Early Miocene Carbonate “G-0” Distribution Analysis Using Spectral Inversion

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Abstract. “KHM” structure is one of PT. Pertamina EP oil producing field in Subang, North West Java Basin. One of the hydrocarbon producers of this structure is located in thin bedded Early Miocene carbonate reservoir which in Upper Cibulakan Formation. The thin bedded reservoir becomes a challenge because the post stack time migration seismic resolution can’t resolve the each layer. To distinguish and delineates the reservoir’s lateral continuity needed spectral decomposition analysis. This analysis obtained 3 best frequencies to acquire a better imaging which known as tuning cube, they are 15 Hz, 20 Hz, and 25 Hz. Furthermore, these frequencies were blended to get spectral decomposition volume. The volumes have same frequency and amplitude with post stack time migration seismic data, so it can be used for further interpretation. To predict the distribution and depositional facies of Early Miocene carbonate, performed seismic interpretation by using model based acoustic impedance inversion on spectral decomposition volume and porosity analysis. The result of this study suggest the lateral distribution of Early Miocene carbonate can be characterized. Acoustic impedance zone that associated with porous carbonate have ranges values of 8050 – 9800 gr/cc m/. This is supported by petrophysics analysis that generates porosity values of 7.4 – 13.9 % in this zone. The relationship of both analysis based on the correlation of well, known that porous carbonate was deposited on a shelf margin facies.

Keywords: Spectral decomposition; acoustic impedance inversion; facies

1. Introduction
“KHM” structure is one of PT. PERTAMINA EP oil producing field in Subang, North West Java Basin. Based on Regional Geology, it lies at Pamanukan High formed as result of bed rock lifting with a North-South orientation and it is part of Pasir Putih Sub-Basin system. This high is surrounded by fault system which separates Kepuh Low at West and Cipunegara Low at East [1].

Hydrocarbon producer of this structure is located in Zone G of Upper Cibulakan Formation that formed in Early Miocene with dominant lithology is sandstone, shale and limestone [2]. Based on correlation well of KHM-02-11-01-15-03-13-06 (Figure 1), this zone divides into four reservoirs that
having a relatively thin thickness: limestone G0 (5 meters), sandstone G (5 meters), sandstone G1 (8 meters) and limestone G2 (7 meters). From production data on KHM-15 wells, limestone reservoir G0 produces 171.7 billion barrel of oil, this is the reason for doing reservoirs characterization analysis on this reservoir.

Figure 1. Well correlation KHM-02-11-01-15-03-13-06 Zone-G

3D post stack time migration (PSTM) seismic data resolution can't resolve the thin bedded reservoir on Zone G (Figure 2). Spectral decomposition attribute is applied to converting seismic data into spectral component so that the stratigraphic features can be seen clearly. Then the interpretation proceeds by inversion of acoustic impedance on the spectral decomposition volume. The result of this research is conceptual geological model built from acoustic impedance volume. Acoustic impedance inversion can shows carbonate characteristic that associated with porosity of reservoir. Then, association between acoustic impedance, porosity from petrophysics, and well correlation used for creating a conceptual geological model of carbonate build up that refers to Bubb & Hatlelid concept (1976) [3].

Figure 2. Seismic section Post Stack Time Migration
2. Methodology
2.1. Spectral Decomposition Attribute
Spectral decomposition is a method that describes seismic data into spectral components so that can reveal stratigraphic features and structure where this features is not clearly visible on seismic data. By converting seismic data into frequency domain, amplitude spectrum will delineate thickness of layer in time domain, while the phase spectrum will indicate lateral discontinuity. Spectrum is the size of the amplitude distribution and phase for each frequency [4]. The type of spectral decomposition that used is multiple volume with frequency range of 5-50 Hz.

2.2. Acoustic Impedance Inversion
Acoustic impedance inversion is process to get back reflection coefficient value from seismic record that will used to determine quantitative rock property such as acoustic impedance value. Inversion method that used for this study is model based method. It needs an early impedance model (initial model) from well log data, which are velocity log and density log [5, 6]. Parameters used for inversion in this research are background value 2776.8 gr/cc . m/s, 40% model weight and 40x iteration in inversion process.

3. Results and Discussion
Figure 3 is tuning cube from frequency of 5 Hz into 50 Hz of the result spectral decomposition analysis. From some tuning cube are selected best frequencies that describe thin bedded layer on the research area. At the frequency of 5 Hz and 10 Hz seen the value of amplitude is too strong so the reflector is too large. Neither is the frequency above 25 Hz seen the amplitude is getting down so the display of reflector is too small. [7]. The result of frequency sorting is taken three best frequency there are 15 Hz, 20 Hz, and 25 Hz. Frequency sorting is also controlled by the dominant frequency value in post stack time migration seismic data (Figure 4a).

Figure 3. Tuning cube from frequency of 5 Hz - 50 Hz
Figure 5 is section of spectral decomposition volume from frequency blending for 15 Hz, 20 Hz and 25 Hz. This section shows that reflector is getting sharper and the continuity on interest area more clearly so interpretation on the top layer becomes easier. Furthermore, is performed comparison between volume of frequency spectrum analysis with post stack time migration seismic volume. Figure 4b shows spectrum similarity between both volume, so the spectral decomposition volume is feasible to used for acoustic impedance inversion due to it doesn't change the information from post stack time migration seismic data but the results is better [8].

