Evaluation of Continuous Wavelet Transform (CWT) Attribute in Analysis of Gas Reservoir Distribution on Talang Akar Reservoir in “QDR” Field of Northwest Java Basin

M N Qodri\textsuperscript{1}, M C Mulyani\textsuperscript{2}, A W Kaisagara\textsuperscript{2}, S Sukmono\textsuperscript{3} and D S Ambarsari\textsuperscript{3}

\textsuperscript{1}Department of Geophysical Engineering, Faculty of Mining and Petroleum Engineering, Bandung Institute of Technology, Jl. Ganesha10, Bandung 40132, West Java
\textsuperscript{2}Pertamina EP ASSET 3 Cirebon
\textsuperscript{3}Exploration and Engineering Seismology Group, Faculty of Mining and Petroleum Engineering, Bandung Institute of Technology, Jl. Ganesha10, Bandung 40132, West Java

E-mail: nazarqodri@yahoo.co.id

Abstract. The presence of seismic data as a non-stationary signal is a challenge to be processed with good resolution. Frequency value that change with increasing time make processing in the time domain no longer able to be used optimally, so that a tool is needed to be able to change the domain into the frequency domain. Spectral decomposition with continuous wavelet transform (CWT) method is one of the tools that can be used. The window width used by the CWT method can be applied flexibly with wavelets contained in seismic data and become superior compared to the short time fourier transform (STFT) method. The "QDR" research location in the Talang Akar Formation has a reservoir with a target zone in the form of thin layers (below the thickness of tuning). The purpose of this study was to evaluate how well the CWT method was in mapping the distribution of gas reservoirs at the study areas. The wavelet used in the CWT analysis is a selected Mexican Hat wavelet from two other wavelets (Morlet and Gaussisian). The interpretation stage is done by combining CWT maps with log data and TAF 3 and TAF3.2 structural maps. The presence of a gas reservoir can be seen in the CWT section for a frequency of 60 Hz after being validated with log data for the QDR-02 and QDR-04 wells. The frequency value will affect the thickness of the reservoir, the thicker the frequency value will be lower. The distribution of amplitude values for some frequency values at the study location tends to be randomly distributed. So that the CWT method is not good enough to map the distribution of the reservoir in the "QDR" field.

Keywords: continuous wavelet transform, Talang Akar Formation, log, reservoir, frequency
1. Introduction
Seismic data, naturally, is a non-stationary signal where the frequency value that is owned will change with time. Various methods have been studied to create high resolution in the signal analysis, including using spectral decomposition.

The principle used in this spectral decomposition is to do discrete fourier transforms from seismic data to obtain the frequency spectrum (Partyka et al., 1999). There are 2 types of methods that can be used, namely STFT (Short Time Fourier Transform) and CWT (Continuous Wavelet Transform). In this study the author uses the CWT method, because it has the advantage that the width of the window used can be applied flexibly to the input seismic data used. In addition, CWT also has the advantage of being able to know the spread of thin reservoirs that are not well resolved in time and depth domains.

The use of CWT can also separate various characteristics at various scales displayed in a single time-frequency section / map. This section can be used to characterize reservoirs associated with low frequencies. The target zone used in this layer is the Talang Akar Formation in the North West Java Basin. Another advantage of using the CWT method is that it can be applied to thin layers such as those found in the Talang Akar Formation.

In this study, an evaluation of the CWT method used was carried out. How good is the method in analyzing reservoir distribution at the research location.

2. Theory
The theory is divided into 2 parts, continuous wavelet transform attribute and geological setting.

2.1 Continuous Wavelet Transform
Continuous Wavelet Transform (CWT) method was modified as alternative way to solve a resolution problem from STFT. The advantage of this CWT method is the width of the window which can change with changes made to each spectral component. The equations used in CWT are as follows:

\[
\text{CWT}_\psi(\tau, s) = \psi^*_\psi(\tau, s) = \frac{1}{\sqrt{s}} \int x(t)\psi^\ast\left(\frac{t-\tau}{s}\right)dt
\]

Where, \( \tau \) = translation
\( s \) = scale
\( \psi^\ast(t) \) = mother wavelet

Depends on the equation above, it can be seen that CWT method is a function of 2 variables, namely \( \tau \) as a function of translation and \( s \) as scale. \( \psi^\ast(t) \) is mother wavelet which derived from transformation function.

2.2 Geological Setting
In this study, the target formation is the Talang Akar Formation shown by the black box in Figure 1. The Talang Akar Formation was deposited in the second syn-rift phase in an inconsistent manner over the Jatibarang Formation. This formation is formed when volcanic activity has decreased so that the area tends to be stable, but the Ciputat Sub-Basin is still active. In the Early Miocene, water inundated the mainland except the Tangerang Heights from northwest-southeast. The product produced is a clastic height called Talang Akar Formation. This formation has a lithology in the form of carbonatan flakes with intercalations of sandstone, siltstone, coal, and conglomerates below and changes to batipih and limestone intervals at the top of the formation (Arpandi dan Padmosukismo, 1975).
3. Methodology
The main goal of this research is to evaluate the continuous wavelet transform (CWT) method in the analysis of gas reservoir distribution. The flowchart used is as follows (Figure 2).

![Figure 2. Research/study workflow](image-url)
Seismic data used was the data 3D Post Stack Time Migration that is the result of the acquisition in 2010 and processed in 2015. The 3D PSTM data was analyzed using Paradigm and Opendtect software for varying inline (1761-2304) and crossline (7095-7760). In the study, the writer used 9 wells, named QDR.

Seismic horizon TAF3 and TAF3.1 marking the horizon that were picked to create the structure map for time and depth domain. This was done by identifying continuous reflection events and picking peaks for TAF3 and zerocross for TAF3.2 along the cross line for every crossline and inline in the seismic volume (Figure 3).

