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Identification of Reservoir Thickness and Estimation of Hydrocarbon Reservation used the Pre-Stack Depth Migration (PSDM) in Cikung Area

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Abstract
Information from the geological data shows that the Cikung field has the complex structure which is characterized by carbonate reef. Therefore, it is required in the domain depth migration (PSDM) using interval velocity model is sensitive to variations in vertical and horizontal velocity to identify the thickness of the reservoir and estimation of hydrocarbon reserves. Stages include making the depth structure maps, map making the thickness of the reservoir, and the calculation of hydrocarbon reserves. The results showed that the thickness of the reservoir in Cikung Field, estimated to range from 71 meters to 175 meters with the prospect reservoir is at a depth of 1216 meters to 1247 meters from the surface. Hydrocarbon deposits (oil) is estimated at $1{,}134 \times 10^6\ STB$ or $1{,}311 \times 10^8$ kilo litre by the porosity of 22.6% and 70.7% water saturation.

Keywords: *reservoir, hydrocarbon, Pre-stack Depth Migration*

1. Introduction

1.1 Sub Introduction

The existence of a complex structure, in this case there is a change in speed in the high lateral direction requires a separate technique in seismic data processing. Commonly the used technique in seismic exploration is pre-stack depth migration (PSDM). Pre-stack time migration (PSTM) is less appropriate to process seismic data with lateral velocity variations [1]. In the migration process with the Kirchhoff migration technique produces subsurface imaging on the possibility of a more continuous reflector [2].

In Figure 1 illustrates the failure of the time migration method in moving the reflector position on the seismic data tape to the actual subsurface position, when the lateral velocity is constant has resulting in a hyperbola-shaped travel time curve with its peak at the below of the geophone datum. At the time of migration the hyperbola curve is summed toward the hyperbola peak (Fig. 1b). If there is a lateral velocity variation then the travel time curve does not form a hyperbola. In Figure 1c, the lateral velocity is not constant or varied due to the overburden structure such as carbonate reef or salt dome, the formed hyperbola peak shifts its position to the datum geophone recorder position on the x axis (Fig. 1d). This distortion causes the migration time was not suitable in the areas with high lateral velocity variations due to the occurrence of deflection bending (ray bending) at the boundaries of the layers. This light beam causes the wave propagation time to be non-hyperbolic, so that its amplitude and travel time are not appropriate if conventional CMP stacking is used, this assumption is based on the hyperbolic curve. If a conventional CMP stacking is still used, the stack will be further away from the ideal zero offset section [3].

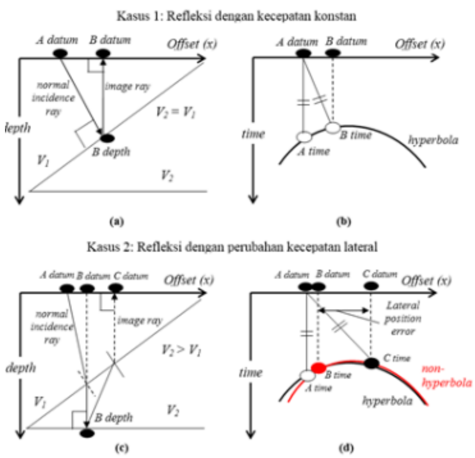

Fig 1. (a) The reflection occurring at a medium with a constant lateral velocity, (b) the travel time curve of figure (a) with its peak just beneath the receiving geophone (datum B), (c) the reflection occurring in the medium with lateral velocity changes, (D) any errors in peak position time that are no longer directly under the receiving geophone.

Determination of velocity model in depth domain can use tomographic inversion of normal wave incident kinematic incident point from CRS process, then migration to depth domain [4]. The results of the CRS stack method can be useful as an initial data source to determine the potential of existing natural resources beneath the surface [5]. According to the seismic cross section with complex geology and / or the presence of large lateral velocity variations present in the seismic data of a migratory time stack of an area can be overcome by making accurate speed models.

