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The 3D Seismic Survey Design of South Walio Offshore, Indonesia: Optimizing the 3D Survey Design Parameters

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ABSTRACT - The background of this research is to support the plan to carry out 3D seismic acquisition in the Salawati Kepala Burung Working Area located in Sorong Regency. The 3D seismic design study was applied to better understand the physical properties of the Mesozoic clastic reservoir in the Salawati basin and its surroundings, especially in the offshore area. The study aims to evaluate the parameters of a reliable 3D seismic acquisition design to meet efficiency in financing in realizing the 3D seismic data acquisition program. Determine the recording parameters to image the Kais Formation and Waripi Formation targets by building a geophysical analysis model using existing 2D data and well-log information. Based on this model, using the Kais and Waripi formation properties to calculate and analyze vertical and horizontal resolution, bin size, aperture migration, and maximum offset. Synthetic acquisition 2D modeling is applied in this study to perform vertical and horizontal resolution analysis and obtain optimum and reliable bin size parameters and aperture migration. With this knowledge, we calculate the theoretical parameters of the survey. After determining the most critical theoretical parameters of the study, the next step is to determine the distance between the source and receiver. Then define the recording template. It is done by considering the bin size for the 3D model, offset boundaries, and suitable folds for inner targets. In the second, an analysis of the other two most important attributes is carried out, namely the offset and azimuth distribution. It is realized that every 3D survey design compromises technical factors affecting 3D survey costs starting from the technical requirements of field activities. The results of this study are recommendations and suggestions for two main alternative models of recording parameters and templates in the form of ideal source-receiver layout models, namely orthogonal and diagonal, and the minimum prerequisites that are expected to be able to map and determine the characteristics of the shallow and deep play type models in the South Walio offshore areas.

Keywords: 3D survey design, salawati basin, salawati working area, kais formation & waripi formation, parameter recording & templates

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INTRODUCTION

General

This study is addressed to support the 3D seismic acquisition plans in the Salawati area. In which the 3D seismic design is applied to realize the exploration mindset to go deeper to understand better and explore the Mesozoic clastic reservoir. It is suggested that better definition and possible characterization of the reefal facies' existence may be possible when the new seismic data is with the proper seismic data acquisition parameters. According to (Doust & Noble 2008), Aifam–Roabiba's petroleum system is critical since it gives rise to most new LNG projects. More than 18 tcf has been certified for the gas reserves in the Tangguh field area. The existence of a secondary target reservoir is in the Palaeocene turbiditic sandstone. However, the reservoir properties appear less uniform than the primary Roabiba petroleum system. It has been suggested by (Doust & Noble 2008) that the source of the petroleum system of the Permian/Jurassic began during the Pliocene with widespread subsidence and burial in the western foreland of the Lengguru thrust fault.

To understand the better possible characterization of the reefal facies' existence as well as the existence of a secondary target reservoir in the Palaeocene turbiditic sandstone, the three-dimensional seismic will play an important role in the appraisal and the development planning (Rijks & Jauffred 1991). The better definition and possible characterization of the facies as well as stratigraphy existence will be possible when the 3D seismic with the optimal parameters for survey design and realization is done in the seismic data acquisition (Moldoveanu 2003); (Stork 2011); (Babu et al. 2022).

This study is also addressed to evaluate the reliable 3D design parameter for better cost-effectiveness in 3D seismic data realization. The strategy is to establish the recording parameters to image both targets of the Kais Formation and deeper targets of the Waripi Formation. The works start by defining the geological and geophysical objectives.

The motivation for this study is to evaluate, analyze, and determine the optimal parameters for survey design and realization of South Walio Offshore seismic data acquisition according to the target of interest, namely the Mesozoic clastic reservoir and a relatively deep exploration target according to the existing subsurface interpretation model. The aim is to provide recommendations for source and receiver layout models and acquisition parameters according to the results of several simulation studies based on available subsurface data. This study will also offer suggestions for improving seismic data quality and optimal 3D parameter design and analysis for the new 3D seismic acquisition program. Thus, this study aims to evaluate reliable 3D design parameters for better 3D seismic data.

The geological and geophysical model of the Reservoir Pay Zone thickness of Kais, Waripi, and Pre-Tertiary Formation based on the Jaya-Deep-1 well are summarized using well log data in Figure 1.

