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RESEARCH NOTE

Lithological Characteristics Analysis of Ridderkerk Area in the Western Netherlands using Wavelet Transform

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ABSTRACT
Various wavelet transform techniques have been used for delineating lithological boundaries and to provide subjective leads for reservoir characterization. A multi-scale analysis of the well log data was performed using both the Continuous Wavelet Transform (CWT) and Discrete Wavelet Transform (DWT) analyses. The gamma ray log was first DWT analyzed using the Haar Wavelet and decomposed 7 times. The discrete coefficients pertaining to the 7th level of decomposition were CWT analyzed using the Haar Wavelet at various scales ranging from 2-10 m, 10-20 m, and 20-100 m and the results of the analysis have been presented. This study demonstrates that Wavelet Transforms can effectively be used for bed boundary detection as a first approximation, as demonstrated through the comparison with the facies log presented. This technique can, therefore, be used cost-effectively in a short time span for valuable resource delineations in Geoexploration.

Key words: Lithological characteristics, wavelet transform, gamma ray log, Ridderkerk, western Netherlands

INTRODUCTION

The accurate identification of lithofacies is of prime importance especially in complex geological environment pertaining to hydrocarbon reservoirs. Conventional core has been used extensively for obtaining detailed information of the well, but recovery of cores is an expensive and exhaustive process. An alternate to this is well log analysis, which is incongruous and interpreter dependent, and can lead to multiple interpretations and inferences. Various wavelet transform techniques have been used for delineating lithological boundaries and to provide subjective leads for reservoir characterization. We have tested disparate wavelet-types on radioactivity logs of wells belonging to the Stratton Field and come up with an innovative approach using Continuous Wavelet Transform (CWT) and Discrete Wavelet Transform (DWT) towards lithological characterization , which are very crucial especially in the exploration of hydrocarbons.

METHODOLOGY

A multiscale analysis of the well log data was performed using CWT and DWT analysis (Perez-Muñoz et al., 2013), which is defined given by Equation 1 and Equation 2.

$$CWT_f(u,s) = \int_{-\alpha}^{\alpha} f(x)\psi_{u,s}(x)dx = \frac{1}{\sqrt{|s|}}\int_{-\alpha}^{\alpha} f(x)\psi\left(\frac{x-u}{s}\right) dx \quad \text{..... (1)}$$

$$DWT_f(m,n) = \int_{-\alpha}^{\alpha} f(x)\psi_{m,n}(x)dx \quad \text{............ (2)}$$

Here f(x) represents the well log data, $\psi_{m,n}(x)$represents the mother wavelet, while u and s represent the translation and scale parameters. The scale parameter varies inversely with frequency while the translation parameter shifts the mother wavelet and analyses various components of the signal. The well log data was analysed under various scales to study the variation of high and low frequency components of the dataset. The CWT and DWT coefficients are together called the scalogram variation, which denote the frequency localization at various scales and depths. It is commonly represented as a colour scale, signifying the variation in magnitudes of the wavelet coefficients. Low pass and high pass filters are generally necessary when evaluating the DWT and are represented by Equations 3, 4, 5 and 6 (Mallet, 1989).

$$\Phi_{j,k}(n) = 2^{j/2}\,\Phi(2^j n-k) \quad \text{...............(3)}$$

$$\psi_{j,k}(n) = 2^{j/2}\,\psi(2^j n-k) \quad \text{...............(4)}$$

$$W_\Phi[j,k] = \frac{1}{\sqrt{N}}\,\Sigma_n\, f[n]\,\Phi_{j,k}[n] \quad \text{...............(5)}$$

$$W_\psi[j,k] = \frac{1}{\sqrt{N}}\,\Sigma_n\, f[n]\,\psi_{j,k}[n] \quad \text{...............(6)}$$

Here W_Φ represents the detail coefficients given by the high pass filter, and W_ψ approximation coefficients given by the low pass filter, which is the average signal. They are passed onto the next level and again resolved into detail and approximation coefficients, respectively. At each level the frequency is halved while the number of input samples remains the same.