According to [7] the determination of petro-physical parameters using the logging method is performed to obtain the subsurface geological data quickly and accurately. Distribution of petro-physical parameters is used to find the areas that indicate good hydrocarbon accumulation. The resulting maps are porosity maps, permeability maps, and water saturation maps [8]. According to [9] hydrocarbon reserves can be calculated by volumetric methods using physical quantities and Net to gross obtained from petro-physical analyzes as well as seismic interpretations to obtain the area of hydrocarbons. The parameters are used to calculate the hydrocarbon reserves using the original oil in place (OOIP) equation.

Information from geological data shows that in the field of Cikung have a complex structure, this is marked by the reef carbonate. In a complex structure such as this will cause a high variation of lateral velocity. The existence of lateral velocity variations caused the ray bending when crossing the boundaries of the layers so that the wave propagation time becomes not hyperbolic. The high lateral velocity variation in the Cikung field causes migration in the time domain, commonly known as PSTM, using the inaccurate RMS speed model used because it is only sensitive to vertical speed variations only. Therefore, migration is required in the depth domain (PSDM) by using interval speed models that are sensitive to vertical or horizontal velocity variations. PSDM results can be used to identify reservoir thickness and hydrocarbon reserve estimates.

2. The Research method

2.1 Creating the top MMC and bottom MMC depth structure map

Initial stage to create the isopach map (thickness in depth domain) is picking on layer or formation that allegedly as reservoir. In this study, the estimated layer as reservoir is Mid Main Carbonates (MMC). The MMC layer consists of two parts of the top MMC (top) which is at a depth of 916 meters and MMC bottom (bottom) which is at a depth of 1219 meters. Picking is done on each layer so that obtained two picking result that is picking MMC top and picking MMC bottom (Figure 2). Each of these picking is then gridded so as to produce a map of the top MMC depth structure and map of the MMC bottom depth structure. The next process is editing the two maps, which include the process: filtering, smoothing, and extrapolating. The final stage, both maps are made in the form of 3D models using 3D model builder. Figure 3 shows a map of the depth structure of the top MMC layer and bottom MMC that has been created 3D model.

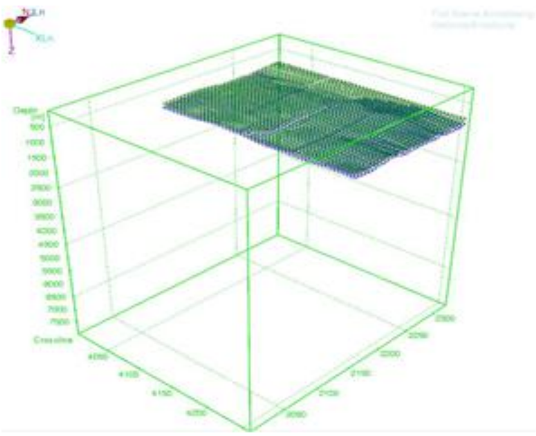

Figure 2. The results of the top MMC picking horizon (green) and the bottom MMC (blue) on the last section of PSDM.

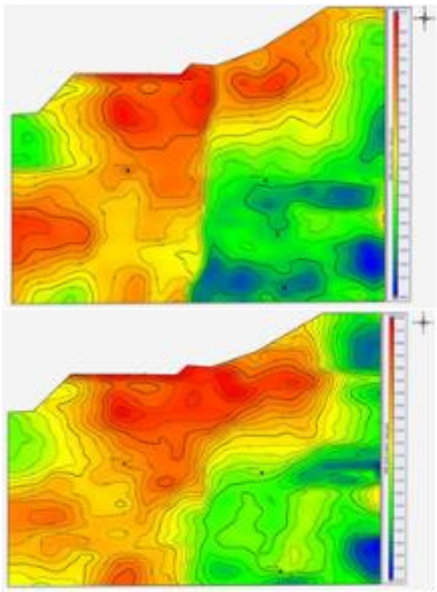

Figure 3. The depth structure map of top and bottom MMC has been resulting of picking horizon of the PSDM section by the contour interval as well as 10.

