Journal of Applied Geophysics 101 (2014) 116–123

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

Predicting the distribution of reservoirs by combining variable wavelet model of seismograms with wavelet edge analysis and modeling

Yujiang Xie [a,*], Gao Liu [a,b]

[a] School of Civil Engineering and Mechanics, Lanzhou University, Lanzhou 730000 China
[b] Key Laboratory of Mechanics on Disaster and Environment in Western China, Ministry of Education of China, Lanzhou University, Lanzhou 730000 China

ARTICLE INFO

Article history:
Received 2 September 2012
Accepted 10 December 2013
Available online 19 December 2013

Keywords:
Reservoir simulation
Acoustic impedance inversion
Wavelet edge analysis
Simulated annealing
Seismic data
Enhancing resolution

ABSTRACT

Reservoir prediction with its unique role in oil and gas fields is constantly facing new challenges, such as high-resolution seismic data and fast-accurate impedance inversion are needed. Generally, conventional methods used to enhance the resolution of seismic data, for example the spectral whitening, sometimes called balancing or broadening, is hard to yield valuable results as the seismic wavelets change during traveling subsurface. Besides, impedance inversion used in reservoir such as acoustic impedance inversion (AII) also confronts problem—low computational efficiency when more geological and geophysical parameters are taken into consideration in the modeling inversion. Based on these questions, in this study, a joint approach is presented. The first approach is the variable wavelet model of seismograms (VWMS), which is carried out by a series of processes such as time partition and frequency domain processing, to enhance the resolution of the seismic traces. Another approach that can improve the computational efficiency of the AII is the acoustic impedance inversion based wavelet edge analysis and modeling (AII-WEAM). In this approach, the algorithms of the AII were replaced by the modified very fast simulated annealing (MVFSA), to improve the inversed speed. By using a gas reservoir predicting example, we show that the joint approaches produce results that are feasible and reliable after comparing with the well data. Hence, these joint approaches have great potential to be the next-generation tools for reservoir description and prediction.

1. Introduction

With reservoir complexity increasing in oil and gas fields, processing and interpretation of seismic data are facing new challenges, such as more accurate and finer delineations of structure and lithology are required (e.g., Gao et al., 2009). Commonly used methods to enhance the vertical resolution of seismic traces include deconvolution, broadband constrained inversion and spectral-whitening, which are based on conventional convolution model and several basic assumptions (e.g., Gao et al., 2009; Yilmaz, 1987). However, the seismic traces usually do not fit this model when the seismic wavelet change during traveling subsurface, which requires new models delineating wave propagation more accurately and improving the resolution of seismic traces more effectually (e.g., Gao et al., 2009).

In reservoir prediction, seismic impedance inversion for reservoir is needed after acquiring the seismic traces with high resolution (e.g., Bosch et al., 2010; Francis and Syed, 2001; Madiba and McMechan, 2003; Xie and Liu, 2013; Xie et al., 2012). However, conventional acoustic impedance inversion (AII) related to complex reservoir calculation is confronting with the low computational efficiency, especially in predicting the complex reservoir where more geological and geophysical parameters have to be considered (e.g., Xie and Liu, 2013; Xie et al., 2012). The low computational efficiency of the AII is mainly caused by its limited algorithms, such as the very fast simulated annealing (VFSA) (e.g., Xie and Liu, 2013; Xie et al., 2012). Hence, a new algorithm that can speed up the computational efficiency of the AII should be taken into consideration.

In this study, we present a joint approach to address the aforementioned issues facing in reservoir prediction domain. Briefly, it uses the VWMS to enhance the resolution of the seismic data and then utilize the AII-WEAM to compute the values of acoustic impedance that are useful for predicting the reservoir.

2. Methods

2.1. VWMS

The VWMS—a method improving the resolution of seismic traces by using a variable wavelet model (e.g., Gao et al., 2009; Ziolkowski, 1991), was presented by Ziolkowski considering the seismic wavelets change during traveling subsurface. In the VWMS, non-stationary seismic signal is first being partitioned appropriately into several stationary segments in the time domain and then each segment is being processed in the frequency domain. Simply, it can be summarized here.

2.1.1. Time partition

The seismic signal is divided into proper segments by Gabor molecule-windows produced adaptive to the signal, where each segments are regarded stationary, and then transform it into the

* Corresponding author.

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http://dx.doi.org/10.1016/j.jappgeo.2013.12.005

Gabor domain. Suppose that there are L molecule windows that divide the seismogram into L segments that are partially overlapping each other. Let M^{j-1} and M^j denote the sequence number for the start and end points of the jth segments. And when $g^j(t)$ denotes the jth molecule window, then the corresponding Gabor slice is

$$s_j(t) = s(t)g^j(t) \tag{1}$$

where $s(t)$ represents the seismic record, and $s_j(t)$ represents the jth segment of $s(t)$.