![Figure 3. Seismic section across "QDR" field, with horizon TAF3 (blue) and TAF3.2 (green)](image)

Continuous Wavelet Transform (CWT) method was processed using Opendtect software application. This application transforms the time amplitude PSTM volume to amplitude frequency volume based on Mexican Hat wavelet through a time varying analysis window on each seismic trace in the seismic volume. Depends on recovery data, gas reservoir indication can be found in horizon TAF3 at QDR-02 well for 60Hz frequency. Data slices of 20 Hz to 70 Hz frequency maps were extracted along the TAF3 seismic horizon and analyzed for possible hydrocarbon distribution in study area.

4. Result and Discussion

4.1 Log Analysis

Log analysis was done using qualitative method, by comparing 3 kinds of log, gamma ray, resistivity, neutron porosity, and density. From the Figure 4, green circle indicates the reservoir zone, that contain low value of Gamma Ray, high value of resistivity (LLD>>, and cross over from neutron porosity and density.
4.2 Tuning Thickness Calculation
Tuning thickness analysis is done to see the resolution of the seismic data used. Tuning thickness calculation (2) is carried out using dominant frequency data and average speed in each well (3) (Brown, 2011).

\[ D \text{ (tuning thickness)} = \frac{\lambda}{4} \]  

\[ \lambda = \frac{V_{avg}}{f} \]  

Where,  
\( \lambda \) = wavelength (m)  
\( V_{avg} \) = average speed (m / s)  
\( f \) = dominant frequency in the target area (Hz)

Based on the amplitude spectrum analysis, the dominant frequency of the study location is 25Hz (Figure 5).

```
Figure 5. Dominant frequency from study area
```
The results of tuning thickness calculation for each well can be seen in Table 1. Based on the results of these calculations it can be seen that all wells can be resolved well, but the thickness of the target reservoir in the target zone is smaller than the thickness of the tuning.

Table 1. Tuning thickness calculation

| Well  | Frequency (Hz) | Velocity (m/s) | \( \lambda \) (m) | Tuning Thickness \((\lambda/4)\) | Target Zone Thickness (m) | Reservoir Target Thickness (m) |
|-------|----------------|----------------|------------------|-------------------------------|---------------------------|-------------------------------|
| QDR-01 | 25             | 3820,2         | 152,8096        | 38,2024                       | 60,65                    | 20                            |
| QDR-02 | 25             | 3734,2         | 149,368         | 37,342                        | 48,21                    | 15                            |
| QDR-03 | 25             | 3839,57        | 153,5828        | 38,3957                       | 55,34                    | 5                             |
| QDR-04 | 25             | 3545,86        | 141,8344        | 35,4586                       | 52,65                    | 5                             |
| QDR-05 | 25             | 3908,2         | 156,328         | 39,082                        | 42,33                    | 5                             |
| QDR-06 | 25             | 3846,7         | 153,868         | 38,467                        | 46,04                    | 10                            |
| QDR-07 | 25             | 3911,01        | 156,4404        | 39,1101                       | 84,85                    | 20                            |
| QDR-09 | 25             | 3645,6         | -               | -                             | 42,11                    | 5                             |
| QDR-10 | 25             | 3658,3         | 145,824         | 36,456                        | 41,95                    | 7,5                           |
| QDR-11 | 25             | 3884,55        | 146,332         | 36,583                        | 42,4                     | 10                            |

4.3 Structure Map

Time structure map was obtained after several steps, which is picking fault and horizon. Picking fault and horizon was done in every 10 ms interval for inline and crossline. Figure 6 shows that there is high structures in the middle of study area and lower strucutre at northeastern part of study area. The major fault is orientated north-south and scattered in the middle of study area.

Figure 6. Time structure map for TAF3 (left) and TAF3.2 (right) horizon

4.4 CWT Analysis

The well used in determining the frequency is the well of QDR-02 based on data recovery with frequency value 60 Hz. Based on crossline and inline section in Figure 7, gas reservoir zone can be determined by green circle. The determination of this zone is based on log data for QDR-02 well.
After getting the frequency value, then TAF3 horizon slice is performed for several frequency values to see the distribution of the reservoir. Figure 8 shows that gas reservoir distribution scattered in study area and can not be interpreted and associated with time structure map. CWT method just only can determined the presence of gas hydrocarbon for recovery well.

Figure 7. 60 Hz frequency map of TAF3 horizon (left) and inline & crossline section (right) for QDR-02 well

Figure 8. Single time frequency-time section for TAF3 horizon
5. Conclusion

(1) Reservoir target thickness is thinner than tuning thickness, so based on the theory tuning thickness can dissolve the thickness of gas reservoir

(2) Gas reservoir can be determined using QDR-02 well that has recovery data for TAF3 horizon. Reservoir zone is obtained from log data analysis

(3) High structure can be found in the middle part and lower structure can be found in northeastern part of study area

(4) CWT method can determines the presence of gas hydrocarbon for QDR-02 well, but it does not give a good resolution to maps the gas reservoir along study area

Reference

[1] Arpandi, D. dan Patmosukismo, S. (1975): The Cibulakan Formation as One of the Most Prospective Stratigraphic Units in the Northwest Java Basinal Area, IPA Proceeding, Vol 4th Annual Convention, Jakarta.

[2] Brown, A. R. (2011): Interpretation of Three-Dimensional Seismic Data, Seventh Edition: AAPG Memoir 42, 7th Edition/SEG Investigation in Geophysics, No. 9.

[3] Partyka, G., Gridley, J. dan Lopez, J., (1999): Interpretation applications of spectral decomposition in reservoir characterization, The Leading Edge, March, pp.353-360.