2.2 Creating of the reservoir thickness map

The final result of the picking and gridding process of the upper and lower formation of the MMC layer is the map of the 3D model depth structure of the top MMC model and the bottom MMC, as an input to create a reservoir thickness map known as the isopach map, which is then contoured. The isopach map is the distribution of reservoir thickness in the depth domain (units of meters or feet) (Figure 6).

2.3 Calculating the reserve Hydrocarbon

The initial stage in determining the hydrocarbon reserves is to calculate the physical properties (petrophysics) of the identified reservoir such as porosity, water saturation, shale volume, and bulk volume of the reservoir. Log data that has been "pasted" with depth map will be the basis in this calculation, the log data is log density, log resistivity, log gamma ray (GR), and log neutron. The well that becomes the benchmark is the well of 1 because it is contained in the reservoir area that is suspected to contain hydrocarbons.

2.3.1 Calculating the porosity value of Neutron Density (ϕ_D)

The neutron density porosity has been calculated by calculating the density log and the neutron log. It has been known that the rock matrix density as well as $\boldsymbol{\rho_{ma} = 2,71}$, the rock bulk density as well as $\boldsymbol{\rho_b = 2,6715}$, $\boldsymbol{\rho_f = 1,1}$ (using the salt mud) and $\boldsymbol{\phi_N = 0,479}$, so the porosity value could be:

$$\phi_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} = \frac{2,71 - 2,6715}{2,71 - 1,1} = 0,0239 \quad (1)$$

$$\phi_{DN} = \sqrt{\frac{{\phi_D}^2 + {\phi_N}^2}{2}} = \sqrt{\frac{(0,0239)^2 + (0,479)^2}{2}} = 0,339 \quad (2)$$

So the reservoir porosity as well as 33.9 %, could be categorized by very well.

2.3.2 Calculating the volume shale (V_{sh})

The value of gamma ray log as well as $GR_{log} = 35, GR_{min} = 26, GR_{max} = 53,$ so it is obtained that:

$$\phi_D = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} = \frac{35 - 26}{53 - 26} = \frac{9}{27} = 0,333 \quad (3)$$

Therefore, the reservoir volume shale as well as 33,33%.

2.3.3 Calculating the porosity effectiveness (ϕ)

According to the calculation result, the neutron density porosity has been obtained by $\phi_{DN} = 3.339$ and that volume as well as $V_{sh} = 0.48$, therefore the effective porosity value as follows as the below:

$$\phi = \phi_D \times (1 - V_{sh})$$

$$\phi = 0.339 \times (1 - 0.333)$$

$$\phi = 0.226 \quad (4)$$

Therefore the effective porosity or reservoir porosity has the value as 22.6%.

2.3.4 Calculating the water saturation value (S_w)

The value of $\boldsymbol{a} = \mathbf{1}$ on limestone, $\boldsymbol{\phi} = \boldsymbol{\phi_{DN}} = \mathbf{0,339}$, and $\boldsymbol{m} = \mathbf{2}$ on limestone, therefore by applied all of the parameter to the Asquith equation, can be obtained:

$$F = \frac{a}{\phi^m} = \frac{1}{(0,339)^2} = 8,702 \quad (5)$$

According to the log data and the value of $R_t = 1,7$, so:

$$R_W = \frac{R_t}{2F} = \frac{2,7}{8,702} = 0,0975 \quad (6)$$

Therefore the water saturation value was:

$$S_w = \sqrt{\frac{F \ x \ R_W}{R_t}} = \sqrt{\frac{8,702 \ x \ 0,0975}{1,7}} = 0,706 \quad (7)$$

Therefore the reservoir water saturation value which was suspected contained by hydrocarbon as well as 70.6%.

