similarity of the same type of reservoirs and the fracture development heterogeneity in the same block, a three-level classification method of fracture development was established on the basis of fracture porosity distribution and its cumulative features. According to the actual production data, based on the effectiveness analysis of the matrix pores and fast inversion of fracture parameters from dual laterolog data, we divided the effective reservoirs into three classes: Class I with developed fractures and pores, and high-intermediate productivity; Class II with moderately developed fractures and pores or of fractured type, and intermediate-low productivity; Class III with poorly developed fractures and matrix pores, and extremely low productivity. Accordingly log classification standards were set up. Production data shows that the classification of effective reservoirs is highly consistent with the reservoir productivity level, providing a new approach for the effectiveness evaluation of tight reservoirs.

Key words: Matrix porosity, fracture porosity, reservoir effectiveness, reservoir classification, petrophysical log characterization

1 Introduction

The combination of matrix pores and fractures determines the storage space type of carbonate reservoirs. Generally the matrix pore development characteristics and the type of pore structure determine the reservoir storage capacity, while fractures serve as both storage space and seepage channels. The degree of fracture development even controls reservoir productivity behavior (Guerriero et al, 2012; Guo et al, 2012; Li et al, 2012; Wang et al, 2011; Xu et al, 2013). The effectiveness of matrix pores is evaluated according to the pore structure by utilizing techniques such as core analysis, optical microscopy, image analysis, scanning electron microscopy, and mercury injection capillary pressure, and NMR T_2 distribution combined with logs (Chekani and Kharrat, 2012; Kim et al, 2011; Kuz'min and Skibitskaya, 2012; Mai and Kantzas, 2007; Marathe et al, 2012; Mohammadlou et al, 2012; Schoenfelder et al, 2008; Tsakiroglou et al, 2009; Westphal et al, 2005).

Fracture evaluation is one of the core tasks in tight carbonate reservoir evaluation (Lamarche et al, 2012). Electric imaging logging cannot only directly show the degree of fracture development and occurrence, but also accurately predict the fracture effectiveness. However, its high cost and thus limited quantity restricts its large-scale application

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