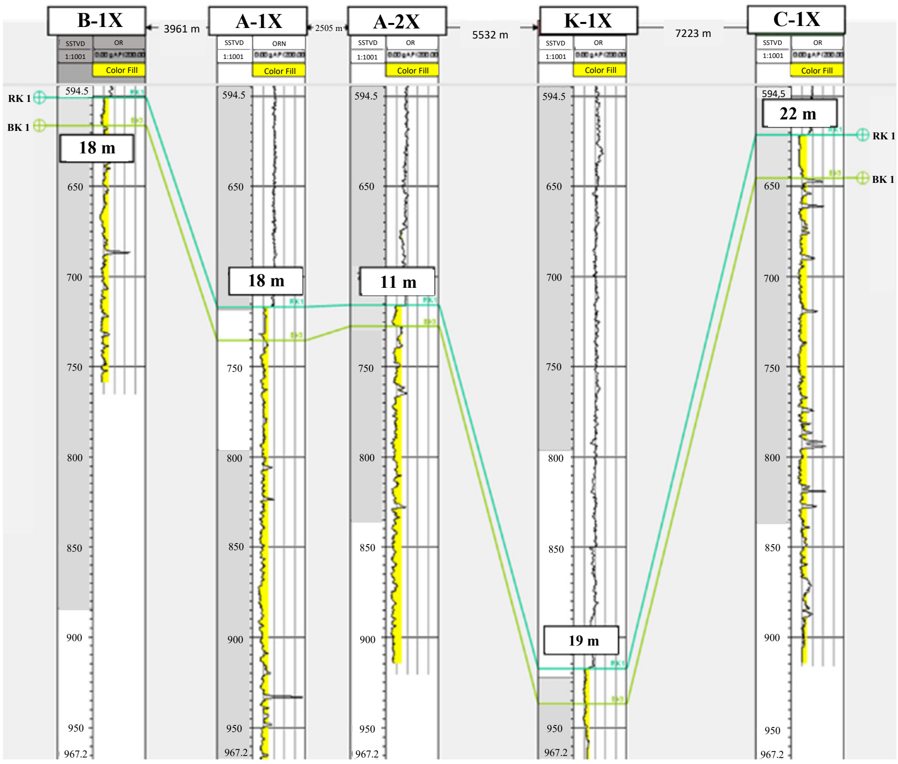
Survey objectives

The primary objective is to apply the 3D seismic design to realize the optimum and reliable parameters for the 3D seismic data acquisition plans, especially for Kais Formation. In addition, it should include imaging any strike-slip (wrench) faults that may exist in South Walio Offshore (Doust & Noble 2008). The secondary objectives are to map the deeper target of Waripi and Pre-Tertiary. A further aim is to obtain detailed possible stratigraphic information of sufficient quality to map reservoir features and the ability to detect and map the existence of hydrocarbon lead or prospect. 3D data is expected to have a better chance of catching the possible Direct Hydrocarbon Indicator (DHI) with the better imaging inherent in 3D migration. In addition, advanced seismic processing studies may prove fruitful when 3D data is acquired.

Survey area

The South Walio Offshore is a part of the Salawati basin; West Papua is a prolific Basin in Eastern Indonesia, which is proven to produce oil and gas from the Miocene carbonate reservoir, mainly the Kais Reef limestone Formation. The Salawati Basin area is bounded by the Sorong Fault Zone (SFZ) in the north and west. On the southern part, it is determined by the Misool-Onin anticline, and on the west, the Ayamaru Plateau separates the basin from the adjacent Bintuni Basin (Ovinda et al. 2018). According to (Doust & Noble 2008), based on regional geological studies showed that the Kais Reef limestone has two types of carbonate reservoirs. The reef carbonate reservoirs have good to excellent reservoir properties, and non-reefal carbonate reservoirs (platforms) have moderate to good porosity and permeability. The carbonate reef of the Kais Formation was suggested to be developed within the carbonate platform without any correlation between one and other reservoir types (Doust & Noble 2008). However, the Tertiary-Kais Formation system has produced very few commercial oil discoveries. Figure 2 shows the regional stratigraphy of the Salawati Basin (Satyana 2001). The 3D South Walio Offshore covers an area of approximately 100 square kilometers. The Boundary control points' coordinates are shown in the following Figure 3.

