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Integrating seismic attributes in the accurate modeling of geological structures and determining the storage of the gas reservoir in Gorgan Plain (North of Iran)

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ABSTRACT

Three dimensional seismic operation of Gorgan Plain was studied around a well, which is situated in North of Iran following the hitting of a thin overpressure gas layer (thickness of 9.6 m), with the purpose of the accurate modeling of geological structures and determining the approximate gas storages. The geological structures of the reservoir were modeled using the seismic attributes (coherence, instantaneous amplitude and spectral decomposition (FFT)). The obtained results clearly demonstrated the shape and volume of the existing structural traps in the studied area. In order to estimate the thickness of gas layer in the 3D seismic volume and determining the gas storage, the thickness changes based on the seismic amplitudes were used because its thickness was less than the critical resolution thickness for this layer. However, due to its low thickness, the lack of indicator peak in seismic sections and strong faults of area, it was difficult to pursue this layer in the seismic volume and map its exact amplitude. Considering this issue, a new method with integrating of seismic attributes was recommended. First, the instantaneous amplitude attribute of the thin reservoir layer reflector in computed synthetic seismogram were fabricated and then the frequency regarding the highest amount (dominant frequency) was chosen by Fourier Transform. Finally, spectral decomposition (FFT) with the resulting frequency was gained over the cross-section of the layer's instantaneous amplitude attribute in the 3D seismic volume choosing a proper time window. In such a situation, an increase of its thickness was seen as its amplitude increase and the minimum gas storage of this reservoir was calculated using the area of the restricted part of high thickness (over 9.6 m).

1. Introduction

This article is an example of how to implement and integrate seismic attributes in 3D seismic data (post stack) and one well to determine geological structures (structural traps) and the approximate estimation of the existing gas in a gas reservoir (Gorgan Plain). The attributes used for this purpose include 1. coherence, 2. instantaneous amplitude, and 3. spectral decomposition, Fast Fourier Transform (FFT).

1- coherence attribute is the best determiner of anticline structures, faults, deltas, river channels, dikes and other stratigraphic anomalies (Bahorich and Farmer, 1995; Gersztenkorn et al., 1999; Marfurt et al., 1998). In fact, this method calculates the similarity between the seismic traces. 2- instantaneous amplitude is gained by finding quadrature trace from Hilbert transform of actual trace and the calculation of numerical amount of seismic trace which resulted from these two traces (Taner, 1977) and is directly related to acoustic impedance differences (Taner, 2000) (Fig. 1). 3- spectral decomposition (FFT) is calculated by Fourier Transform of traces from time domain into frequency domain and countering the amplitude magnitudes in concerning frequency bands (Partyka et al., 1999). For instance, the red seismic trace in Fig. 2 changes to a trace with amplitude-frequency functions through Fourier Transforms (from time domain to frequency domain). Then, Fourier Transform all the traces are given in a time window and subsequently the frequency cross-sections of the spectral decomposition attribute is achieved. The results gained from this attribute can be considered in the accurate interpretation of layer thickness, demonstrating thin layers and determining the exact anomalies of the amplitudes (Bahorich et al., 2002; Hall and Trouillot, 2004). Each of these attributes contains a particular function and determination of geological structures and hydrocarbon potentials. Therefore, by integrating these, some significant results could be achieved.

In order to determine the gas storage of the reservoir in 3D seismic volume, a relevant thickness modeling of gas layer is needed. Nevertheless, in conditions where the layer thickness is less than its critical resolution thickness it is impossible to estimate thickness of the layer accurately, because for the reflections from the upper and lower surfaces of the layer form one reflector (Widess, 1973). In this

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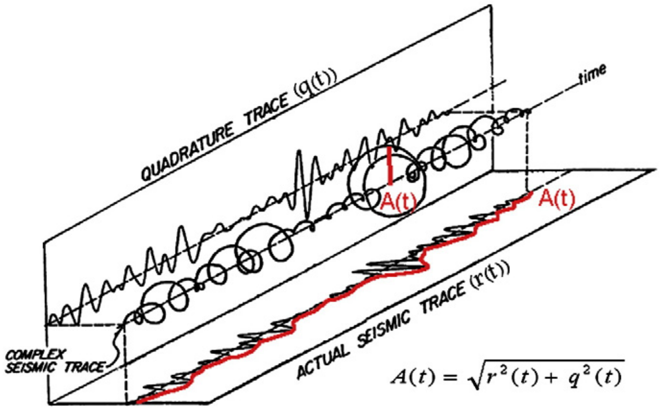

Fig. 1. The method of obtaining the instantaneous amplitude attribute, quadrature trace (q(t)) through Hilbert transform of the real seismic trace (r(t)) which is later achieved and instantaneous amplitude attribute (A(t)) by calculating the numerical amount of the seismic traces is obtained (Taner, 1977).

condition, the increasing model of layer thickness based on seismic amplitude increase should be taken into account (Neidell and Poggiagliolmi, 1977) and so an approximate estimation of layer thickness could be achieved (the increase of the thickness up to tuning thickness is increased and later decreased). For this purpose, the amplitude changes of the reservoir layer can be mapped by following the layer in the 3D seismic volume and calculating the amplitude instantaneously. However, the reservoir layer contains no index peak in its seismic section because of the low thickness and the area is badly filled with faults, therefore it is impossible to follow the layer and map the accurate amplitude magnitudes in the 3D seismic volume with the usual methods. In the present article, a new method of integrating the attributes has been provided.

