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Seismic Attribute Analysis for Reservoir Characterization

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Summary

Seismic attributes can be important qualitative and quantitative predictors of reservoir properties and geometries when correctly used in reservoir characterization studies. Seismic attributes reveal information, which are not readily apparent in the raw seismic data. While the ultimate goal of reservoir characterization is to identify reservoir, delineate the pay zone and determine the distribution of their relevant properties such as thickness, porosity and lithology.

This paper discusses the seismic attribute and reservoir characterization analysis for the data from F3 block in the Dutch sector of the North Sea. Instantaneous amplitude attribute is computed which confirms the bright spot due to the presence of gas in the reservoir. Next, the thickness information is estimated from the spectral decomposition. To determine the porosity in the reservoir zone, the cross plot analysis is carried out using the well log data. The porosity log data derived from the well log with different seismic attributes was plotted to establish a linear regression relationship which is then used to get the porosity. From the seismic attribute studies and well log analysis the estimated thickness of the reservoir zone is about 12.2 m and the porosity in the reservoir zone varies from 28-32 %.

Keywords*: Seismic attribute, Reservoir characterization, Thickness and Porosity*

Introduction

Seismic attributes have been increasingly used in both exploration and reservoir characterization studies and routinely been integrated in the seismic interpretation processes (Partyka et al., 1999). There are different classes of seismic attributes based upon the nature of estimation and property of the reservoir they reveal. For estimation of seismic attributes any of the following can be used as input: a single seismic trace, a set of pre-stack CMP or CRP gathers or the entire seismic volume (Partyka, 2001; Liu and Marfurt, 2006).

The principle objective of the attributes analysis is to provide accurate and detailed information to the interpreter on structural, stratigraphic and lithological parameters of the reservoir. In our current study, the attribute analysis is estimated to characterize the reservoir in terms of porosity and thickness of the hydrocarbon bearing zone. The instantaneous amplitude attribute is calculated to confirm the presence of bright spot suggestive of presence of gas in the reservoir zone. Next, the cross plot and spectral decomposition analysis is performed to estimate the porosity and thickness of the reservoir zone. For the cross plot analysis, the porosity data is provided by dGBEarthSciences from the well F-304 present in the survey area F3 block in the Dutch sector of the North Sea.

Methodology

There are different techniques for estimation of different seismic attributes. The instantaneous amplitude attribute to locate the reservoir (gas bearing zone) is calculated. This is achieved through complex trace attribute analysis as explained by Taner et al. (1979). In this method, a seismic trace is considered as a complex trace having real and quadrature component. Real part is the actual seismic trace recorded.

Next, the thickness is estimated following the spectral decomposition analysis in the reservoir zone to get the dominant frequency in that zone. The studies performed by Partyka et al. (1999), Partyka(2001), and Liu and

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Marfurt(2006) demonstrate the effectiveness of spectral decomposition using the discrete Fourier transform (DFT) as a thickness estimation tool. In thickness mapping there is an inverse relation between the dominant frequency and the thickness of the target zone. Dominant frequency characterizes the thickness of the bed and the amplitude is known to be maximum at the tuning thickness estimated from the dominant frequency (Partyka et al., 1999). Thus, spectral decomposition can reveal and map seismic features as a function of spatial position, travel time, frequency, amplitude and phase and help us to visualize, interpret and quantify the seismic response to an extent that was previously unattainable (Partyka et al., 1999).

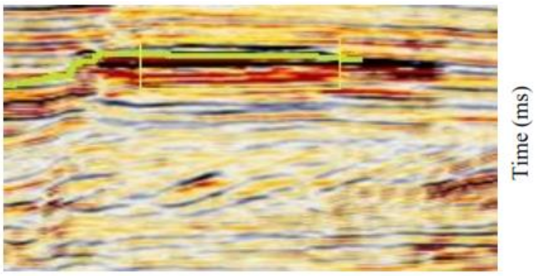


Fig 1: Seismic section containing the reservoir zone along inline 228. The reservoir is calculated to be at the depth of about 520 ms and is highlighted with a yellow rectangle. Horizon H1 is marked with green color.

For Porosity estimation the crossplot analysis was performed using well data located in the survey area. The porosity log data derived from the well log with different seismic attributes was plotted to establish a linear regression relationship. This regression relation was used throughout the survey area to get the porosity in the reservoir zone.