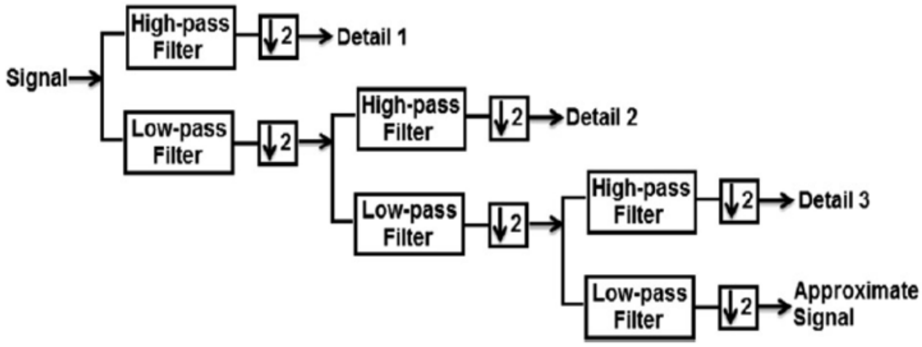

Figure 1. Block diagram for decomposition into three levels of a signal

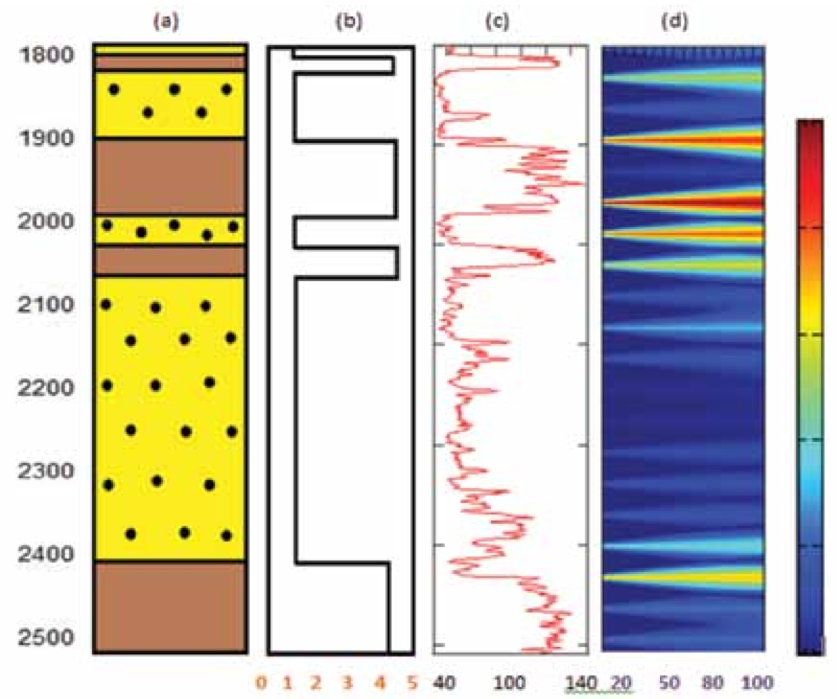

Figure 2 . (a) Facies log representation of the given well (1800-2500) m depth.**(b)** Mathematical representation of eFA,**(c)** Given gamma ray response and **(d)**eFA (20-100) m scales**.**

Analysis of Well logs

The Ridderkerk Field is situated in the western Netherlands, in the province of South Holland.Structures in the upper Jurassic Delfland subgroup are generally rather strongly faulted and IntraDelfland shale seals are typically thin. While these shales are considered to be effective as top seals, most traps at this level also rely on favourable cross fault juxtaposition. The gamma ray log was first DWT analysed using the Haar Wavelet and decomposed 7 times. The discrete coefficients pertaining to the 7th level of decomposition were CWT analysed using the Haar Wavelet at various scales ranging from 20-100 m and the results of the analysis are presented in Figure 2. Other wavelets like Symlet, Morlet, Gaussian, and Coiflets, were also tried but the best results for obtaining stratigraphic formation interfaces was obtained using the Haar Wavelet (Alvaraz et al., 2003).

RESULTS

The lithological characterization of the well is given by Figure 2(a). The lithological units maintain clear distinct electrofacies association with each other for the sand and the shale series. The mathematical representation of eFA is shown in Figure 2(b). The gamma ray log is represented in Figure 2(c). The low energy red pattern represented in Figure 2(d) represents shale layers, while the high energy blue patterns give sand units.

DISCUSSION AND CONCLUSION

The Haar wavelet is capable of detecting the abrupt changes in the well log signal, with high energy depositional sequences represented by lower scales and at the same time low frequency components represented by high scales of the signal associated with facies changes. The variations in the depositionary sequences suggest the variations in depositionary energy. The smaller scales (<30) detect the presence of high energy sedimentary deposits, while the high scales (60-100) detect low energy deposits, like shale. The CWT analysis was performed with the d7 detail coefficients, as it corresponded with the largest number of facies association that was found in the region as was inferred from the facies log. Each decomposition corresponds to dyadic decimation, in terms of increase of powers of 2. The study demonstrates that wavelet transforms can effectively be used for bed boundary detection as a first approximation, as demonstrated through the comparison with the facies log presented.

This method can prove to be very effective as it can help us save valuable time and also resources during exploration by not having to take core samples from every well. It is sufficient to have core samples from one well and use them to verify the results.

Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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