Kais reservoir pay zone thickness



Waripi & pre-tersier pay zone thickness

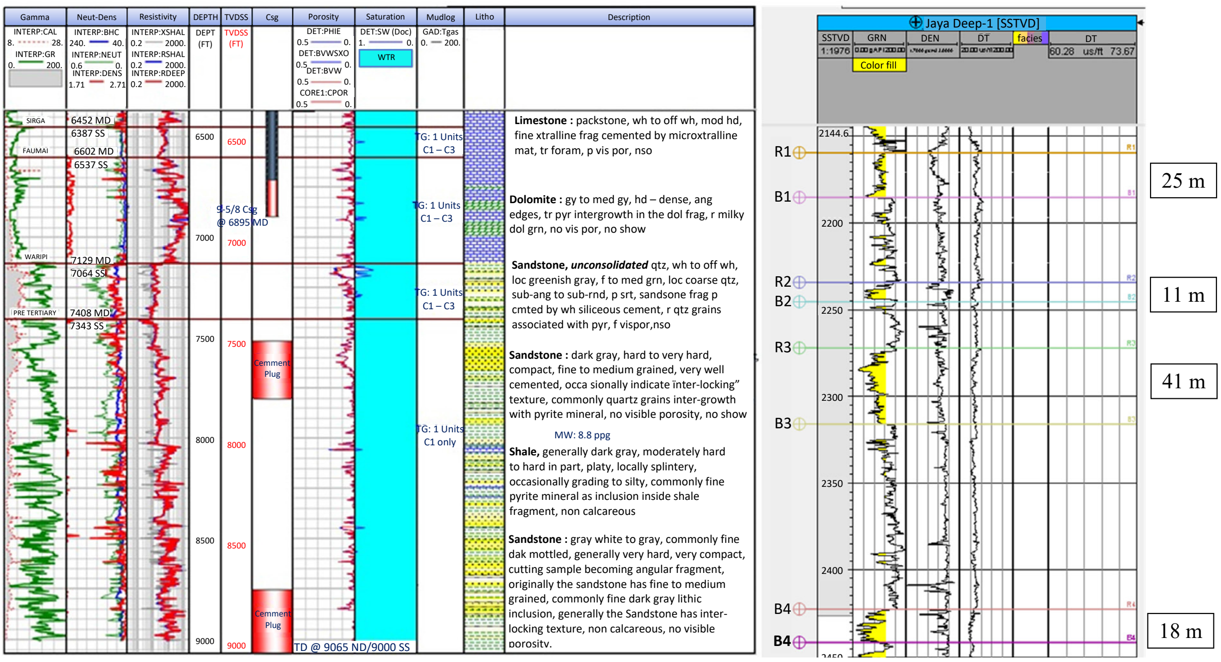


Figure 1
The geological and geophysical model of the reservoir pay zone thickness of kais, waripi, and pre-tertiary formation based on the jaya-deep-1 well are summarized using well log data.

