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STRIKE-SLIP FAULT IDENTIFICATION BENEATH OF THE WIRIAGAR OIL FIELD

IDENTIFIKASI SESAR MENDATAR DI BAWAH LAPANGAN MINYAK WIRIAGAR

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ABSTRAK

Eksplorasi minyak dan gas (migas) bumi di Kawasan Timur Indonesia (KTI) masih tertinggal dari Kawasan Barat Indonesia (KBI). Kompleksitas struktur geologi dan kondisi geografisnya menyebabkan KTI menjadi kawasan yang belum terjamah yang biasa dikenal sebagai daerah frontier, sehingga biaya dan resiko eksplorasi migas menjadi lebih tinggi. Lapangan Wiriagar adalah satu-satunya lapangan produksi minyak bumi di Cekungan Bintuni dengan kapasitas produksi yang signifikan. Pencarian lokasi migas baru bisa menggunakan analogi dari lapangan migas yang sudah ada. Dengan demikian pola struktur geologi bawah permukaan lapangan Wiriagar dapat digunakan sebagai template (kunci) dalam pencarian lapangan migas baru di Cekungan Bintuni. Analisis struktur bawah permukaan di daerah Wiriagar dilakukan berdasarkan data gayaberat dengan seismik dan sumur eksplorasi sebagai kendala. Ada indikasi keberadaan sesar mendatar mengiri dengan arah SW-NE yang memotong tinggian antiklin yang memiliki kelurusan NW-SE. Sesar mendatar tersebut kemudian diverifikasi melalui data penampang seismik. Pola struktur ini diduga mempengaruhi perangkap hidrokarbon yang memungkinkan terjadinya migrasi dari formasi PreKais ke reservoir Formasi Kais di bawah Lapangan Minyak Wiriagar.

Kata Kunci: *kawasan Timur Indonesia, Cekungan Bintuni, Wiriagar, gayaberat, perangkap hidrokarbon, sesar mendatar.*

ABSTRACT

The oil and gas explorations in the Eastern Indonesia is still lagging behind the Western Indonesia. The complexity of the geological structures and the geographical conditions caused Eastern Indonesia become virgin areas which commonly known as the frontier areas, such that the cost and risks of the oil and gas explorations become higher. Wiriagar Field is the only oil production field in the Bintuni Basin with significant production capacity. The search for new oil and gas location can use the analogy of the existing oil and gas fields. Thus the pattern of subsurface geological structures beneath the Wiriagar Field can be used as a template (key) in the search for new oil and gas field in the Bintuni Basin. Analysis of the subsurface geological structures in the Wiriagar area conducted based on the gravity data with seismic and exploration well data as the constraints. There is an indication of the left-lateral strike-slip fault existence with SW-NE direction intersecting the anticline ridge with NW-SE alignment. The strike-slip fault then verified through seismic section data. This structure pattern is suspected to influence the trap of the hydrocarbon which allows the migration from PreKais Formation to the Reservoir of Kais Formation beneath the Wiriagar Oil Field.

Keywords: eastern Indonesia, Bintuni Basin, Wiriagar, gravity, hydrocarbon trap, strike-slip fault.

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I. INTRODUCTION

Wiriagar Field is located in the province of West Papua, precisely in the southern part of the Bird's Head region or at the north of the northern coast of Bintuni Bay. The Wiriagar Oil Field was discovered after drilling at the Wiriagar-3 exploration well by Conoco in 1981. The previous exploration drilling wells had been conducted at the Wiriagar-1 and Wiriagar-2 sites by NNGPM in 1939 and 1950 but both of these wells were dry holes. The Kais Limestone (Upper Miocene) Formation was the objective of exploration drilling in the Wiriagar area, but most of the drilling wells were dry holes even though it has reached the objective formation. The oil and gas traps in the Kais Limestone Formation are thought to be a combination of geological structure, stratigraphic trap and diagenetic processes that make oil migrate from source rock to the Kais Formation (Dolan & Hermany 1988).

The discovery of the oil field in the Wiriagar area was followed by several exploration drilling wells in the Block of *Kepala Burung Selatan A* (KBSA) targeted at the Kais Limestone Formation, but oil discovery only occurred in the Wiriagar area. The Wiriagar-4 well conducted in 1981 discovered a significant hydrocarbon accumulation. While other exploration wells such as Rawarra, Tanemot, West Wiriagar, Ayot, Aum, Aimau River provide dry hole results. Such conditions indicate that the Wiriagar area is a unique area in the Bird's Head region, so this makes the Wiriagar area become important for further study.

Based on recent gravity research data conducted by the Centre of Geological Survey in 2016, the obtained residual anomalies shows anticline patterns with a southeast (SE) - northwest (NW) alignment. These anticline patterns are thought to be the product of the compression force due to the ongoing collision between Pacific Ocean Plate and the Australian Continental Plate. According to the result of subsurface structure modeling in the study area (Figure 1), there is shallowing basement rock to Mogoi and Kamundan area from the Bird's Neck (Ransiki) area. The basement depth in the Mogoi area is estimated to be ±4 km, while the basement depth in the Kamundan area is estimated to be ±2 km (Handyarso & Grandis 2017). There is an interesting location in the Kamundan which has low gravity anomaly but according to the basement relief estimation, it has high basement topographic. This area ever mentioned as Kamundan Sub Basin (Handyarso & Padmawidjaja 2017).

The primary gravity data in the Bintuni Basin has been conducted with ±2 km measuring intervals points which is bounded within the coordinates 210000 m – 350000 m Easting and 9743000 m – 9800000 m Northing in the UTM 53S Zone. The survey area covered ± 8029.87 km^2 wide. Whereas, the gravity study in this paper only covers partially of the whole survey location. The gravity study in this paper are limited by the coordinates of 221987.3 m – 277248.5 m Easting and 9746065.6 m – 9789680.4 m Northing marked with black square in Figure 1.

Pertamina EP continues to seek new oil and gas reserves to increase oil and gas production in Eastern Indonesia, especially from Bintuni Basin. This effort is realized in the form of 2D seismic exploration "Kupalanda" with a total seismic length of 431 km covering Bintuni Bay District (Kamundan District, Wiriagar District, Tomu District and Aranday District) and South Sorong District (Kokoda District). Meanwhile, through its subsidiary, Petro Energy Utama Wiriagar as a *Kerja Sama Operasi* (KSO) with Pertamina EP has reactivated the abandoned Wiriagar Oil Field.

The Wiriagar area is the only oil production field with significant production capacity in Bintuni Basin. Understanding of subsurface geological conditions in the Wiriagar area is expected to provide a bright spot regarding the play concept evolve in the area, thus it can be used for minimizing exploration risk. The subsurface geological modeling in the Wiriagar region, especially in terms of proving the existence of strike-slip fault through the analysis of gravity and interpretation of seismic data. The strike-slip fault is allegedly linked to the hydrocarbon traps model at Wiriagar Oil Field.

II. METHODOLOGY

This paper discusses the identification of the strike-slip fault existence in Wiriagar area by involving three methods namely gravity method, seismic method and Anderson's theory of faulting principles. These three methods are expected to provide a good agreement related to the existence of fault structures in the study area. The flowchart of the three methods used in this study is shown in Figure 2.