2.3.5 Calculating Bulk Volume (V_b)

Determination of the wide in contour area can be done manually by using millimeter paper, in Figure 4. According to the manual calculation can be obtained:

$A_n = 80 \ kotak \ x \ 0,0625 \ cm^2 = 5,000 \ cm^2$ (in map)

$= 945.178,40 \ m^2$ = 233.558 acre (actual wide)

$A_{n+1} = 31 \ kotak \ x \ 0,0625 \ cm^2 = 1,938 \ cm^2$ (in map)

$= 366.256,63 \ m^2$ = 90,503 acre (actual wide)

Therefore, the ratio between the bottom wide area and top wide area of isopach map is:

$$Rasio = \frac{A_{n+1}}{A_n} = \frac{366.256,63 \ m^2}{945.178,40 \ m^2} = 0.388 \quad (8)$$

Which is the ratio value as well as 0.388, so the calculation of volume bulk use the approach of pyramidal method, it is caused by $\frac{A_{n+1}}{A_n} < 0,5$. Since the value of $h = 5 \ meter = 16,405 \ feet$

$$V_b = \frac{h}{3}\left[A_n + A_{n+1} + \sqrt{A_n A_{n+1}}\right] \quad (9)$$

$$V_b = \frac{16,405}{3}\left[233,558 + 90,503 + \sqrt{233,558 \ \mathrm{x} \ 90,503}\right] \quad (10)$$

$$V_b = 2.567,104 \ acre.ft$$

So, the reservoir volume which was contained by hydrocarbon as well as 2.567,104 $acre.ft$.

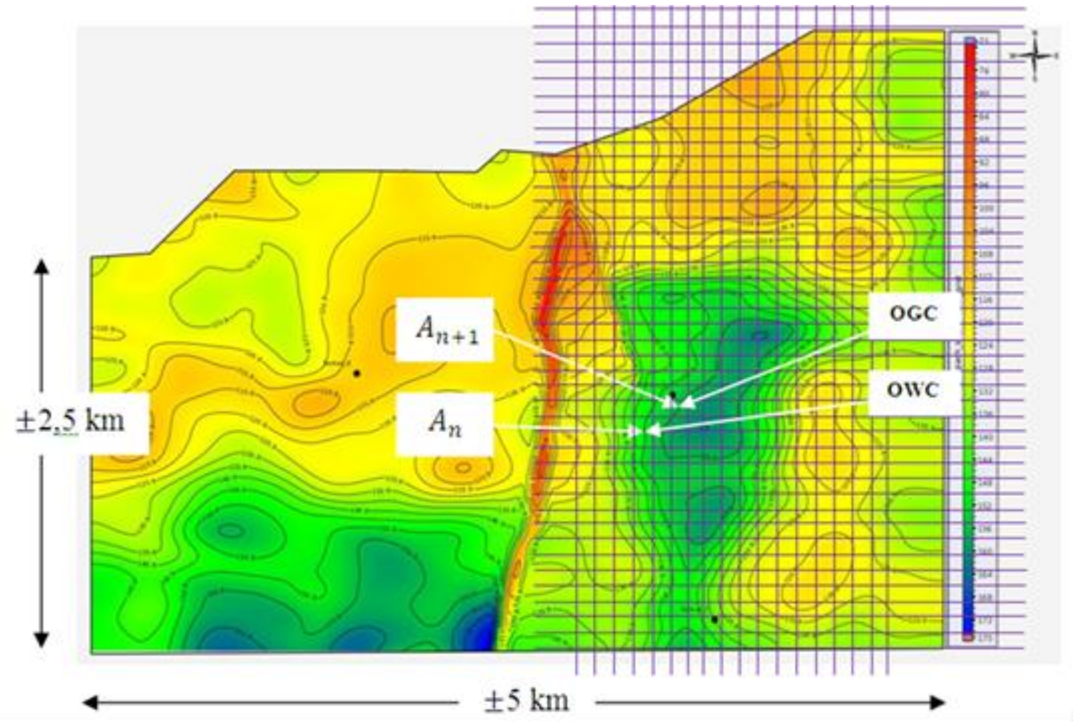

Figure 4 creating the grid to calculate the wide of reservoir contour area to the isopach map by 1 box indicate the value as well as 0.0625 cm^2 (map) or 11.814,73 m^2 in actual.