Case Study

The case study analyses the post-stack time migrated 3D seismic data provided by dGBEarthSciences through Opendtect share seismic data repository. Data is originally collected from the F3 block in the Dutch sector of the North Sea. The seismic data is accompanied with only one well F-304 data in the region. A horizon H1 along the seismic inline 228 is picked for the analysis (Fig-1). The section contains a bright spot at about 520ms possibly due to the presence of biogenic gas packet. Bright spot is clearly visible in the seismic section which is indicated with a yellow rectangle. The instantaneous attribute is computed using Opendtect software which verifies this bright spot in the section. Fig-2 shows the instantaneous amplitude attribute along the inline 228 and the horizon H1 passing through the bright spot zone. Both the above attributes clearly show the bright spot zone.

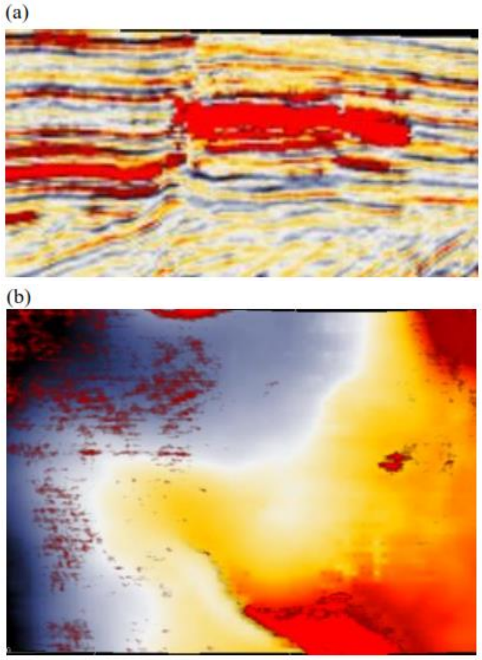


Fig 2: Instantaneous amplitude attribute along (a) inline 228 and (b) horizon H1 showing the bright spot

For the estimation of thickness of the zone, the spectral decomposition analysis is performed along the inline 228 at different point of intersections with seven cross lines. Since the thickness of the layer is inversely proportional to the dominant frequency, the spectral analysis helps to obtain the dominant frequency in the reservoir zone. Fig-3 shows the spectral decomposition (amplitude vs frequency plot) performed at seven points in the reservoir zone which are intersection points of inline 228 and cross lines 1010,1016,1022,1028,1034,1040 and 1046.

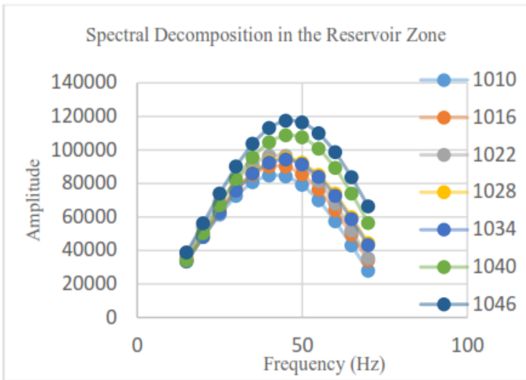


Fig 3: Spectral decomposition (FFT) plot of amplitude vs frequency calculated at different points of intersection of inline 228 and cross lines: 1010, 1016, 1022, 1028, 1034,1040 and 1046.

Fig-3 shows the maximum amplitude occurring at 40-45 Hz which is the dominant frequency in the reservoir zone. A P wave velocity (v) of about 2200 m/s is assumed because of non-availability of the well derived velocity information in the reservoir zone. From the relation of frequency (f) with velocity (v) and wavelength (λ) we have:

$$v = f\lambda$$

$$\lambda = \frac{v}{f} = \frac{2200}{45} = 48.88\ m\ ;$$

Hence, the tuning thickness is

$$\frac{\lambda}{4} = \frac{48.88}{4} = 12.22\ m\ .$$

Thus from the above analysis the thickness of the reservoir zone is approximately 12.22 m.

It is well known that a shadow frequency zone below a gas reservoir is common; therefore a spectral decomposition analysis is performed below the reservoir zone as well to detect this shadow zone. Fig-4 shows the result from the spectral decomposition. The dominant frequency in this case is between 25-30 Hz. This indicates lowering-off the frequencies due to the presence of gas pocket in there servoir zone, confirming the shadow frequency zone.