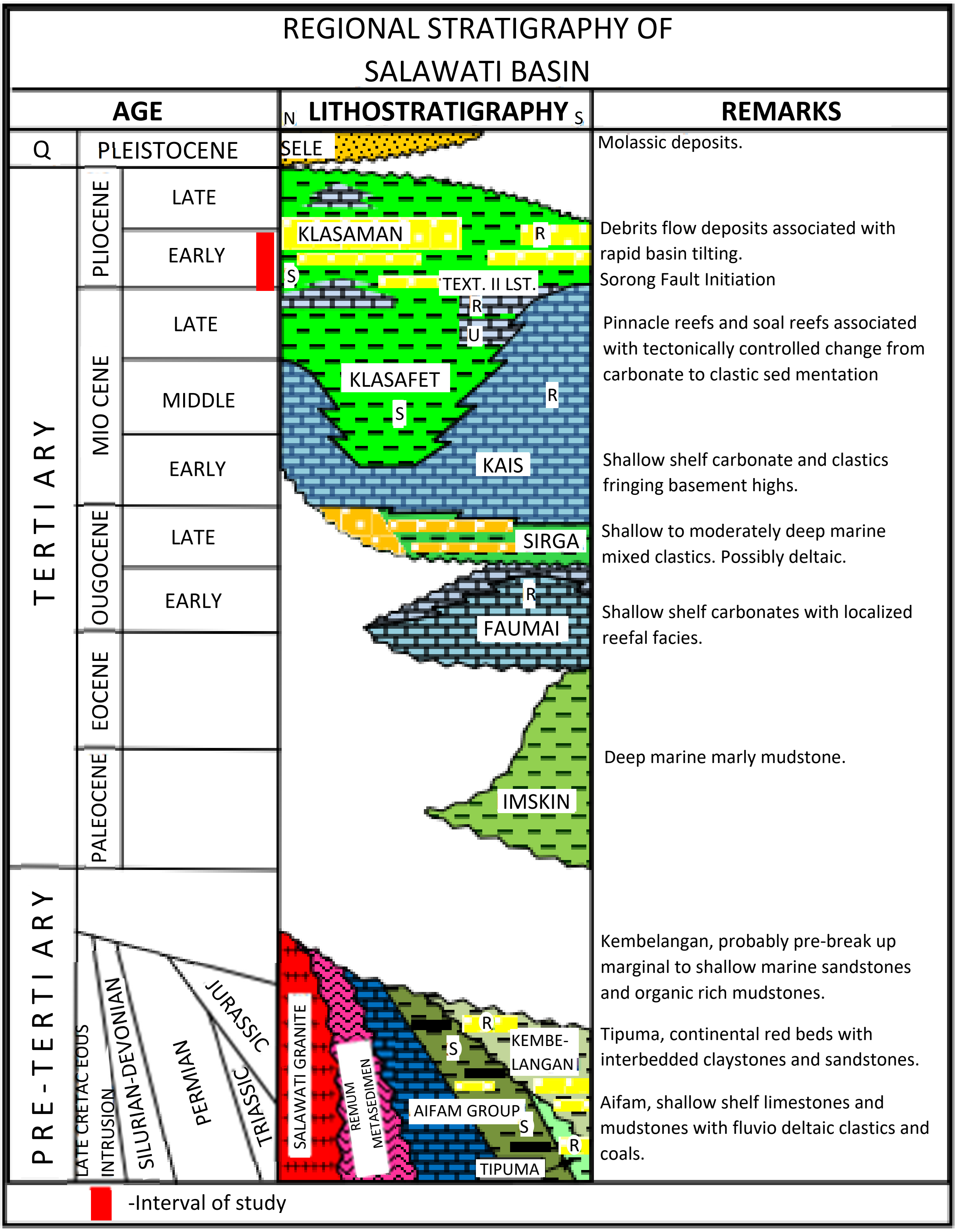


Figure 2
Regional stratigraphy of the Salawati Basin (Satyana 2001)

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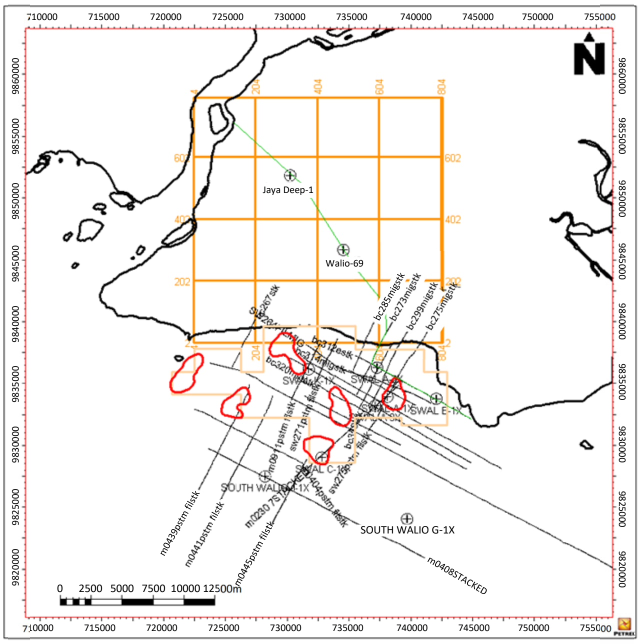

South Walio Offshore	
North	East
9835947.87	720666.14
9835946.20	722521.27
9837789.44	722522.93
9837786.09	726233.16
9835942.82	726231.47
9835941.11	728086.66
9839627.80	728090.04
9839620.97	735510.98
9838385.74	735520.78
9838393.70	741070.02
9835928.73	741073.29
9835926.91	742928.53
9831625.34	742924.22
9831629.07	739213.73
9832243.50	739214.34
9832247.16	735503.92
9828560.30	735500.27
9828563.98	731789.88
9832250.76	731793.47

Figure 3
The coordinate location map of the study area. The red rectangle plot shows the boundary area of the study.