Interpretation of gravity methods is based on three-dimensional forward modeling following a simple and ideal anomalous source forms such as spheres, cylinders, 3D prisms etc. The 3D prism model is built in such a way that it represents a strike-slip fault beneath the surface. Then the model

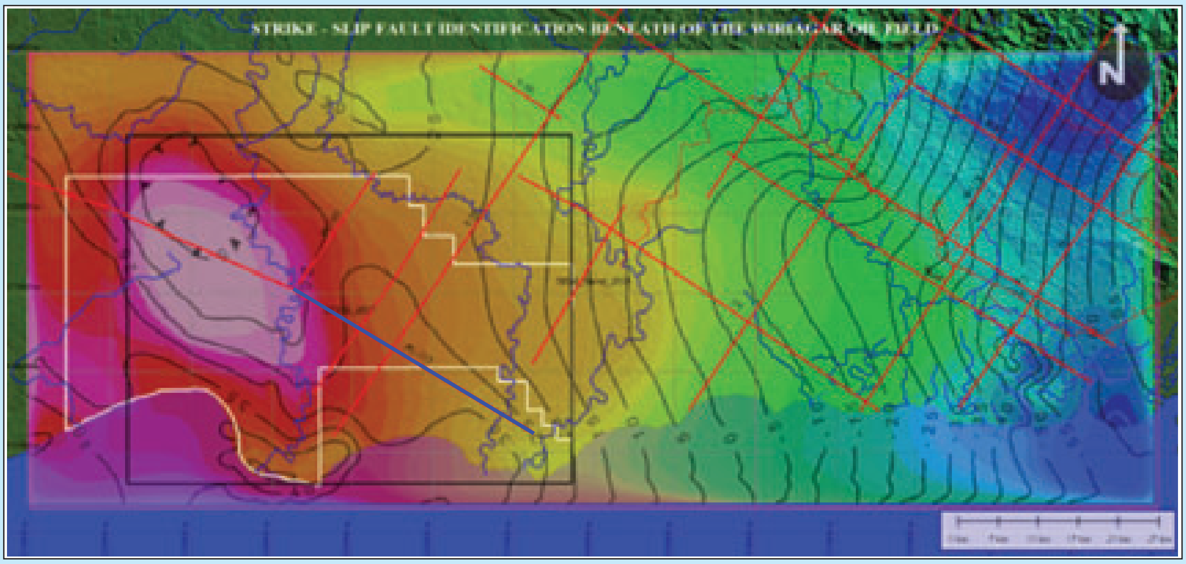
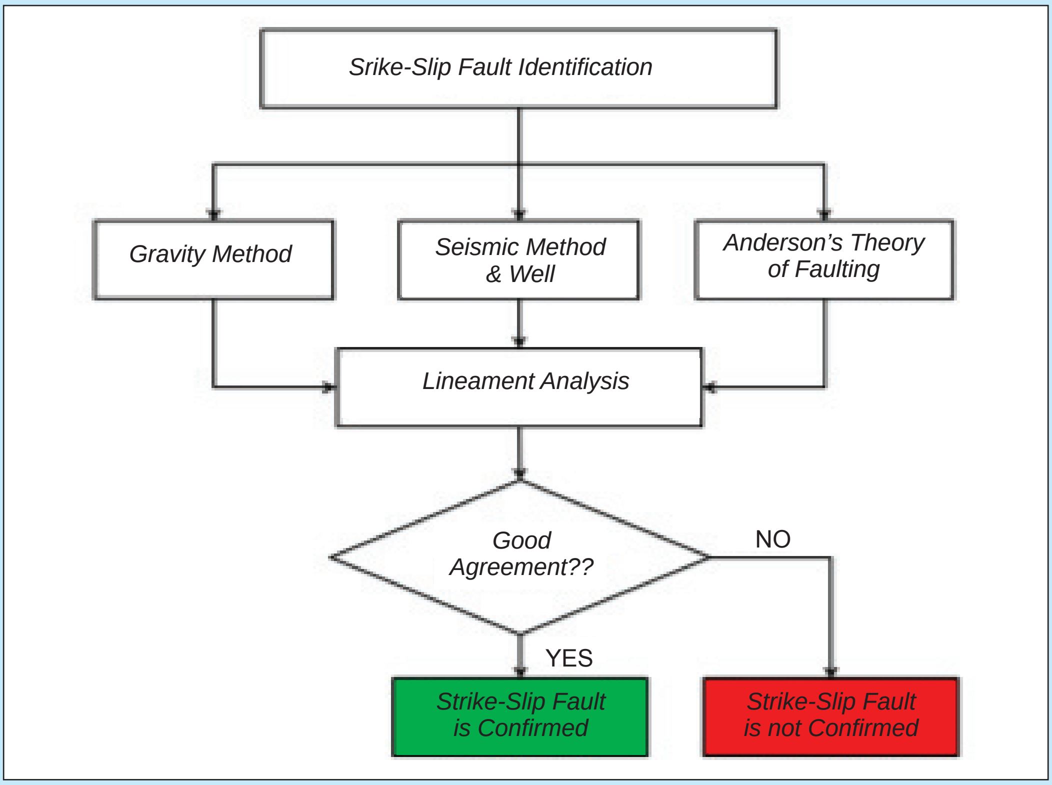


Figure 1
Study area in the Bintuni Basin. The purple square is the location of CGS's gravity survey in 2016, the white bordered area is Kamundan block belonging to Pertamina, and the black square is the study area in this paper (Wiriagar area). The black contour is the Bouguer anomaly while the red line is the seismic section data availibility in the study area and the blue line is the seismic section analyzed in this study.



response obtained from the forward modeling is processed with Second Vertical Derivative (SVD) and compared with the field dataset. Similarities of anomalous patterns that indicate the existence of strike-slip fault are then further evaluated on the basis of seismic data.

Interpretation of 2D seismic data is conducted with two purposes i.e. identifying the boundary layer (interface or horizon) and showing the existence of fracture structures. The evaluation results in the faulted structure lineament then compared with Anderson's theory of faulting concept. This combination method is expected to strengthen the conclusions obtained. If the conditions are not matching among these three methods, then the existence of the strike-slip fault is still in doubt (strike-slip fault is not confirmed).

