Pull-Up Effect Correction and Oil In Place Sensitivity Test by Comparing Velocity Model Method in JAX-Field, Offshore North West Java

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Abstract. The pull-up effect is the condition of lithology elevated in seismic imaging because of rapid seismic wave propagation through carbonate build-up on it. Pull-up effect conditions can lead to misinterpretation, so it needs to be corrected until the actual geological conditions are obtained. This research was conducted in the JAX-field working area of PT Pertamina Hulu Energi ONWJ. The target reservoirs of this study are in the Main (Upper Cibulakan) Formation under the Carbonate Parigi Formation. The reflectors of the target reservoirs show pull-up effect in time domain seismic data. Thus, building a velocity model for velocity anomaly correction is needed to reduce uncertainty for structure maps and oil in place calculation. The method of correcting the pull-up effect in this study uses three variations of the velocity model: variation structurally controlled model, variation RMS velocity with well control, variation calibrated RMS velocities model. The three variations of the velocity model result can correct the pull-up effect on JAX-Field. Velocity model with variation RMS velocity with well control had the lowest error with 17.31 feet average of depth difference with actual depth from well. Based on three velocity models, the value of original oil in place on the JAX-32 reservoir surface had a range of 59.14-84.59 mmbo, while on the JAX-35A surface has a range of 27.77-31.23 mmbo. These values can be considered in reserve calculation sensitivity.

1. Introduction

The seismic method is an excellent method for subsurface imaging. Seismic method for subsurface imaging has high accuracy and resolution in modelling the geological structure under the earth’s surface. In certain cases, 3D seismic images have a pull-up effect that can cause misinterpretation. The pull-up effect is the lifting of lithology in seismic imaging due to the influence of the propagation speed of the build-up on it. The pull-up effect is not a real geological condition and is included in the pitfall/not real [1].

Depth conversion is a technique used to eliminate structural ambiguity inherent in the time domain and verify the structure and present it in a more precise geological senses in the depth domain. Geological and reservoir engineering studies are always in-depth domain, it enables the interpreter to integrate seismic depth with geological, petrophysical, and production data. There are two categories on the depth conversion method. First, the direct time depth conversion method, employs assumed velocities. Second, the velocity modelling method, uses more precise velocities of the subsurface
layers, which are obtained by dividing the subsurface layers and defining each layer’s velocity, as velocity changes with depth. Both methods can accurately tie wells and effectively predict depth[2].

This study area is in the Northwest Java Basin, more precisely in the Southern Ardjuna Sub-Basin (Figure 1). The South Ardjuna Sub-Basin has long been recognized as a major source area for ONWJ oil and gas fields [3]. In the Parigi Formation, there are carbonate build-ups that impacts a pull-up effect on seismic images. The occurrence of pull-up effect is due to the differences in velocities on shale and carbonate. The objective of this study is to understand how to correct the pull up effects that are formed by the Carbonate Build up on The Main and Massive Formation.

![Figure 1. Location Map of J-Field (a) and Stratigraphic Column (b), Offshore North West Java, Indonesia [3]](image)

### 2. Data and Methodology

In this study, the data used by researchers are 3D seismic data, seismic surfaces, seismic $V_{RMS}$, well pick, and well logging data (13 wells). The log data used in this study area are sonic log, gamma ray log, density log, neutron porosity log, and checkshot data.

In this study, researchers made three velocity models that can be seen in the flow chart (Figure 2). Velocity modeling using Depth Team Express software requires multiple data inputs. In the $V_{RMS}$ data a Dix Inversion will be used using the Dix Equation. The Dix Equation calculates interval velocities directly from stacking velocities. Assuming a flat layered velocity and structure model, the interval velocity is related to the stacking velocity by the Dix equation [4],[5]:

$$V_{int n} = \sqrt{\frac{\sqrt{v_n^2 T_n^2 - v_{n-1}^2 T_{n-1}^2}}{T_n - T_{n-1}}}$$

Where:

- $V_{int n}$ = interval velocity above the horizon n
- $T_n$ = TWT of the normal incidence ray at the horizon
- $V_n$ = RMS velocity for the horizon n

surfaces are used for guiding the interpolation of well TD curves, associating with well picks to create pseudo-velocities. Since velocities are often controlled or influenced by geological structure, the application of structural information for model building can often lead to a more accurate velocity.
model. Surfaces that used in build velocity modeling are Top Parigi, Base Parigi, Top JAX-27, JAX-32, Top Baturaja, and Base Baturaja.