2.3.6 Perhitungan cadangan dengan metode volumetric

Perhitungan cadangan menggunakan metode volumetric IOIP, jika diketahui $\boldsymbol{V_b = 2.567,104\ acre.ft}$, $\boldsymbol{\phi = 0,226}$, dan $\boldsymbol{S_w = 0,706}$, maka:

$$IOIP = \frac{V_b\ x\ \phi\ x\ (1 - S_w)}{Boi} x\ 7758 \quad (11)$$

$$IOIP = \frac{2.567{,}104\ acre.ft\ x\ 0{,}226\ x\ (1 - 0{,}706)}{1{,}163} x\ 7758 \quad (12)$$

$$IOIP = 1.133.938{,}787\ STB$$
$$\approx 1{,}134\ x\ 10^6\ STB \quad (13)$$
$$IOIP = 1{,}311\ x\ 10^8\ kilo\ liter$$

So, the estimation of the hydrocarbon alternative in the Cikung field as well as 4.633 x 10^6 STB.

3 Results and Discussion

3.1 The analyze of the Reservoir Thickness Distribution in the Cikung Field

The thickness of the reservoir is estimated from the isopach map, which is the result of the iso grid between the upper depth structure map and the bottom depth structure map of the bottom depth structure map of the Mid Main Carbonates layer and the bottom depth structure map. The reservoir thickness map in this study is included in the gross isopach map, it means that the reservoir thickness is not hydrocarbon but also contains water and gas.

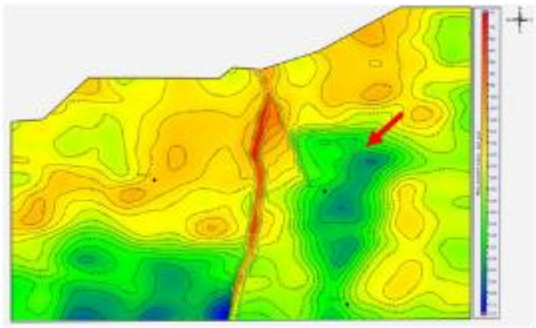

Figure 6. Gross isopach map, the result of iso grid on the depth structure map of the top MMC layer and the bottom of MMC layer.

Based on the scale on the map (Figure 6) can be estimated the reservoir thickness ranges from 71 meters to 175 meters. Red indicates that the reservoir thickness is about 71 meters to 104 meters, the yellow color indicates a thickness of about 105 meters to 124 meters, the green color indicates a thickness of about 125 meters to 156 meters, and the blue indicates the thickness of the reservoir in the West Java Basin SBI field around 157 Meters to 175 meters. Based on the appearance of contours on the isopach map, the reservoir portion which is suspected to contain hydrocarbons is the designated red arrow. This can be seen from the contours and closures of the contours that resemble such a hydrocarbon container. Other evidence is the existence of wells 1, well 2, and well 3 contained in the suspected area as reservoir containing hydrocarbon (oil) which has a thickness of about 150.9 meters and the depth between 1216 meters to 1247 meters.

Geologically, the suspected reservoir of this hydrocarbon lies in a layer beneath a carbonate reef that acts as a hydrocarbon trap. The carbonate reservoir as in the study area is represented by a reef or bioherm which is a hydrocarbon trap because it is able to block oil out of the reservoir rock.