A. Strike-slip fault 3D Gravity Modeling

Three-dimensional gravity forward modeling is performed to simulate the effects of the strike-slip fault existence according to the gravity anomaly imaging. These things are necessary such that the anomaly pattern due to the strike-slip fault on the

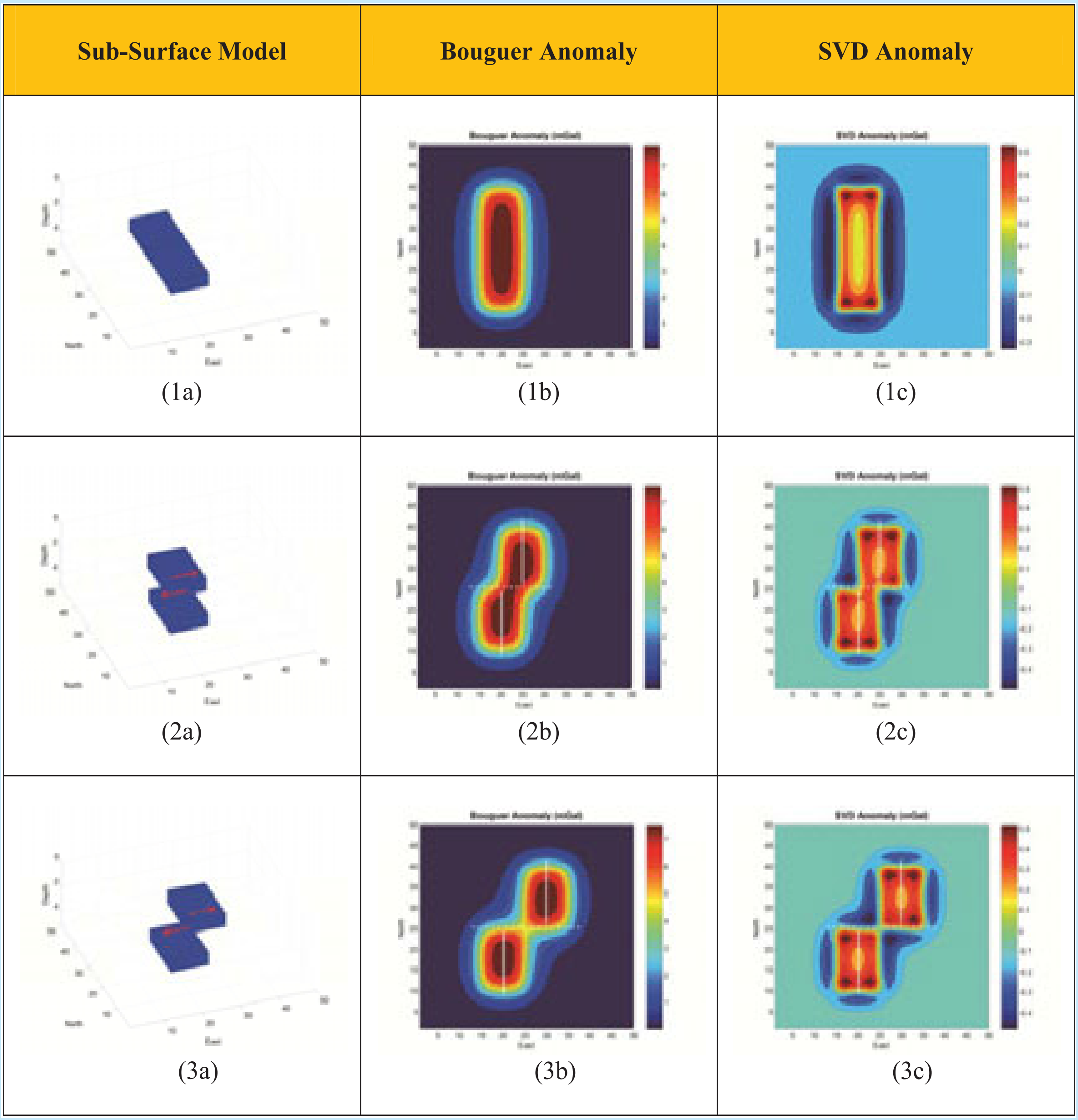


Figure 3
Strike-slip fault modeling based on gravity model response using three-dimensional prism of body source under three conditions: (1) no strike-slip fault, (2) partially strike-slip fault, and (3) totally strike-slip fault. The columns a, b, and c are sequentially sub surface models, Bouguer anomaly, and SVD anomaly patterns.

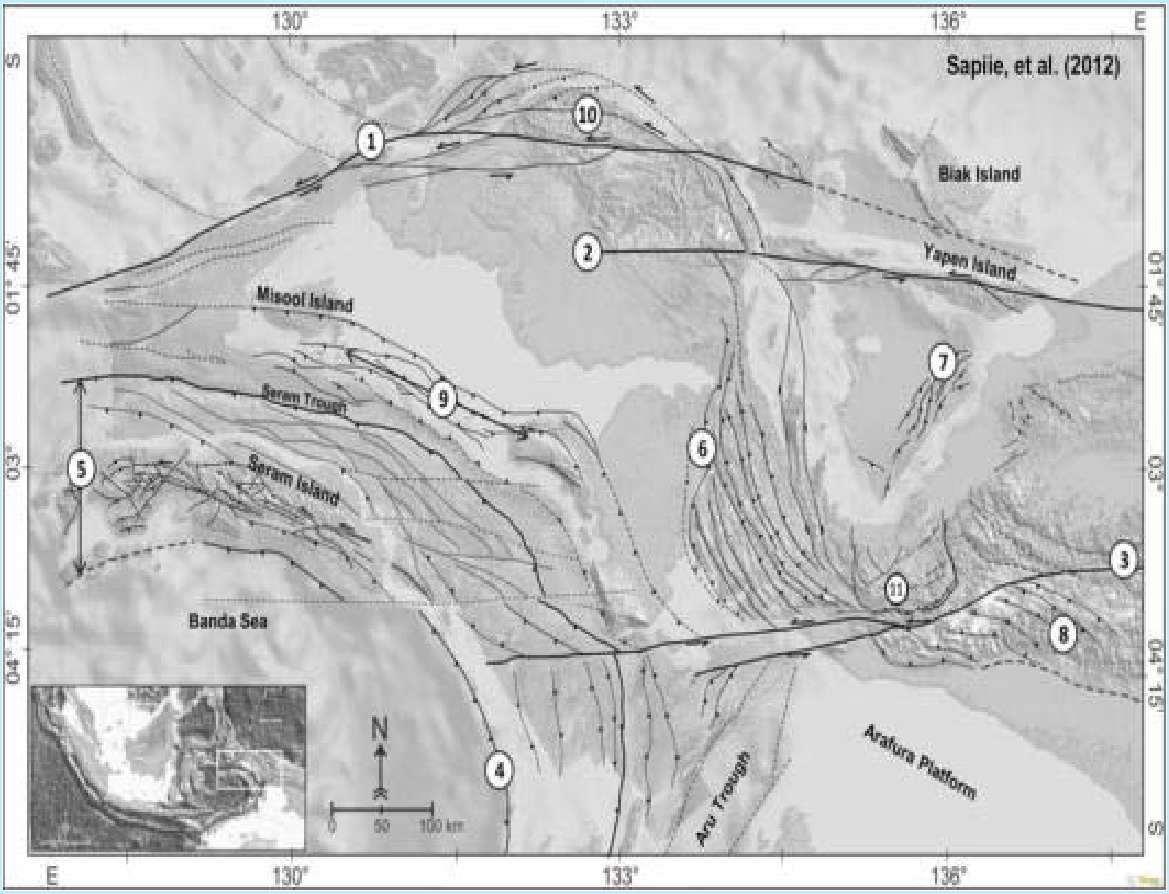


Figure 4
Regional geological structures of the Bird's Head region. (1) *Sorong Fault Zone*, (2) *Yappen Fault Zone*, (3) *Tarera–Aiduna Fault Zone*, (4) *Banda Trench*, (5) *Seram Fold–Thrust–Belt*, (6) *Lengguru Fold–Thrust–Belt*, (7) *Cendrawasih Bay Fold–Thrust–Belt*, (8) *Central Range Fold–Thrust–Belt*, (9) *Misool–Onin–Kumawa Ridge*, (10) *Kemum High*, (11) *Weyland Overthrust* (Sapiie et al, 2012).