Time to depth curves are converted into instantaneous velocity functions. These functions are then interpolated into a velocity volume. Functions can be interpolated linearly or along surfaces. A well pick is the depth value in a well that corresponds to a specific horizon or geological event. They typically are the most accurate source of depth data available to an interpreter. Well depth picks are associated with surfaces to create pseudo-velocities.

![Velocity Model Development Flow Chart](image)

**Figure 2.** Velocity Model Development Flow Chart (a) Variation Structurally Controlled Model, (b) Variation RMS Velocity with Well Control, (c) Variation Calibrated RMS Velocities Model

After completing the velocity modeling, researchers do depth conversion on the surface reservoir (JAX-32 and JAX-35A) using TDQ software. Surface with depth domain will be used to calculate Original Oil In Place with the following equation:

\[
OOIP = \frac{B_R V x \phi x (1 - S_w)}{B_o i} x 7758
\]

Where,
- \(OOIP\) = Original Oil In Place (STB)
- \(S_w\) = Water Saturation (%)
- 7758 = conversion factor from acre/ft to barrel
- \(B_o i\) = Oil formation volume factor
- \(\phi\) = Porosity (%)

3. Result and Discussion
The depth conversion results of the three variations in velocity model can be seen in Tables 2 and 3. The true vertical depth (Z) values in the JAX-32 and JAX-35A well picks will be compared with the surface results of depth conversion which will result in a residual value (the differences between the depth of well pick of each well with the depth value of depth domain surface). A positive residual value means that depth conversion results are shallower than well picks depth, while the negative residual value...
means depth conversion results are deeper than well picks. The calculation of depth residual values shows that the structurally controlled velocity model has the smallest average value for surface JAX-32, while the RMS velocity with well control velocity model has the smallest average value for surface JAX-35A.

### Tabel 1. Depth Residual for JAX-32 Using Velocity Model With 3 Variation

| Well | Well Picks | Surface Value | Depth Residual | Depth Residual | Depth Residual |
|------|------------|---------------|----------------|----------------|----------------|
|      |            | Variation 1   | Variation 2   | Variation 3   | Variation 1   | Variation 2   | Variation 3   |
| J - 1| -3321.16   | -3354.10      | -3344.13      | -3377.47      | -3293.0       | -22.97        | -38.11        |
| J - 11| -3268.79   | -3296.47      | -3291.38      | -3309.74      | -27.68        | -22.59        | -40.95        |
| J - 15| -3154.90   | -3081.29      | -3064.91      | -3081.41      | 73.61         | 89.99         | 73.49         |
| J - 16| -3318.97   | -3277.18      | -3288.47      | -3298.99      | 41.79         | 30.50         | 19.99         |
| J - 19| -3368.19   | -3297.43      | -3312.24      | -3298.04      | 70.76         | 55.95         | 70.15         |
| J - 3| -3130.49   | -3075.80      | -3050.80      | -3057.47      | 54.69         | 79.69         | 73.02         |
| J - 9| -3302.73   | -3254.12      | -3238.99      | -3253.99      | 48.61         | 63.73         | 48.74         |
| JH - 1| -3186.94   | -3118.21      | -3089.96      | -3108.70      | 70.73         | 87.98         | 78.25         |
| JJ - 1| -3298.19   | -3311.93      | -3302.84      | -3316.48      | -13.74        | -4.65         | -18.29        |
| JK - 1| -3097.25   | -3022.44      | -3003.42      | -3014.06      | 74.82         | 93.84         | 82.99         |
| JL - 1| -3342.52   | -3252.33      | -3313.15      | -3328.18      | 17.19         | 29.37         | 14.34         |
| JM - 1| -3353.75   | -3335.97      | -3300.50      | -3315.40      | 17.77         | 53.25         | 38.34         |
| JN - 2| -3329.79   | -3356.44      | -3356.54      | -3358.79      | -20.65        | -26.74        | -29.00        |
| JN - 4| -3317.87   | -3207.31      | -3187.94      | -3186.55      | 110.56        | 129.93        | 131.32        |
| JNA - 1| -3329.59   | -3332.47      | -3319.34      | -3324.17      | -2.88         | 10.25         | 5.42          |