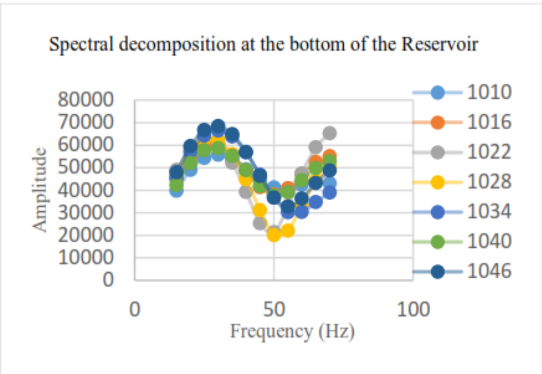


Fig 4: Spectral decomposition analysis immediate below the reservoir zone for different frequencies at different points of intersection of inline 228 and cross lines (1010,1016,1022,1028,1034,1040 and 1046).

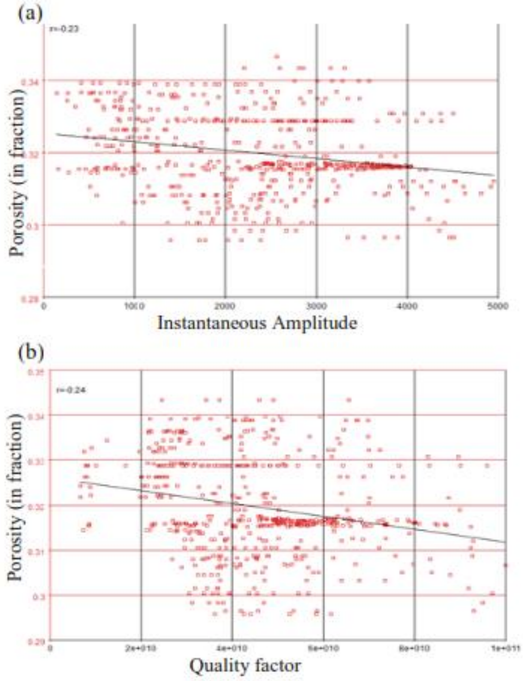
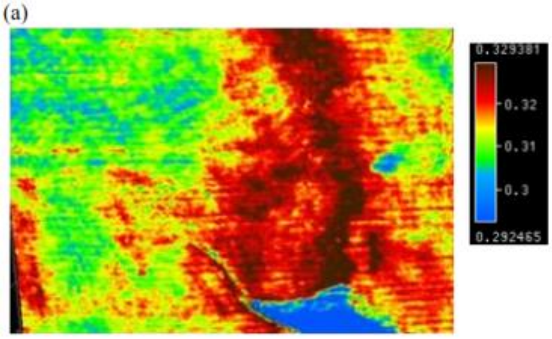


Fig 5: Crossplots of porosity and (a) instantaneous amplitude (b) quality factor.

The porosity is estimated from the crossplot analysis between instantaneous amplitude attribute and the porosity log derived from the well location. The porosity log data gives the porosity at the well location to be 25% - 35%.

From the crossplots shown in Fig-5, a linear regression fit between porosity data and the seismic attribute is estimated. This porosity obtained from the regression relation is extrapolated throughout the reservoir. Fig-6 shows the distribution of porosity in the reservoir zone.

(a)



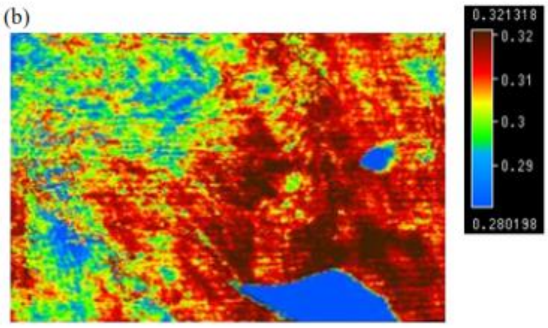


Fig 6: Distribution of porosity (a) using relation established between porosity and instantaneous amplitude, (b) using relation between porosity and quality factor.

Conclusions and Discussions

In this study the seismic attributes computed from seismic sections and analyses of well log data were utilized to characterize the reservoir. Both the qualitative as well as the quantitative characterization of the reservoir were done. The qualitative study includes the identification of the bright spot indicating the presence of biogenic gas packet in the reservoir zone. However to confirm this gas pocket the quantitative analysis was done and the thickness of the reservoir zone was estimated to be 12.22 m which was within the seismic resolution limit. The spatial variation of porosity was also estimated along the horizon H1 passing through the reservoir using the relationship established between seismic attribute (instantaneous amplitude) and the porosity derived from well log. The porosity value in the reservoir zone varies between 28% - 33 % suggesting a good porous reservoir. This result can be further improved with the availability of data from more wells in the F3 block near the reservoir zone and with the use of stochastic inversion and neural network to enhance the predicted value of porosity.

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