gravity data image can be identified easily. The gravity model response from the three-dimensional prism source at the observation point P (0.0,0) in the cartesian coordinate system was calculated using the equation formulated by Plouff (1976) in Blakely (1996) as follows,

$$g_z = G\Delta\rho \sum_{i=1}^{2}\sum_{j=1}^{2}\sum_{k=1}^{2} \mu_{ijk}\left[AA - BB - CC\right] \qquad (1)$$

$$AA = z_k \tan^{-1}\frac{x_i y_j}{z_k R_{ijk}} \qquad (2)$$

$$BB = x_i \log(R_{ijk} + y_j) \qquad (3)$$

$$CC = y_i \log(R_{ijk} + x_j) \qquad (4)$$

Where $G = 6.67x10^{-11} m^3 kg^{-1} s^{-2}$ is a universal gravity constant, $\Delta\rho$ is the density contrast, $\mu_{ijk} = (-1)^i(-1)^j(-1)^k$, (x_i, y_j, z_k) sequentially are easting, northing, and depth, and $R_{ijk} = \sqrt{x_i^2 + y_j^2 + z_k^2}$

The model parameters of body source in the form of three-dimensional prisms is defined to have dimensions (length x width x thick) 30 km x 20 km x 1 km with 300 gr/cc density contrast. Then the body source is faulted in the middle part such as to produce two body sources with dimensions 15 km x 20 km x 1 km each. There are three conditions of faulting at the body sources i.e. unfaulted, partially faulted, and totally faulted. The sub surface model based on the three-dimensional prism and its model response due to the strike-slip fault presence are shown in Figure 3.

Fault delineation using gravity data is based on the anomaly enhancement approach such as Second Vertical Derivative (SVD). The equation used is the following Laplace equation (Blakely 1996).

$$\nabla^2 U(P) = \frac{\partial^2 U(P)}{\partial x^2} + \frac{\partial^2 U(P)}{\partial y^2} + \frac{\partial^2 U(P)}{\partial z^2} = 0 \qquad (5)$$

$$\frac{\partial^2 U(P)}{\partial z^2} = -\frac{\partial^2 U(P)}{\partial x^2} - \frac{\partial^2 U(P)}{\partial y^2} \qquad (6)$$

Equation 6 is then used to calculate the SVD anomaly pattern from the gravity data obtained.

Based on the gravity image from the forward modeling, it is clear that the existence of strike-slip fault can be identified by the offset or shift of the anticline axis (net-slip). Figure 3.1a shows un faulted body source, this model represents when there is no strike-slip fault, then Figure 3.2a represents a partially faulted body-source situation, and Figure 3.3a represents a totally faulted body-source condition. Figure 3.3c has a larger offset (net-slip) than Figure 3.2c and Figure 3.1c.

B. Geological Setting

The island of Papua can be divided into four parts: the Bird's Head covering West Papua; Bird's Neck covering West Papua; Bird's Body covering Papua and Papua New Guinea; And Bird's Tail covering Papua New Guinea (White et al. 2014). The Papua island is formed as a result of the collision process with the convergent interaction of the two plates, the Australian Continental Plate and the Pacific Ocean Plate. Currently, the Pacific Ocean Plate (Caroline) moves southwestward at a speed of 11.0 cm/yr relative to the Indo-Australian Continent Plate (Cloos et al. 2005). The tectonic mechanism produces several regional structures as shown in Figure 4.

The Bintuni Basin is located in the Bird's Head region, West Papua. Bintuni Basin is surrounded by large, west-east structures such as Sorong Fault Zone (SFZ), Kemum High, Yappen Fault Zone (YFZ) in the north and Tarera-Aiduna Fault Zone in the south. Both groups of structures are separated by the Lengguru Fold-Thrust-Belt which trend northwest (NW) - southeast (SE) in the Bird's Neck (Sapiie et al. 2012). The Bintuni Basin is located in the south of Sorong Fault Zone (SFZ), such that basement of the Bintuni Basin is Australian Continental Plate with density ± 2.8 gr/cc (Haddad & Watts 1999). The boundary of the contact between the Australian Continental Plate and Pacific Oceanic Plate in the Bird's Head area is along the Sorong Fault Zone (Ikhwanudin & Abdullah 2015).

Based on the Bintuni Basin stratigraphic review (Figure 5), this basin has several alleged source rock such as Sago / Sirgah Formation, Faumai Formation, Tipuma Formation and Ainim Formation from Aifam Group. While the formation that is suspected as the reservoir are the Kais Formation, Lower Kembelangan Formation, and Tipuma Formation. The Klasafet Formation, the Steenkool Formation, and the Jass Formation are thought to be seal or cap in the Bintuni Basin (Patra Nusa Data 2006).

III. RESULTS AND DISCUSSION

The Second Vertical Derivative (SVD) anomaly pattern shows the offset or axis shifting (net-slip) of the anticline ridge with southeast (SE) - northwest (NW) alignment near the Wiriagar Oil Production Field. Based on three-dimensional gravity modeling, such anomalous pattern can be interpreted as a strike-slip fault. The Wiriagar Oil Production Well with significant production capacity is located on the anticline ridge which is then truncated by a strike-slip fault with southwest (SW) - northeast (NE) direction. This pattern is not found in any other locations around Wiriagar.

The anticline ridge with the southeast (SE) - northwest (NW) alignment has a fault conjugate structure pairs such as a strike-slip fault with southwest (SW) - northeast (NE) direction. These two structures together form an "X" shaped patterns. This corresponds to Anderson's theory of faulting where the intersection between structures with fault conjugate structures is estimated to be ±30° from the maximum stress compression direction (σ1), although there are some cases of fault conjugate structures that have a "V" shaped pattern as in the Eastern Alpen, Western Mongolia, Eastern Turkey, Northern Iran, Northeastern Afghanistan and Central Tibet (Yin & Taylor 2008).

