Fluid quantitative evaluation method of two-dimensional NMR logging

A. Li Chenglin[1], B. Tan Maojin[1]
[1]China University of Geosciences Beijing, Beijing, China

Introduction: The nuclear magnetic resonance (NMR) logging technology is widely used in the interpretation and evaluation of reservoirs. When the signal-to-noise ratio (SNR) of the echo data measured on-site of NMR logging is low, the response of the fluid component overlaps in the NMR 2D spectrum [1][2]. The blind source separation (BSS) method is to separate or recover the original source signals from the received mixed signals without knowing the source signals and the mixing parameters, and this method can be used to obtain the 2D spectra of several common fluid components of NMR logging data [3][4][5]. But a single spectrum extracted by BSS method from logging data always contains characteristics of multiple components. Therefore, we proposed a method combining BSS and the hierarchical clustering algorithms. Each 2D spectrum obtained by this method only contains one fluid component by further separation. The fluid types are determined, and the fluid volumes are quantitatively calculated for reservoir evaluation.

Methods: Assuming there are *r* fluid components in a certain stratum, T2-T1 2D spectra of m depth points are collected. The sample number in the 2D spectra is $n = n_1 \times n_2$, where n_1 and n_2 are the sample number of T2 and T1, separately. Let the 2D NMR spectra of the fluid components be $\boldsymbol{S}r\times n$, the collected data be $\boldsymbol{X}m\times n$, and there is a mixing matrix $\boldsymbol{A}m\times r$:

$$\boldsymbol{X}_{m\times n} = \boldsymbol{A}_{m\times r} \cdot \boldsymbol{S}_{r\times n} \quad \text{Eq. 1}$$

The update iteration formulas of the mixed matrix $\boldsymbol{A}$ and the source signal matrix $\boldsymbol{S}$ obtained by the Non-negative Matrix Factorization (NMF) algorithm are as follows:

$$\frac{(XS^T)_{ik}}{(ASS^T)_{ik}} A_{ik} \rightarrow A_{ik}, \frac{(A^TX)_{kj}}{(A^TAS)_{kj}} S_{kj} \rightarrow S_{kj} \quad \text{Eq. 2}$$

Results and discussion: Well A is mainly shale reservoirs, and its 2D NMR logging data are acquired by Schlumberger instrument. The processing results of the spectra of the depth 3470-3610m are shown in Fig. 1, including 8 spectra with a single fluid characteristic, and 6 fluid types are identified. The calculated oil volume (Bound oil and free oil) is compared with the result of pyrolysis experiment, and the former is consistent with the later.

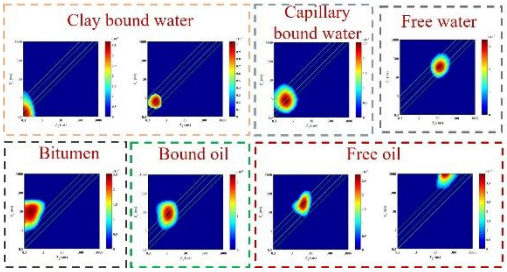

Fig. 1: Separated results by the proposed method

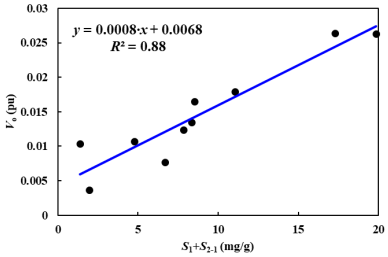

Fig. 2: Cross-plot of experiment and calculated results

Conclusion: A fluid quantitative evaluation method of 2D NMR logging, which could extract the spectra with a single fluid characteristic, was proposed by combining the BSS and hierarchical clustering algorithms. The processing results of well A are consistent with the pyrolysis experiment, indicating that this method is accurate and effective.

References: [1] Coffey, IEEE GRSL. (2019). [2] Fleury, J. Magn. Reson. (2013). [3] Jiang, Comput. Geosci. (2019). [4] Gu, J. Magn. Reson. (2021). [5] Venkataramanan, Petrophysics, (2018).