Figure 4. Frequency spectrum comparison; a) seismic volume post stack time migration spectrum; b) spectrum of seismic spectral decomposition volume blend 15 Hz, 20 Hz, 25 Hz

Acoustic impedance inversion volume is used to G0-carbonate reservoir characterization analysis (Figure 6). The crossplot between acoustic impedance log with gamma ray log, G0-carbonate have higher acoustic impedance value than shale and sandstone with cut off on 8050 g/cc. m/s. (Figure 7). In the foot wall area in depth 1950-1980 meters is clearly indicated by the distribution of very high acoustic impedance value (> 9800 gr/cc. m/s) that associated with tight carbonate. This area is interpreted as carbonate platform of G0 carbonate growth. While above of platform (depth 1850-1950 meters) has low acoustic impedance value (<9800 gr/cc. m/s) that associated with porous carbonate. To acquire the lateral acoustic impedance value distribution pattern on G0-carbonate, is performed slicing with window width of 10 ms along the top horizon Go (Figure 8). The results slicing of acoustic impedance is used to interpret the facies from depositional environment of build up carbonate.

Figure 5. Seismic section of spectral decomposition blend 15 Hz, 20 Hz, 25 Hz
that adjusted with porosity value of each well. Distribution of low acoustic impedance value are distribute evenly in the low area so that interpreted as open marine facies (Figure 8b).

Figure 6. The results of acoustic impedance shows that low acoustic impedance value (green) associated with porous carbonate, while high acoustic impedance value (orange-red) associated with tight carbonate at the foot wall high area

Figure 7. Crossplot between acoustic impedance log and gamma ray log using effective porosity log as color scale.
At the top structure of G0-carbonate have low acoustic impedance value <9800 gr/cc. m/s that interpreted as porous carbonate. The petrophysics results show that KHM-13, KHM-14, and KHM-15 wells lies at the top of build up carbonate each have porosity of 7.9%, 7.4%, and 8.3%. While the KHM-06, KHM-07, and KHM-11 that lies in the carbonate flank area has a relatively higher porosity value there are 13.7%, 12.7%, and 13.9% (Figure 8a, 8b). In the carbonate flank area, porosity value is influenced by existence of fault structure that cause secondary porosity at this area. Dissolved carbonate at the top build up has eroded so that part having good porosity value has been transported to the carbonate flank area. In addition, existence of dolomite minerals also affect the size of porosity value [9]. KHM-06, KHM-07, and KHM 11 wells contain more dolomite minerals than KHM-13, KHM-14, and KHM 15 wells so that porosity value is higher as it is presented in the Table 1.

**Table 1.** Abundance of dolomite volume and porosity from petrophysical analysis

| Well   | Vol. Dolomite (%) | Porosity (%) |
|--------|-------------------|--------------|
| KHM-03 | 2.9               | 7.7          |
| KHM-06 | 16.7              | 13.7         |
| KHM-07 | 17.0              | 12.76        |
| KHM-11 | 16.4              | 13.9         |
| KHM-13 | 6.5               | 7.9          |
| KHM-14 | 7.6               | 7.4          |
| KHM-15 | 7.6               | 8.3          |

**Figure 8.** Feature on RMS extract acoustic impedance with window10 ms ; a) slice acoustic impedance with porosity value ; b) slice acoustic impedance overlay depth structure map
Finally, interpretation result using distribution of acoustic impedance value and porosity, conceptual geological model built for describing true geological condition in this research area (Figure 9). Acoustic impedance value distribution supported by porosity data from petrophysical analysis and well correlation. Acoustic impedance zone with value of <9800 gr/cc.m/s has porosity value of 7.4% - 13.9% associated with shelf margin facies. While the very high acoustic impedance zone (> 9800 gr/cc. m/s) interpreted as platform of G0-carbonate. This is adjusted for well correlation which form a build up pattern when performed flattening at the bottom of G-zone (Figure 1). Conceptual geological model refers to carbonate build up conceptual geological model belongs to Bubb & Hatlelid (1976) [3].

4. Conclusions
Spectral decomposition analysis gives a better result to delineate thin bedded layer on G-zone. Acoustic impedance inversion can be performed on spectral decomposition volume due to has same frequency and amplitude spectrum with post stack time migration seismic volume. The reservoir characteristic of Early Miocene carbonate can be generated by acoustic impedance value. Porous carbonate (7.4% - 13.9 %) associated with shelf margin facies is indicated by low acoustic impedance value (< 9800 gr/cc. m/s) at depth of 1850 – 1890 meters. While at depth 1950 –

Figure 9. Some feature to determine facies and depositional environment analysis: a) feature on RMS extract acoustic impedance with window 10 ms; b) the conceptual model Early Miocene carbonate “G-0”; c) the conceptual model carbonate build up from Bubb & Hatlelid (1976) [3]
1980 meters interpreted as a platform carbonate because it is tight character that indicated by high acoustic impedance value (> 9800 gr/cc. m/s).

A conceptual geological model of Early Miocene G0-carbonate can be built from acoustic impedance distribution, porosity value from petrophysical analysis and well correlation. Platform and shelf margin facies generated from high acoustic impedance value distribution based on well correlation and porosity analysis, while low acoustic impedance zone associated with open marine facies.

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