The strike-slip fault delineation in the Wiriagar area is clearly visible based on the gravity data image analysis (Figure 6). This strike-slip fault is similar (match) with the regional structures pattern of the Bird's Head Peninsula derived from depth-based gravity data decomposition (Handyarso & Kadir, 2017). There are several strike-slip faults pattern with southwest (SW) – northeast (NE) direction which is

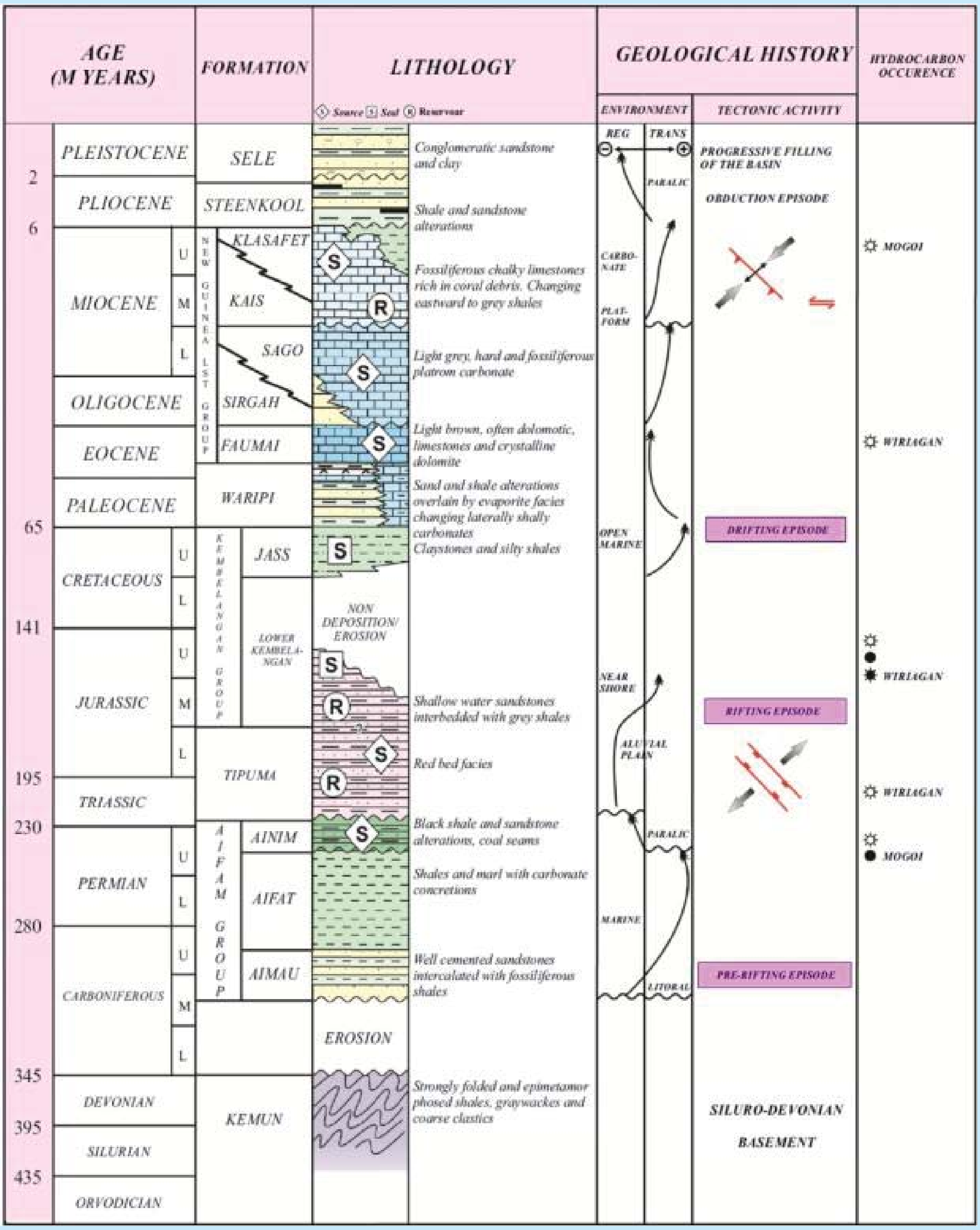


Figure 5
Regional stratigraphic column of the West Papua (Patra Nusa Data, 2006).

formed due to compressional force from on going collision of Australia Continental Plate with Pacific Oceanic Plate as shown in Figure 7.

Interpretation of 2D seismic data in the same location is also performed to confirm the existence of this strike-slip fault. The gravity method has advantages over its lateral distribution but has a poorly vertical resolution, whereas the seismic method has an excellent in vertical resolution but has limited lateral distribution. Elaboration of both methods is expected to provide more comprehensive sub surface modeling.