For partitioning the seismic record into L segments, there is needed function of partition called Gabor transform (e.g., Gröchenig, 2000). In Gabor transform, we adopt the partition of unity to generate the Gabor frames. A partition of unity is a collection $\psi_j{:}j \in Z$ of function that sums to 1 shown as

$$\sum_{j\in Z} \psi_j(x) = 1, \forall_x \in R. \tag{2}$$

According to Eq. (1), we can get the original seismogram as Eq. (3). It means that the L molecule windows completed the partition of the signal.

$$s(t) = \sum_{j=1}^{L} s_j(t). \tag{3}$$

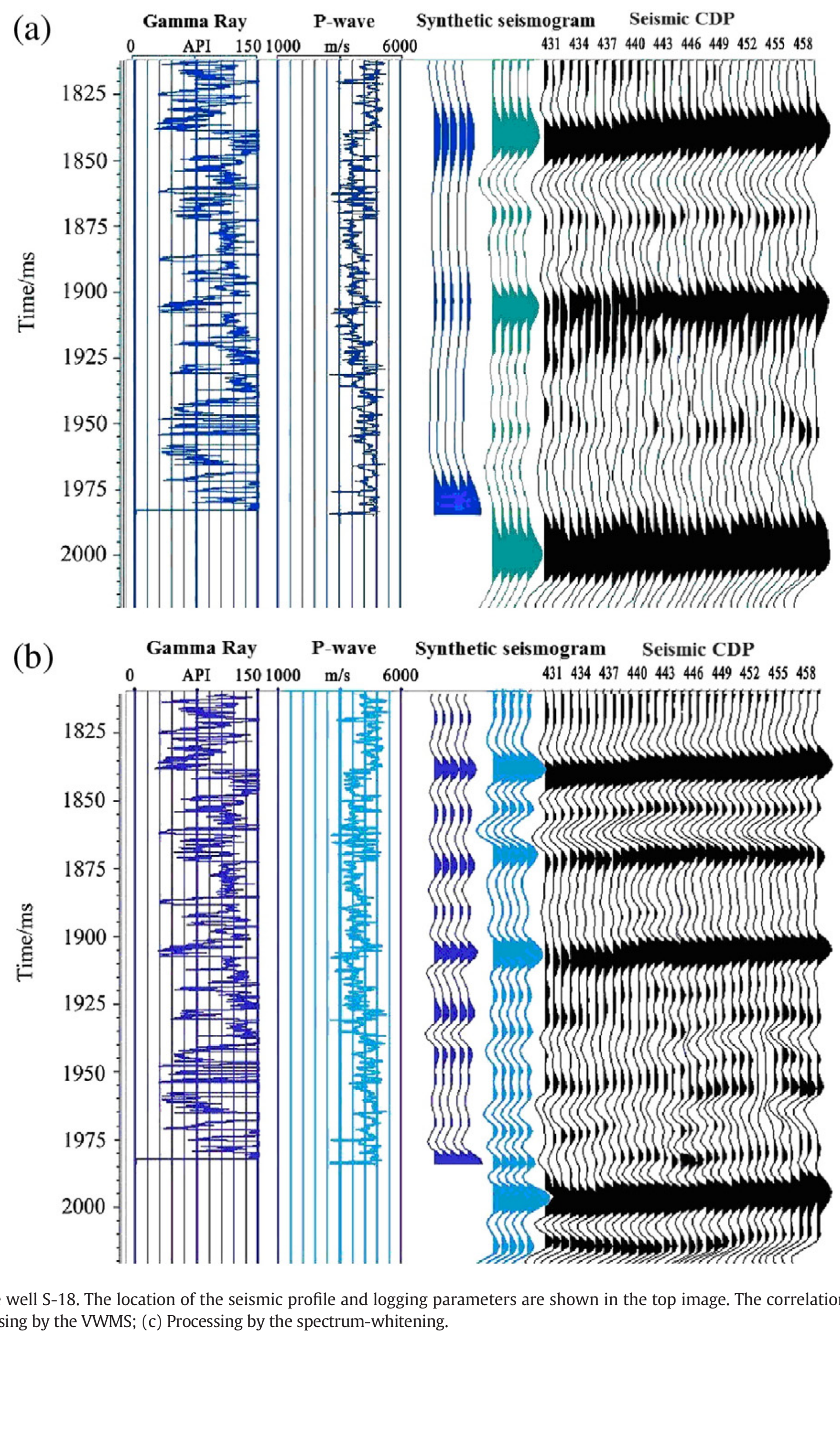

Fig. 1. Seismic-to-well tie at the well S-18. The location of the seismic profile and logging parameters are shown in the top image. The correlation coefficient is 0.91 in the image. (a) Untreated results; (b) Processing by the VWMS; (c) Processing by the spectrum-whitening.