METHODOLOGY

The methodology in this study includes the analysis of subsurface characterization, velocity and density modeling, and acquisition design parameters evaluation and simulation. First, we build geophysical analysis models using existing 2D data and well-log information. Based on these analysis models, we use both Kais and Waripi Parameter Analysis to calculate and analyze vertical and horizontal resolution, bin size, migration apertures, and maximum offset. Then we use the 2D Modeling module to verify parameters such as bin size, migration aperture, and synthetic records. With this knowledge, we begin the task of calculating the theoretical parameters of the survey.

After establishing the survey's most important theoretical parameters, we continue to determine the source and receiver line spacing. We then define the recording template. It is done by considering 3D bin size, offset limits, and folds.

Second, we examine the two other most important attributes by evaluating and defining several proposed templates for seismic 3D design. They are the offset distribution and the azimuth distribution. It is essential to realize that any 3D survey design is a compromise between technical which affects the cost of a 3D survey from a technical, practical, and logistical objective.

Subsurface structure characterizing

Constructing the structural maps at the beginning of the study needs to be done by making seismic horizon interpretations using existing 2D seismic data. Amplitude balancing needs to be done first for better mapping. This study uses gravity data that is addressed to understand better the possible basement profile. About five horizons were picked in this study, and they are Horizon-1, Kais, Horizon-2, Waripi, and Basement. The time structure map of the five horizons can be seen in Figure 4.

Velocity and density model construction

Following the idea of the previous study (Triyoso et al. 2018), the 3D velocity and density modeling has been carried out by structural modeling based on the five horizons. First, the depth structure map is obtained from the conversion using a velocity based on the gravity model. The detailed workflow to construct the 3D velocity and density model can be seen in Figure 5. Next, the gravity model is used to build the velocity model based on the cross plot between velocity and density based on the gravity model after being adjusted and matched to the density log. The adjusted density based on the gravity data was then applied. Finally, the 3D velocity and density model was constructed based on the structural modeling and converted into depth using the velocity model resulting from the gravity model, as shown in Figure 6.