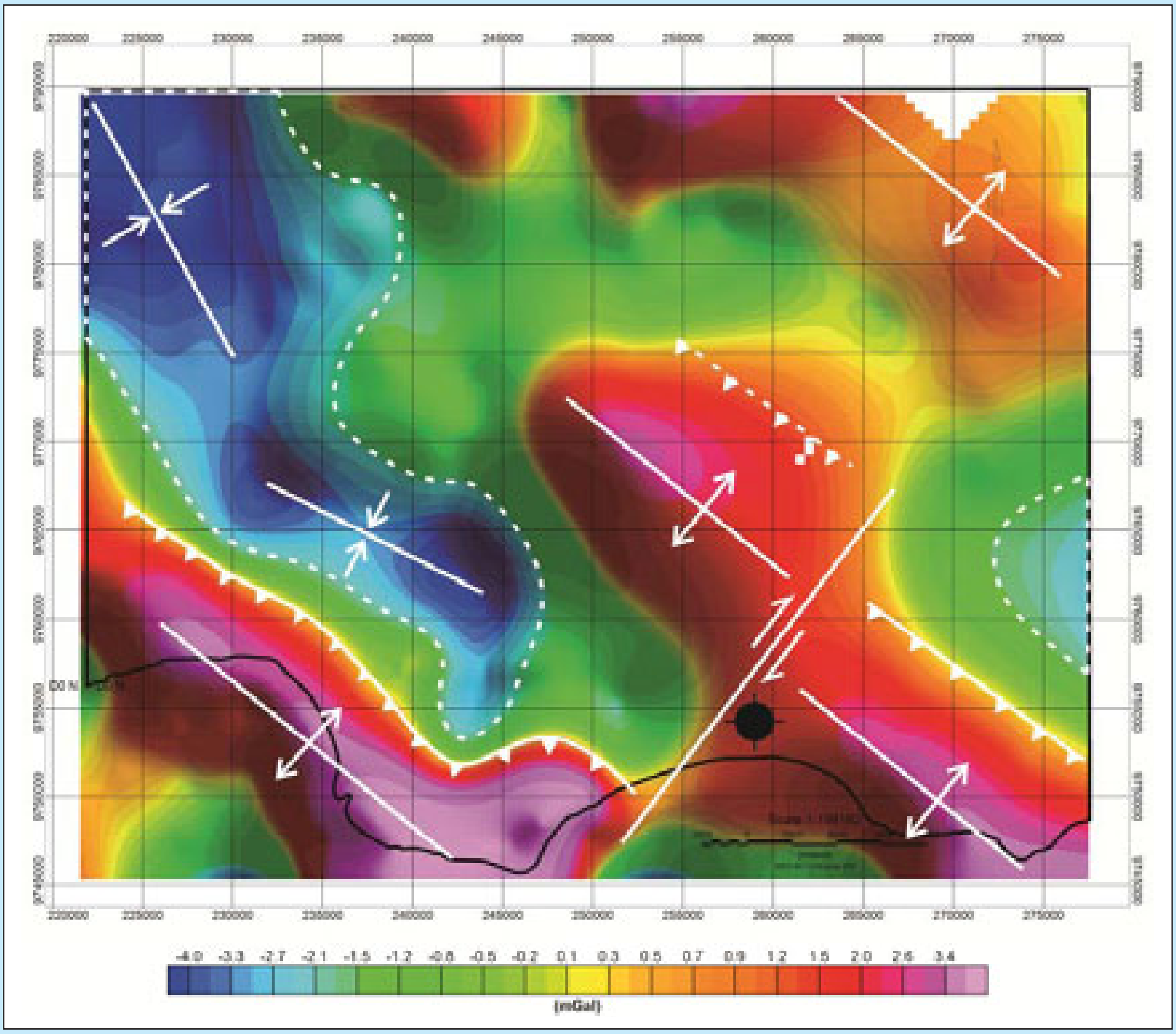


Figure 6
The Second Vertical Derivative (SVD) anomaly pattern of Wiriagar and its surrounding areas shows the existence of the Kamundan Sub-Basin and the Tembuni Sub-Basin. There is a shift in the anticline ridge axis with southeast (SE) - northwest (NW) trend, shown by the offset or net-slip. Wiriagar oil production well is shown by a black node.

The existence of the New Guinea Limestone Group in the study area is an unavoidable problem for Seismic methods. This has an impact on the blurred seismic data at the bottom part and makes it difficult for interpretation (Figure 9). The application of three-dimensional gravity inversion method which utilized the first interface constraint resulted from the seismic data interpretation to estimate the basement depth can provide an alternative solution to such geological conditions (Figure 8).

Above the first interface is interpreted as a Steenkool Formation and/or Klasafet Formation with density of ±2.2 gr/cc, while below the first interface boundary is a group of New Guinea Limestone Group down to the Aifam Group. The existence of lithology in the form of black shale, shale, and sandstone under New Guinea Limestone Group decrease the overall density value. Thus the density value below the first interface is estimated to be ±2.5 gr/cc. The basement of the Bintuni Basin is Australian Continental Plate so it is associated with density value ±2.8 gr/cc (Haddad & Watts 1999). The result of the basement depth estimation in the study area is shown as the second interface in Figure 8.

Basement depth estimation is an important aspect of oil and gas exploration. Estimation of the

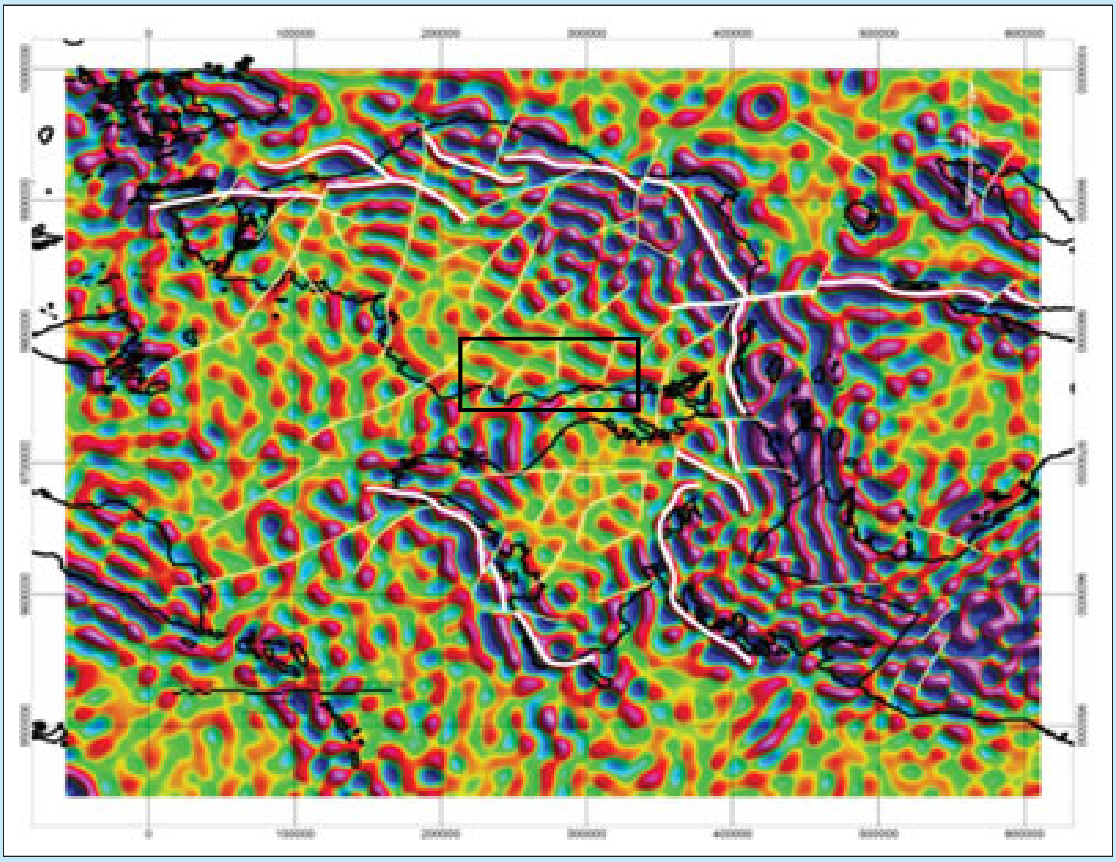


Figure 7
Second Vertical Derivative (SVD) anomaly derived from Depth-based Gravity data decomposition at 4 km depth below the surface. The result shown strike-slip fault with southwest (SW) – northeast (NE) direction in the Bird's Head Peninsula (Handyarso & Kadir, 2017) including in the study area (black square area).

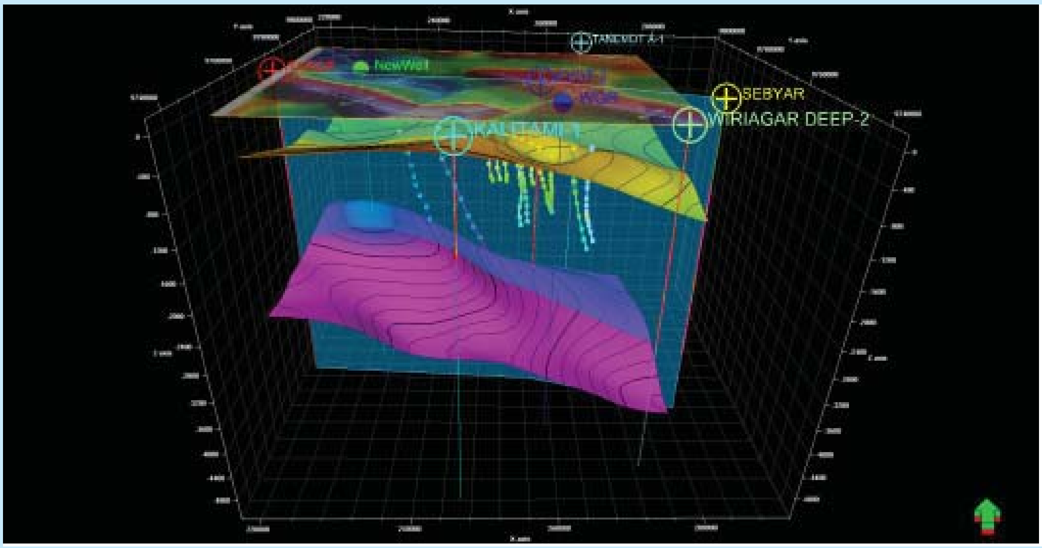


Figure 8
Visualization of first interface boundary based on seismic data and the basement depth estimation result based on Bouguer anomaly in the research area. The SVD gravity anomaly pattern is overlayed on the top layer with several exploration wells locations in the research area such as Tarof, Kalitami-1, Ayot-2, Tanemot-1, Sebyar, Wiriagar Deep-2.