**Average**

32.18 43.17 34.10

### Tabel 2. Depth Residual for JAX-35A Using Velocity Model With 3 Variation

| Well | Well Picks | Surface Value | Depth Residual | Depth Residual | Depth Residual |
|------|------------|---------------|----------------|----------------|----------------|
|      |            | Variation 1   | Variation 2   | Variation 3   | Variation 1   | Variation 2   | Variation 3   |
| J - 1| -3669.11   | -3771.43      | -3716.19      | -3773.95      | -102.32       | -96.08        | -104.64       |
| J - 11| -3625.68   | -3618.41      | -3619.87      | -3635.85      | 6.26          | 5.81          | -10.17        |
| J - 15| -3699.45   | -3636.24      | -3655.06      | -3659.69      | 63.21         | 44.39         | 39.76         |
| J - 16| -3784.61   | -3773.83      | -3787.30      | -3771.90      | 10.78         | -2.69         | 12.71         |
| J - 3| -3478.93   | -3506.07      | -3482.02      | -3480.62      | -27.14        | -3.09         | -1.69         |
| J - 9| -3464.51   | -3661.47      | -3655.28      | -3661.53      | -16.06        | -17.77        | -17.02        |
| JF - 1| -3402.04   | -3344.32      | -3323.30      | -3322.10      | 57.72         | 78.73         | 69.94         |
| JH - 1| -3502.16   | -3570.50      | -3549.99      | -3557.60      | -68.14        | -47.63        | -55.24        |
| JF - 1| -3681.36   | -3703.91      | -3704.90      | -3709.59      | -22.55        | -23.53        | -28.23        |
| JN - 2| -3430.93   | -3388.50      | -3373.93      | -3376.08      | 42.43         | 57.00         | 54.86         |
| JN - 4| -3761.60   | -3822.18      | -3774.71      | -3795.63      | -60.57        | -13.11        | -34.03        |
| JNA - 1| -3672.59   | -3795.01      | -3787.65      | -3795.36      | -122.42       | -115.06       | -122.77       |

**Average**

27.99 17.31 24.06

On the JAX-32 and JAX-35A surfaces in time domain (Figure 3.a and 4.a), researchers predicted two pseudo anticlines due to carbonate build-up in the Parigi Formation (marked with a red circle). If we look at the depth conversion results using three variations of velocity model, the area of the alleged pull up effect had been fixed because the velocity anomaly in the carbonate build up is included in the making of velocity model.
Figure 3. Surface and Result of Depth Conversion at JAX-32 (a) JAX-32 Time Surface, (b) Variation Structurally Controlled Model, (c) Variation RMS Velocity with Well Control, (d) Variation Calibrated RMS Velocities Model
Figure 4. Surface and Result of Depth Conversion at JAX-35A (a) JAX-35A Surface, (b) Variation Structurally Controlled Model, (c) Variation RMS Velocity with Well Control, (d) Variation Calibrated RMS Velocities Model

In Figure 5 is a comparison graph of the original oil in place (OOIP) value using equation 2 on surfaces JAX-32 and JAX-35A. OOIP calculations use porosity values of 0.18, water saturation of 0.5, and Oil formation volume factor of 1.24. It can be noticed that the largest OOIP value on the JAX-32 surface uses depth conversion results from velocity model variation RMS velocity with well control 84.59 mmbo, while on the JAX-35A surface the largest OOIP value on the result of depth conversion using velocity model variation calibrated RMS velocities model is 31.23 mmbo. On the JAX-32 surface, the differences in OOIP values of the three variations is quite fluctuating compared to the JAX-35A surface, most likely due to the position of JAX-35A is deeper, so that the pull-up effect is smaller than JAX-32, where velocity anomaly decreases with increasing depth.

Figure 5. Original Oil In Place Calculation Results

4. Conclusions
This study explained the three variations of velocity model that can be applied to filter the pull-up effect on JAX-Field with range of average error 17.31 – 43.17 feet. In addition, the result defined the sensitivity value of the OIIP around 59.14 – 84.59 mmbo on JAX-32 while on JAX-35A has a range of 27.77-31.23 mmbo. The OOIP range on the JAX-32 had the greater value due to the position of the JAX-32 above the JAX-35A, where the velocity anomaly decreases with increasing depth.
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