Time structure map

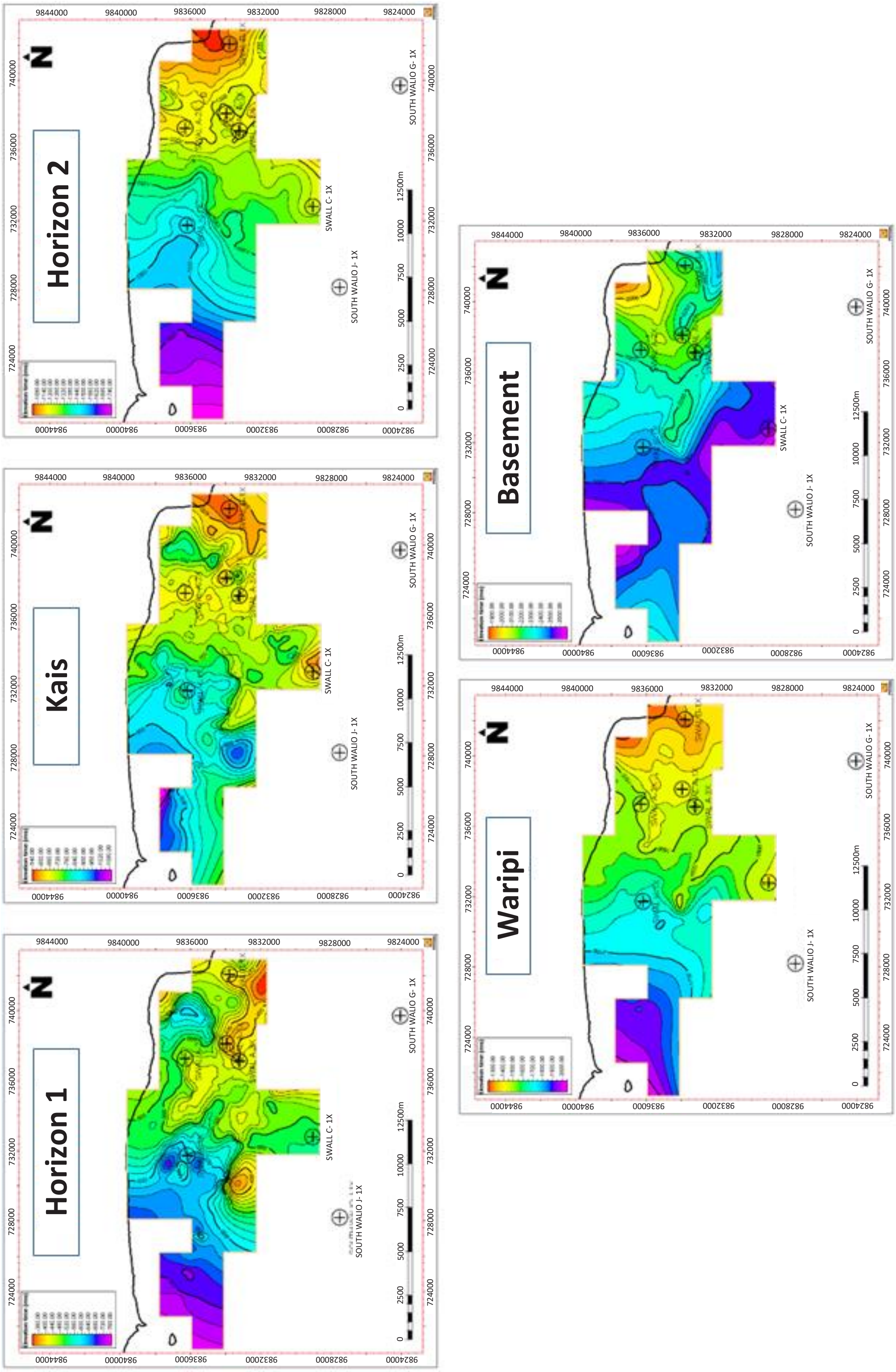

Figure 4
The time structure maps of the five horizons were used to realize the 3D model.