2. Gorgan Plain

Gorgan Plain is located in north of Iran and south east of the Caspian Sea (Fig. 3). The most important construction in the region called Chelekan, belongs to the Paleocene Period that is mostly formed of green or dark red sand-containing marls together with somehow thick layers of sandstone and conglomerate. This construction is often watery, contains hydrocarbon (mostly gas layers) and is among the inner layer sand masses. Most of the gas collections are inside Chelekan construction and near mud volcano of the region. Most of these mud volcanos have not reached the surface and a few of them like GARNIARIK TEPPE mud volcano have outcrop on the ground. About 10 wells were dug from which the well Go-3 hit an over pressure gas sand layer near GARNIARIK TEPPE mud volcano and burnt. Thus, the other well Go-3A was dug in a distance 300 m from this well (Fig. 3). This well also hit Chelekan construction. The thickness of this layer was calculated to be 9.6 m with a capacity of 200,000 m^3 extractable gas per day. Following this, a 3D seismic operation with the area of nearly 160 km^2 were carried out around the well Go-3A and GARNIARIK TEPPE mud volcano. The 3D seismic area has 17,575 m length and 8975 m width (number of in line 200 to 560 and cross line 200 to 909) (Fig. 3). In this article, the geological structure modeling of Chelekan construction and the estimation of the minimum extractable gas from well Go-3A is carried out by integrating seismic attributes.

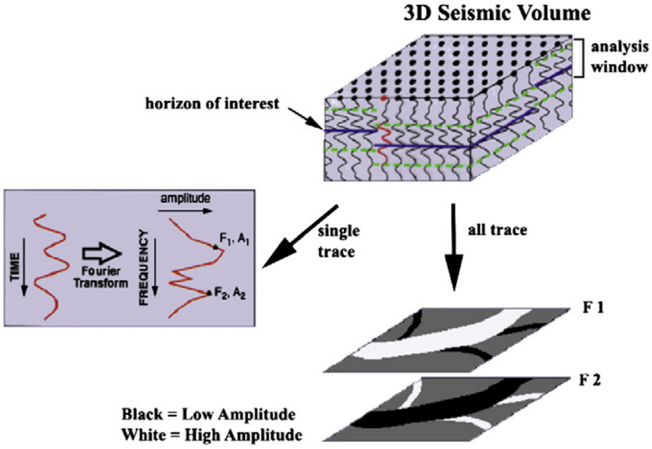

Fig. 2. The method of obtaining spectral decomposition attribute.

3. Methodology

Before the reservoir has been modeled, it is necessary to model the geological structures particularly structural traps (mud volcano and faults) in the reservoir. Regarding to this purpose, the cross-sectional coherence and five instantaneous amplitude of attribute having vertical cross-sections used on the interpreted structures. In addition, the frequency bands of spectral decomposition attribute were implemented to form and develop it laterally.

In order to estimate the thickness of gas layer in the 3D seismic volume, synthetic seismogram of the well (Go-3A) in this region was built by choosing the best wavelet and having high correlation with seismic data, and the index of critical resolution thickness for the gas layer was calculated. Finally, it was found out that the thickness of this layer is less than the critical resolution thickness. Under such circumstances, thickness changes could be implemented based on seismic amplitudes as a criterion to determine the partial thickness of the gas layer in the 3D seismic volume (Neidell and Poggiagliolmi, 1977). It is impossible to follow the layer and map the accurate amplitude magnitudes in the 3D seismic volume with the usual methods because of the low thickness, the reservoir layer contain any index peak in seismic section, and the area is badly filled with faults.

In terms of mentioned problem, the instantaneous amplitude attribute of the reflector were achieved through the upper and lower surface of synthetic seismogram in the thin reservoir layer. So, the layer mentioned appeared as one peak. Therefore, using Fourier Transform (Bracewell, 1965) of the instantaneous amplitude magnitude, the dominant frequency (frequency of the highest amplitude) of the layer easily achieved. By having the frequency of the instantaneous amplitude peak in the layer, instantaneous amplitude in the 3D seismic volume is first calculated and then output amplitude magnitudes of the spectral decomposition is calculated in terms of prior achieved frequency (Rezvandehy, 2006). Therefore, the accurate changes of the seismic amplitudes in the mentioned layer are achieved in the 3D seismic volume that could be a sign of some partial changes in the thickness (thickness increases with the increase of the amplitude). The instantaneous amplitude was used because this attribute does not depend on seismic phase and is directly related to acoustic impedance differences and negative amounts of seismic traces is omitted. Moreover, the changes of seismic amplitudes are obtained between zero and maximum amounts, so computing dominant frequency for the gas layer would be more straightforward.

4. Modeling of geological structures

4.1. Coherence and instantaneous amplitude attributes

In this region, the upper part of Chelekan construction has more significance than its lower part (Tertiary–Mesozoic unconformity). Therefore, the investigations would be mostly about the upper part of Chelekan construction. Fig. 4 shows the coherence attribute cross-section from Chelekan top in the well Go-3A (time slice 1052 ms). The high coherence is shown in white and the low one is shown in black.