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Prediction of Total Organic Carbon Content Based on Geostatistical Inversion: A Case of Qingshankou Formation in Wangfu Depression, Songliao Basin

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Currently, there are two main methods to obtain total organic carbon (TOC) content in mud shale: geochemical analysis and $\Delta\lg R$ model. Geochemical analysis can obtain accurate TOC content, but it has the problem of higher cost and less samples. The $\Delta\lg R$ model can obtain TOC content variable values in well profile conveniently and quickly, but it can't predict TOC content in mud shale in cross-hole area. Both the methods can't meet the needs of resources evaluation of shale oil in the background of strong organic heterogeneous in mud shale.

We propose a new method for predicting TOC content based on the improved $\Delta\lg R$ model and geostatistical inversion. The method combines good lateral resolution of seismic data and high vertical resolution of logging data, and can predict the spatial distribution of TOC in mud shale accurately. It has great practical significance for the exploration of shale oil.

The new method requires to obtain TOC variable values in well profile at first. In the traditional $\Delta\lg R$ model, acoustic travel time and resistivity curves are overlapped together artificially with a fixed overlapping coefficient, then defined the baseline value and background content of TOC to calculate $\Delta\lg R$ and TOC content. The traditional $\Delta\lg R$ model has several deficiencies on applicability, objectivity, convenience from the aspects of baseline value, background content of TOC and overlapping coefficient. Therefore, we improve the $\Delta\lg R$ model based on the theory of the traditional $\Delta\lg R$ model. The improved $\Delta\lg R$ model can select overlapping coefficient automatically, obtain TOC content accurately and rapidly by computer in absence of mature degree parameters, and manual definition of TOC background value.

Haas (1994) proposed geostatistical inversion firstly, and Dubrule (1998) and Rothman (1998) further developed this theory. Its fundamental process is: starting from well

point, the inversion is faithful to logging data at well point and conforms to seismic data in cross-hole area. Geostatistical inversion is generally used to predict the spatial distribution of sandstone and obtains good application effects. Using the geostatistical inversion to calculate TOC content requires to analysis the relationship between p-wave impedance and TOC content in mud shale. Since organic-rich mud shale poses to less density, higher acoustic interval travel time and lower velocity, obviously, p-wave impedance decreases with the increasing of TOC content in mud shale (Fig.1).

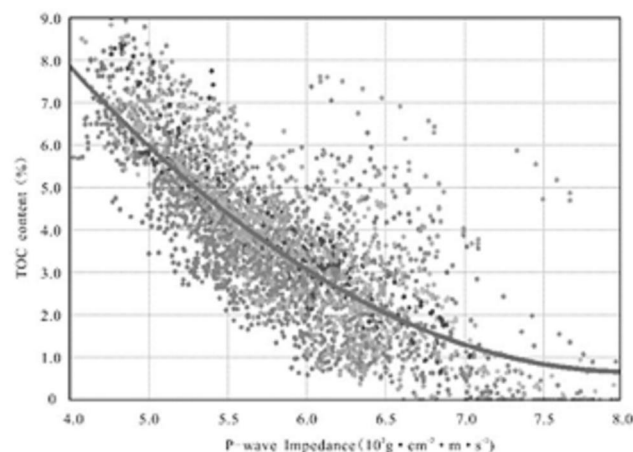


Fig.1 Cross plot P-wave impedance and TOC of Qingshankou Formation in Wangfu Depression, Songliao Basin

Geostatistical inversion of TOC content in mud shale is executed by JASON software (Fig.2). The workflow is as follows: Firstly, obtain the P-wave impedance of formation which reflects the general distribution of mud shale by constrained sparse spike inversion method. Secondly, analysis vertical and horizontal variograms of TOC content, and optimize stochastic inversion parameters, including variable range, nugget effect and sill value. Thirdly, run geostatistical inversion, for getting TOC

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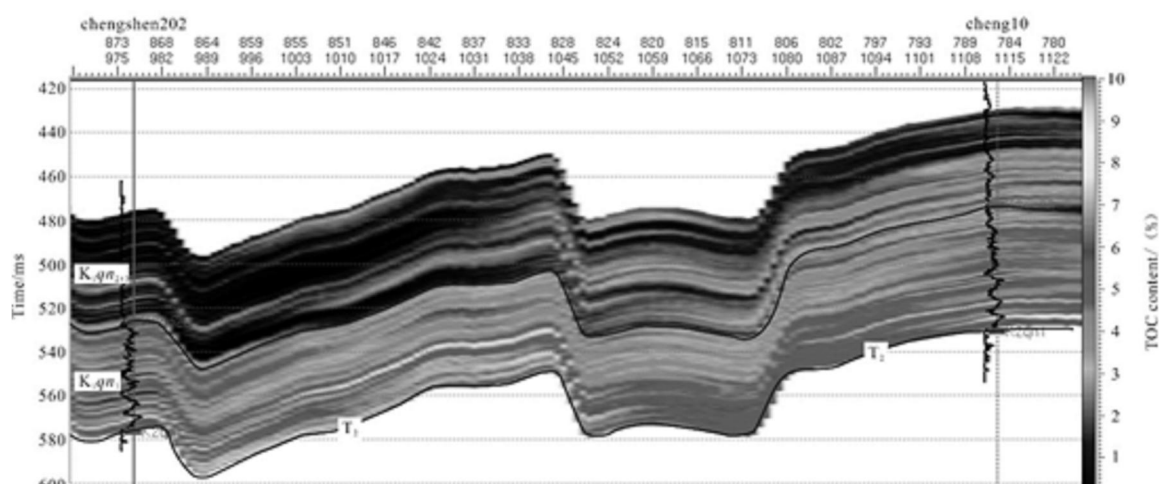


Fig.2 The geostatistical inversion profile of TOC of Qingshankou Formation in Wangfu Depression, Songliao Basin

content data with geological significance, stochastic simulation adopts Gaussian collocated cosimulation and stochastic inversion adopts simulated annealing algorithm. Finally, evaluation of inversion result, it must follow several principles, including calculated TOC consistent with p-wave impedance in geostatistical inversion profile, TOC content in posterior well profile consistent with calculated TOC, geostatistical inversion TOC, the trend of TOC content on the plane consistent with the law of geological deposit.

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