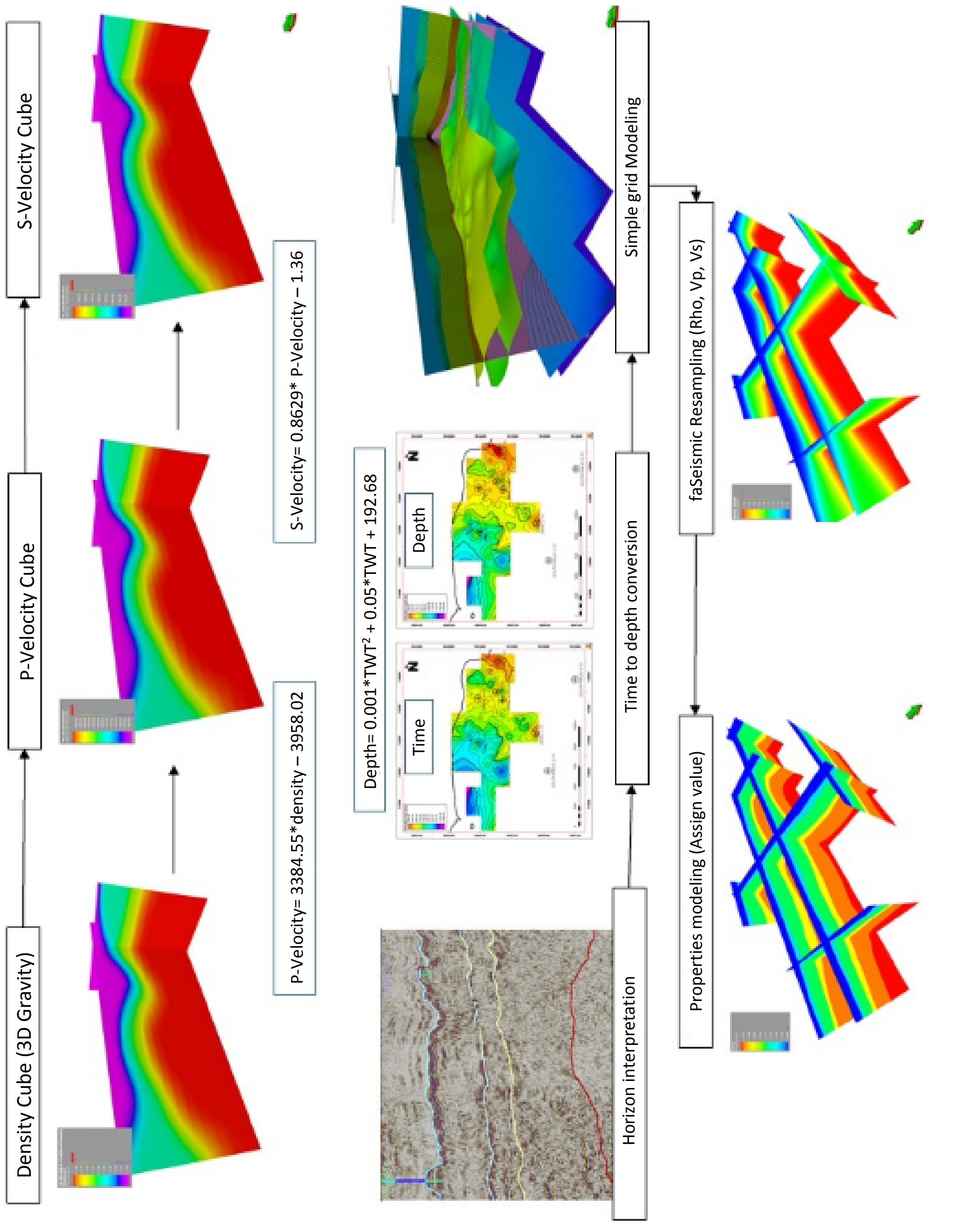

Figure 5
The detailed workflow to construct the 3D velocity and density model

Depth structure map (velocity based on gravity model)

