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Sweet spots prediction and quantitative evaluation of gas-bearing shale based on the optimized log interpretation

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Shale gas is one of the most important unconventional oil and gas resources, and its lithology and reservoir type are both different from conventional reservoirs [1]. Sweet spots prediction and quantitative evaluation are extremely important for exploration and production of gas shale. As we known, sweet spots of organic shale include geological sweet spot and engineering sweet spot. Geophysical well logging can provide a lot of in-site information of formation profile [2], and all parameters describing the sweet spots of organic shale are attained by geophysical log interpretation.
Based on geological and petrophysical characteristics of gas shale, the log response characteristics of gas shales are summarized, and the gas shale show high resistivity, extremely high gamma ray, large neutron porosity, slow velocity, low density, and low PE, which are different from conventional sand and shale. Geological sweet spot includes hydrocarbon potential, porosity, fracture, water saturation and total gas content. Firstly, the based-logging hydrocarbon potential evaluation is carried out, and the RBF neural network method is developed to estimate the total organic carbon content (TOC), which was proved more effective and suitable than empirical formula and ΔlogR methods [2]. Next, the log interpretation method of gas-bearing shale is conducted, and the optimized log interpretation is achieved by using model-searching and genetic algorithms, and the mineral concentrations of kerogen, clay, feldspar and pyrite and porosity are calculated. Based on nuclear magnetic resonance (NMR) and other physical experiments of shale cores, NMR log interpretation models are constructed, the porosity, permeability and water saturation are estimated accurately. Fractures are important space and transmission channels of gas. Full borehole imaging (FMI) log can directly display the fractures in organic shale and provide some fracture parameters including fracture porosity, fracture density and fracture opening. When FMI is not available, a new fracture evaluation method based on dual lateral log is developed, and the fracture porosity and opening can also be calculated accurately. On the other hand, engineering sweet spot of shale refers to the rock physical properties and rock mechanism parameters. The rock physics model for organic shale is developed and preferred, and a suitable method for shear wave estimation is determined. So, some elastic properties including volume module, shear modulus and Poisson's ratio are correspondingly determined from log interpretation, and the brittleness index (BI), effective stress and pore pressure are also estimated. BI is one of the most important engineering sweet spot parameters.
A large number of instances show that the summarized log responses of gas shale can accurately identify the gas-bearing shale from the whole formation, and the proposed RBF neural network for TOC prediction has more suitable and flexibility. The mineral contents and porosity from the optimized log interpretation are in good agreement with core XRD experiment and other core experiments. Fracture evaluation based dual laterolog is an alternative without borehole imaging log. In some polite wells of Jiaoshiba area, china, some parameters in Wufeng-Longmaxi formation are predicted and calculated by using above-described logging evaluation method, and geological and engineering sweet spots are finally determined. For the best sweet spot, TOC is about 6%, the porosity is about 8%,the volume of kerogen is about 3%, total gas content is $8m^3/t$, and the brittleness index is about 90%, and the

minimum and maximum horizon stress are about 30MPa and 45 MPa. Therefore, the optimized log interpretation provides an important support for sweet spots prediction and quantitative evaluation of shale gas.

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