basement depth gives the geometry information and reflect the existence of the geological structure under the surface. Sedimentation processes that occur during the basin evolution will be greatly influenced by the existence of these such sub surface geological structures (Dhiya 2012). Basement depth information is also useful when performing basin modeling (Onuba et al. 2013). Exploration drilling that does not reach the basement and then abandoned will leave questions regarding hydrocarbon potential that may be left behind because it is located at a deeper layer than the drilling depth itself (Koning 2007). In the case of the Bintuni Basin, particularly in the Wiriagar area, there are no drill holes reach the basement which is defined by the three-dimensional gravity data inversion (Figure 8 and Figure 10).

Seismic data besides acting as a first interface constraint during the gravity inversions, it's also useful for interpreting the existence of sub surface fracture structures as shown in Figure 9. Based on the fault interpretation results, there is pattern of fault structures below the Wiriagar area. The pattern of existing fault structures is in agreement with the SVD anomaly pattern from the gravity data. This implies that the strike-slip fault exists under the surface. The position of the Wiriagar-3 well projected into the seismic section shows that the position of the Wiriagar-3 well is surrounded by the fault structures. Such a fracture structures allow hydrocarbon migration from the pre-Kais layer to the Kais reservoir. The existence of the strike-slip fault is allegedly caused the Wiriagar region to be unique and different from the surrounding area.

The drilling log data is utilized as well as seismic data. The comparison between basement depth estimation defined by three-dimensional gravity inversion and the layering interpretation based on the drilling log are performed. it's shown that the first interface interpretation based on the seismic section is matched with the drilling log interpretation at three exploration wells i.e. Tarof, Ayot-2, and Sebyar. The depth of the first interface derived from

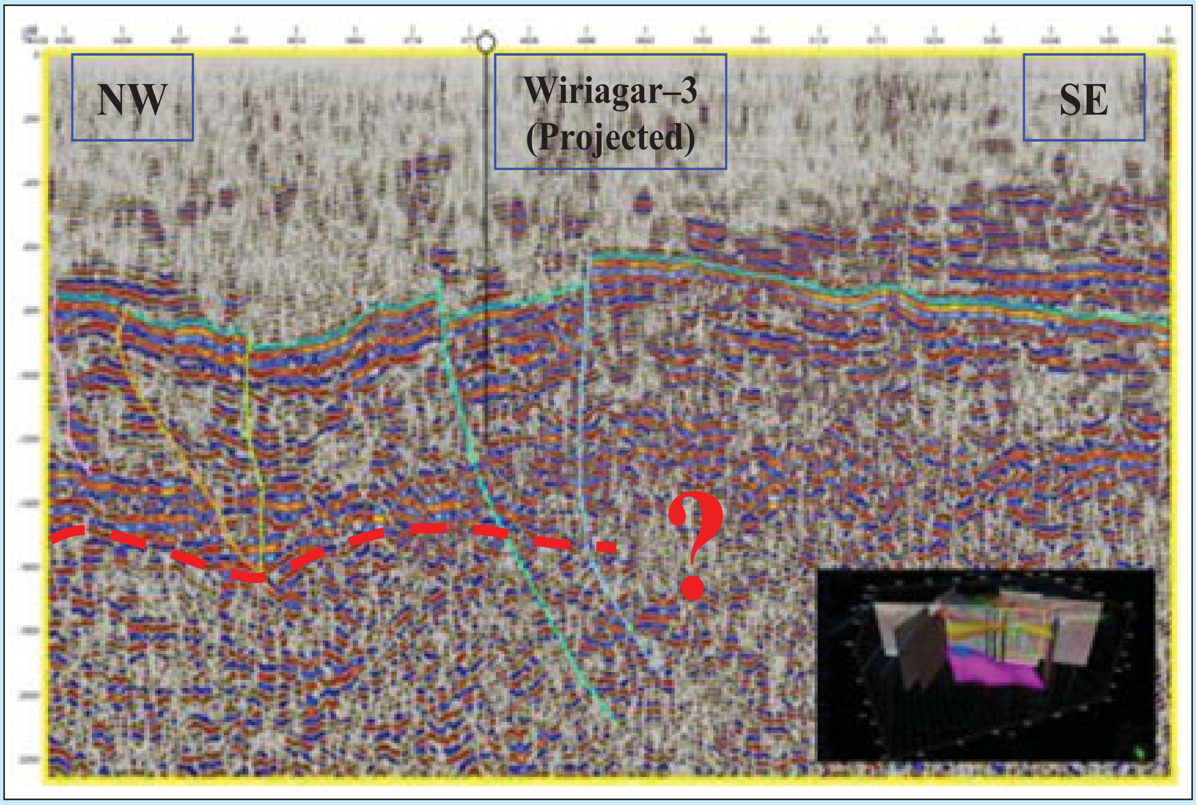


Figure 9
Seismic section in the Wiriagar area. Based on the interpretation result, there are fractured structures underneath in the area around Wiriagar-3 well, the fault structures are suspected as strike-slip fault as shown by SVD gravity anomaly.

