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Factors influencing pore-pressure prediction in complex carbonates based on effective medium theory

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Abstract: A calculation model based on effective medium theory has been developed for predicting elastic properties of dry carbonates with complex pore structures by integrating the Kuster-Toksŏz model with a differential method. All types of pores are simultaneously introduced to the composite during the differential iteration process according to the ratio of their volume fractions. Based on this model, the effects of pore structures on predicted pore-pressure in carbonates were analyzed. Calculation results indicate that cracks with low pore aspect ratios lead to pore-pressure overestimation which results in lost circulation and reservoir damage. However, moldic pores and vugs with high pore aspect ratios lead to pore-pressure underestimation which results in well kick and even blowout. The pore-pressure deviation due to cracks and moldic pores increases with an increase in porosity. For carbonates with complex pore structures, adopting conventional pore-pressure prediction methods and casing program designs will expose the well drilling engineering to high uncertainties. Velocity prediction models considering the influence of pore structure need to be built to improve the reliability and accuracy of pore-pressure prediction in carbonates.

Key words: Carbonates, effective medium theory, elastic properties, pore-pressure prediction, pore structure

1 Introduction

The mechanism of abnormal pore-pressure in carbonates is complicated. It is not the same as the under compaction mechanism of clastic sedimentary rocks. Based on the compaction mechanism, either explicitly or implicitly, the relation of velocity-porosity-effective stress is usually employed to predict the pore-pressure in oil and gas exploration (Dutta, 2002). Although these conventional methods are not appropriate for pore-pressure prediction in carbonates due to abnormal pore-pressure mechanisms, they are still widely used in engineering practice. The accuracy of the velocity-porosity relationship directly affects the reliability of the predicted pore-pressure (Chopra and Huffman, 2006; Gutierrez et al, 2006; Zhang and Wieseneck, 2011).

The elastic wave velocity in underground rocks is an important indicator of abnormal pore-pressure. The velocities in porous rocks are influenced by many factors, such as the mineral composition, porosity, pore fluids, pore structure, effective stress, and temperature (Chen et al, 2009; Wang, 2001). Because of dissolution and dolomitization in the diagenetic process, secondary pores are well developed and the pore structure is extremely complicated in carbonates (Ma et al, 1999). Therefore, an empirical velocity-porosity relationship used for sandstones may lead to a large deviation and even erroneous results when applied for carbonates. Experimental studies indicate that the velocity-porosity relationship of carbonates is scattered due to the complex pore structures of different carbonates (Kenter and Ivanov, 1995; Anselmetti et al, 1997; Wang, 2002; Assefa et al, 2003; Weger, 2006; Verwer et al, 2008). Fig. 1 shows the relationship between P-wave velocity and porosity in carbonates based on logging data from three wells. As can be seen from Fig. 1, the difference of P-wave velocity reaches 3,631 m/s under the same porosity, while the difference in porosity reaches 14.7% with the same P-wave velocity. Eberli et al (2003) pointed out that the pore structure of carbonates is nearly equally important to porosity in their elastic behavior and resultant acoustic velocity. Scatter of velocity-porosity relationships in carbonates increases the uncertainty of pore-pressure prediction using conventional methods, which is the main difficulty in predicting the pore-pressure in carbonates.

The elastic wave velocity is an objective reflection of the rock elasticity. Different pore structures with the same

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