3.2 The analyze of the Hydrocarbon reservation and the Estimation of new prospect area

Based on calculations that have been done, it was obtained the porosity value by 22.6% and water saturation of 70.7%. When comparing the porosity value with the porosity criterion made by Koesoemadinata [10], the porosity value generated in the North Sumatera Basin SBI field has very good criteria, meaning that the reservoir rock in the form of carbonate (limestone) has the ability to store liquid (Hydrocarbons) very well.

Large reserves of hydrocarbons in the field of West Java Basin SBI of 1.134 x 106 STB or about 1.311 x 108 kilo liters. This hydrocarbon reserve is pure hydrocarbon, it means that it contains only oil, because in calculations it has been separated between water and oil (OWC) and between oil and gas (OGC). This separation is based on closure contours and log data, ie the correlation between gamma ray logs, log resistivity, log density, neutron logs, and sonic logs.

The new drilling points were suspected containing the hydrocarbons are estimated from the top MMC maps, as shown in Figure 7. The well of A, B, C, and D are suspected to be new prospect areas containing hydrocarbons (oils). The reason for selecting the prospect area is seen from the shape and closure of the contour, i.e. A, B, C, and D areas are anticlines which are hydrocarbon traps, but the condition of the area can be accumulated oil is the contour should be closed because the contours are closed indicating the area has a structure Prospect reservoir. In addition, the hydrocarbons in the main reservoir migrate. The migration here means secondary migration, ie the movement of fluids from the reservoir rock to the new accumulation site. Differences in the mass of oil and water types are a source of energy in secondary migration so that the "clump" of oil will always find a higher ground, meaning oil rises upward looking for the shallower place like a new prospect area. The new prospect area is shallower than the surrounding area that has a depth between 787 meters to 997 meters from the surface, while the main reservoir has a depth between 1216 meters to 1247 meters from the surface.

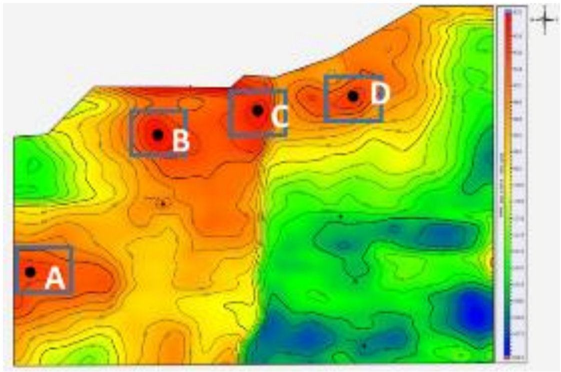

Figure 7. the new prospect area map that was suspected containing by the hydrocarbon is showed by the wells of A, B, C, and D (blue box).

The oil will find in a higher ground if the upward pressure that occurs can reduce the capillary pressure (pressure that prevents the oil from moving up due to the continuous oil droplet difference). The presence of a triggering action such as an earthquake allows the formation of a clump of dispersed oil droplets. The clump moves upward (towards A, B, C, and D) following the slope of the reservoir rock insulation, and the oil drops in its path will be attracted and make the blob grow larger and accelerate its movement and eventually accumulate in the new prospect area. When this oil does not come from the main reservoir, meanwhile it is out of the main rock (primary migration) in the form of "micelle" (colloid or solution), a mechanism that can remove oil into oil drops as a separate phase. In this case it could be due to a salty water containing electrolyte in it that acts to make the colloids become unstable so that eventually formed drops of oil.

4 Conclusion and Suggestion

Migration in the depth domain (PSDM) can present true geological models, it was proven by smoother reflector saturation, reduced pull-up effect, and has a high resolution that can be used to identify reservoir thickness and estimate hydrocarbon reserves. The thickness of the reservoir in Cikung Field is estimated to range from 71 meters to 175 meters with the prospect reservoir at a depth between 1216 meters to 1247 meters from the surface. The hydrocarbon reserves (oil) are estimated at kilo liter with a porosity value of 22.6% and water saturation of 70.7%.

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