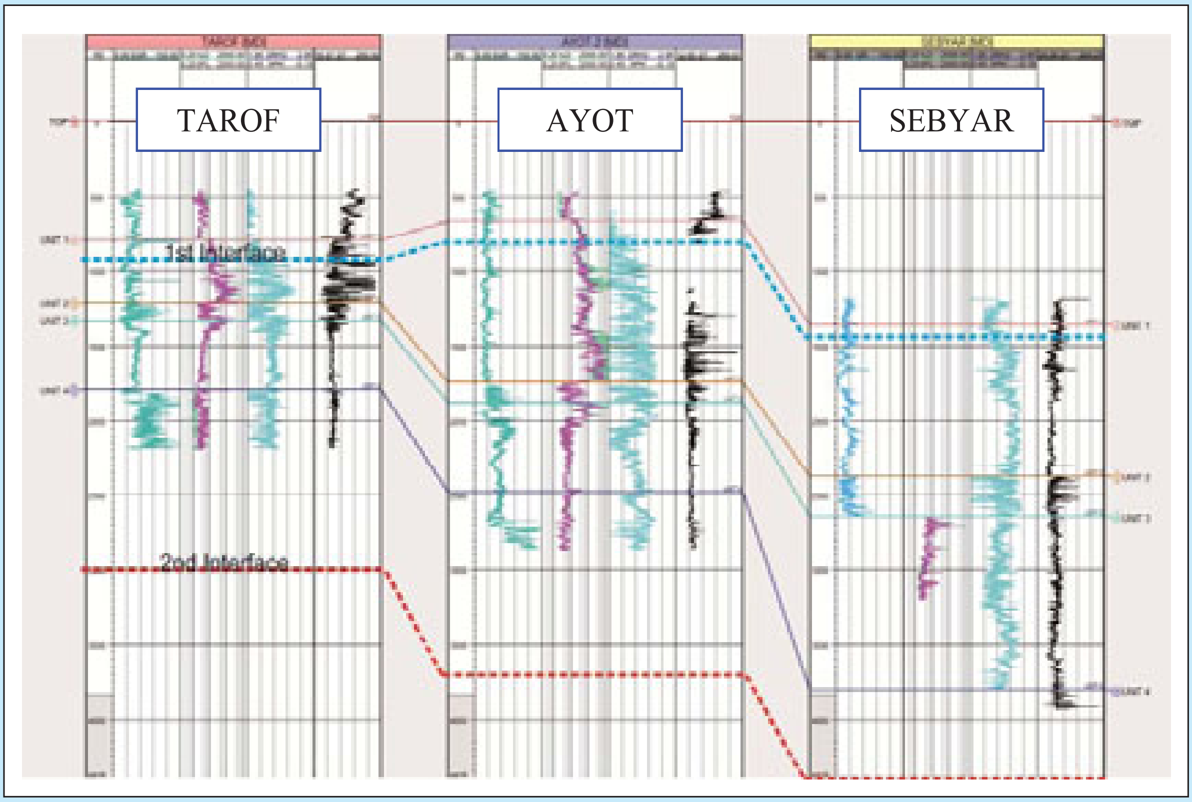


Figure 10
Comparison between layering interpretation based on drilling log and the first interface depth derived from seismic data interpretation as well as the second interface depth defined by three-dimensional gravity inversion at three exploration wells i.e. Tarof, Ayot-2, and Sebyar (The blue section in the Figure 8).

seismic section shown as the blue dash line, while the basement depth at these exploration wells is shown using red dash line at the bottom part of Figure 10. The undulation shape of both the first interface and the second interface are similar with the drilling log interpretations.

IV. CONCLUSIONS

Based on the gravity imaging analysis, there is strike-slip fault with SW-NE direction that truncates the anticline ridge with SE-NW alignment beneath the Wiriagar Oil Field. Hydrocarbons are suspected to migrate from the pre-Kais Formation to the reservoir of Kais Formation through these fault structures. Searching of new hydrocarbons prospect in Bintuni Basin can use such patterns as initial identification. Improved the drilling objectives which is originally from Kais Formations becomes deeper formations such as Sirgah Formation or another formation under the Jass Formation could be an alternatives.

FURTHER RESEARCH

The further research is needed for sealing-unsealing justification of any successfully interpreted sub surface geological structures. Thus the source rock layer and the direction of hydrocarbon migration can be predicted well. In addition, It would be better if there is at least one drilling well that reaches the basement in each sedimentary basin research, this will be very useful in determining the lower bound of the investigated sedimentary basin.

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REFERENCES

Blakely, RJ. 1995. *Potential Theory in Gravity and Magnetic Application*. Cambridge University Press: hal. 128-153; 324-328.

Cloos, M., Sapiie, B., Quarles van Ufford, A., Weiland, RJ., Warren, PQ., Mc Mahon, TP. 2005. Collisional delamination in New Guinea: The geotectonics of subducting slab breakoff. *Special papers of Geological Society of America*.No. 400.

Dhiya Al-Din A., Al-Mashaekhy. 2012. Comparisson Between Basement Depths Estimated from Land Magnetic and Aeromagnetic Surveys, West Iraq. *Iraqi Journal of Science*. Vol. 53, No. 3. pp. 602-607.

Dolan, PJ., Hermany. 1988. The Geology of The Wiriagar Field, Bintuni Basin, Irian Jaya. *ProceedingsSeventeenth Annual Convention IPA*. Jakarta. hal. 53-87.

Haddad, D., Watts, AB. 1999. Subsidence History, Gravity Anomalies, and Flexture of The NorthEast Australian Margin in Papua New Guinea. *Tectonics* Vol 18, No. 5 pp. 827-842.

Handyarso, A., Grandis, H. 2017. Three-Dimensional Gravity Inverse Modeling for Basement Depth Estimation Integrating Maximum Difference Reduction (MDR), Trend Surface Analysis (TSA) and Total Variation Regularization. *Journal Engineering and Technological Science*, Vol. 49 No. 3. pp. 358-372.

Handyarso, A., Kadir, W.G.A. 2017. Gravity Data Decomposition Based on Spectral Analysis and Halo Wavelet Transform, Case Study at the Bird's Head Peninsula, West Papua. *Journal Engineering and Technological Science*, Vol. 49 No. 4. (submitted)

Handyarso, A., Padmawidjaja, T. 2017. Struktur Geologi Bawah Permukaan Cekungan Bintuni Berdasarkan Analisis Data Gayaberat. *Jurnal Geologi dan Sumberdaya Mineral* (JGSM), Vol. 18 No. 2. hal. 53-65.

http://www.petroenergy.id/article/pertamina-ep-lakukan-survei-seismic-2d-di-papua-barat.

Ikhwanudin, F., Abdullah, CI. 2015. Indication Strike Slip Movement a part of Sorong Fault Zone in Yappen Island, Papua, Indonesia. *GSTF Journal of Geological Sciences* (JGS). Vol. 2 No. 1. hal. 25-33.

Koning T., Angola TO., Luanda., Angola. 2007. Remember Basement in your Oil and Exploration : Examples of Producing Basement Reservoirs in Indonesia, Venezuela and USA. *CSPG CSEG Convention*.

Onuba, LN., Onwuemesi, AG., Egboka, BC., Anudu, GK., Omali, A. 2013. A Review of Hydrocarbon Prospects in the Lower Benue Through, Nigeria: Another Insight from Potential Field Study, *Search and Discovery Article #20194*.

Patra Nusa Data, PT. 2006. *Indonesian Basin Summaries* (IBS). Inameta Series, Indonesia Metadata Base.

Sapiie, B., Naryanto, W., Adyagharini, AC. and Pamumpuni, A. 2012. Geology and Tectonic Evolution of Birds Head Region Papua, Indonesia: Implication for Hydrocarbon Exploration in Eastern Indonesia, *Search & Discovery Article*, No. 30260.

White, L.T., Morse, M.P., Lister, G.S. 2014. Lithospheric-scale structures in New Guinea and their control on the location of gold and copper deposits. Solid Earth 5, 163-179 (doi:10.5194/se-5-163-2014).

Yin, A., Taylor, MH. 2008. Non-Andersonian conjugate strike-slip fault. Observation, theory, and tectonic implications. IOP Conference Series: Earth and Environmental Science, Vol. 2, No. 1. (doi:10.1088/1755-1307/2/1/012026).