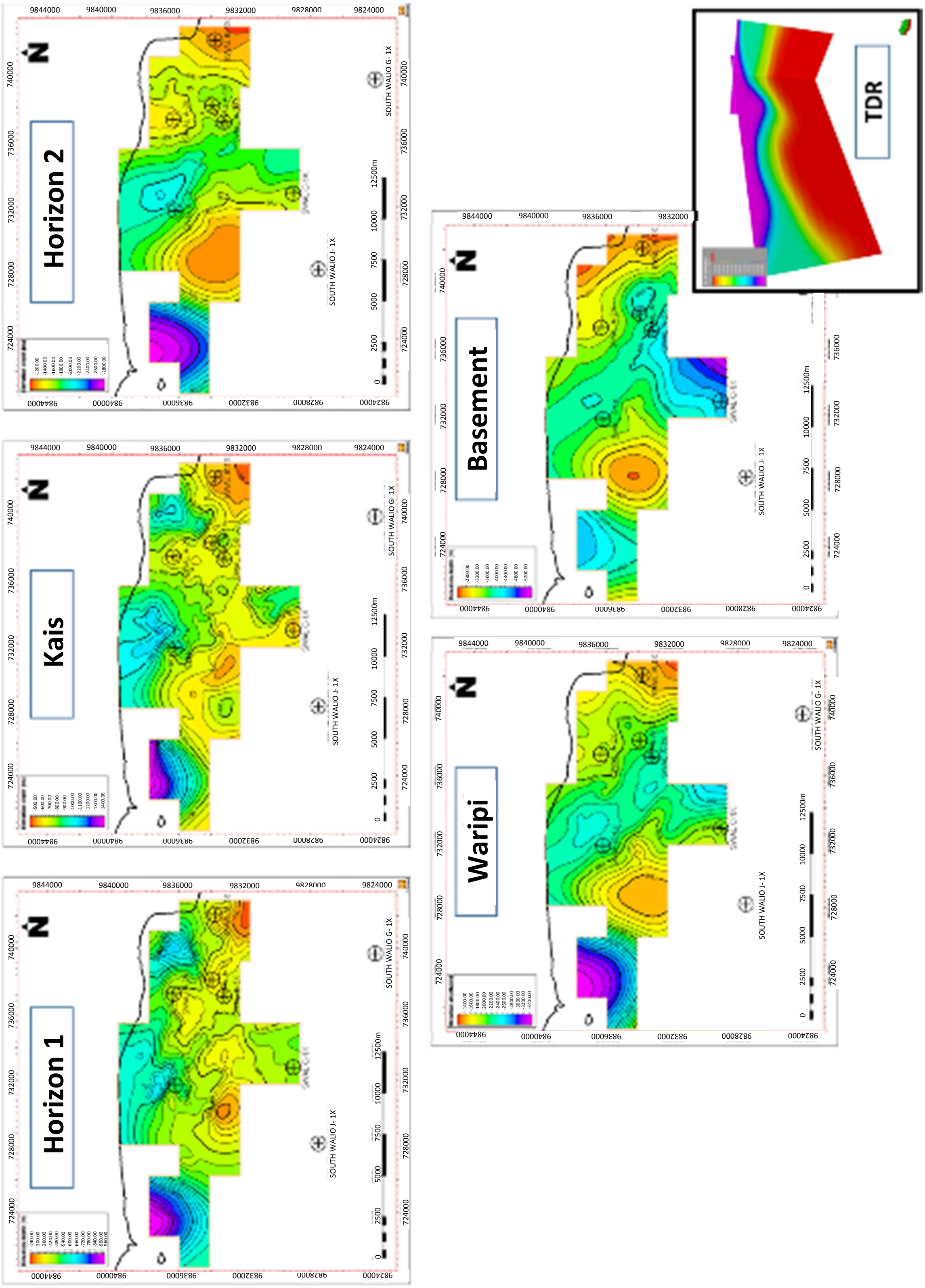

Figure 6
Depth structure of the five horizons.

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Acquisition parameter design

In this study, the 3D seismic acquisition parameters design evaluation includes Resolution versus Frequency, Geological & Geophysical Model, Bin Size, Subsurface Target Length, Spatial Aliasing versus Bin Size, and Migration Aperture, Offset, and Mute (Cordsen et al. 2000); (Evans 1997); (Liner & Gobeli 1996); (Liner & Underwood 1999); (Margrave 1997); (Sheriff & Geldart 1989); (Telford, Geldart & Sheriff 1990); (Vermeer 2002).

RESULT AND DISCUSSION

Based on the result of several simulations of the shooting configuration and layout in which the fold coverage, rose diagram and offset distribution are used to get the reliable image of the subsurface model as well as the proposal for the seismic processing that is addressed to have more reliable azimuthal fold coverage could be described as follows.

Seismic survey layout

Static design analysis is carried out to determine how effective the 3D seismic acquisition design has been planned and applied to the survey site boundary. The survey layout planned for this work is shown in the following Figure 7. In this study, we proposed two shooting configurations. They are orthogonal (option 1) and diagonal shooting layout (option 2). The azimuth distribution and offset of the orthogonal and diagonal shooting configuration can be seen in Figure 8.

Receiver

- Number of RL : 16, each 8km long
- RL orientation : E-W
- Total channel : 2,560 (16 x 160)
- RL interval : 250 m
- Receiver interval : 50 m
- Receiver type : single sensor, Hyd on seabed (& Geo onshore)

Source

- Source type : Dynamite min 2kg (airgun > 2000cu.in)
- Source depth : 25-30m below MSL (note WD < 10m)
- SP interval : 50 m
- SL interval : 400 m (EW direction)
- SL orientation : N-S (orthogonal)

Orthogonal Seismic Shooting configuration (Option 1)

Receiver

- Number of RL : 16, each 8km long
- RL orientation : E-W
- Total channel : 2,560 (16 x 160)
- RL interval : 250 m
- Receiver interval : 50 m
- Receiver type : single sensor, Hyd on seabed (& Geo onshore)

Source

- Source type : Dynamite min 2kg (airgun > 2000cu.in)
- Source depth : 25-30m below MSL (note WD < 10m)
- SP interval : 70 m
- SL interval : 400 m (EW direction)
- SL orientation : NW-SE (135deg)

Orthogonal Seismic Shooting configuration (Option 2)

Figure 7
The proposal of the two shooting configurations i.e: orthogonal (option 1) and diagonal shooting layout (option 2)

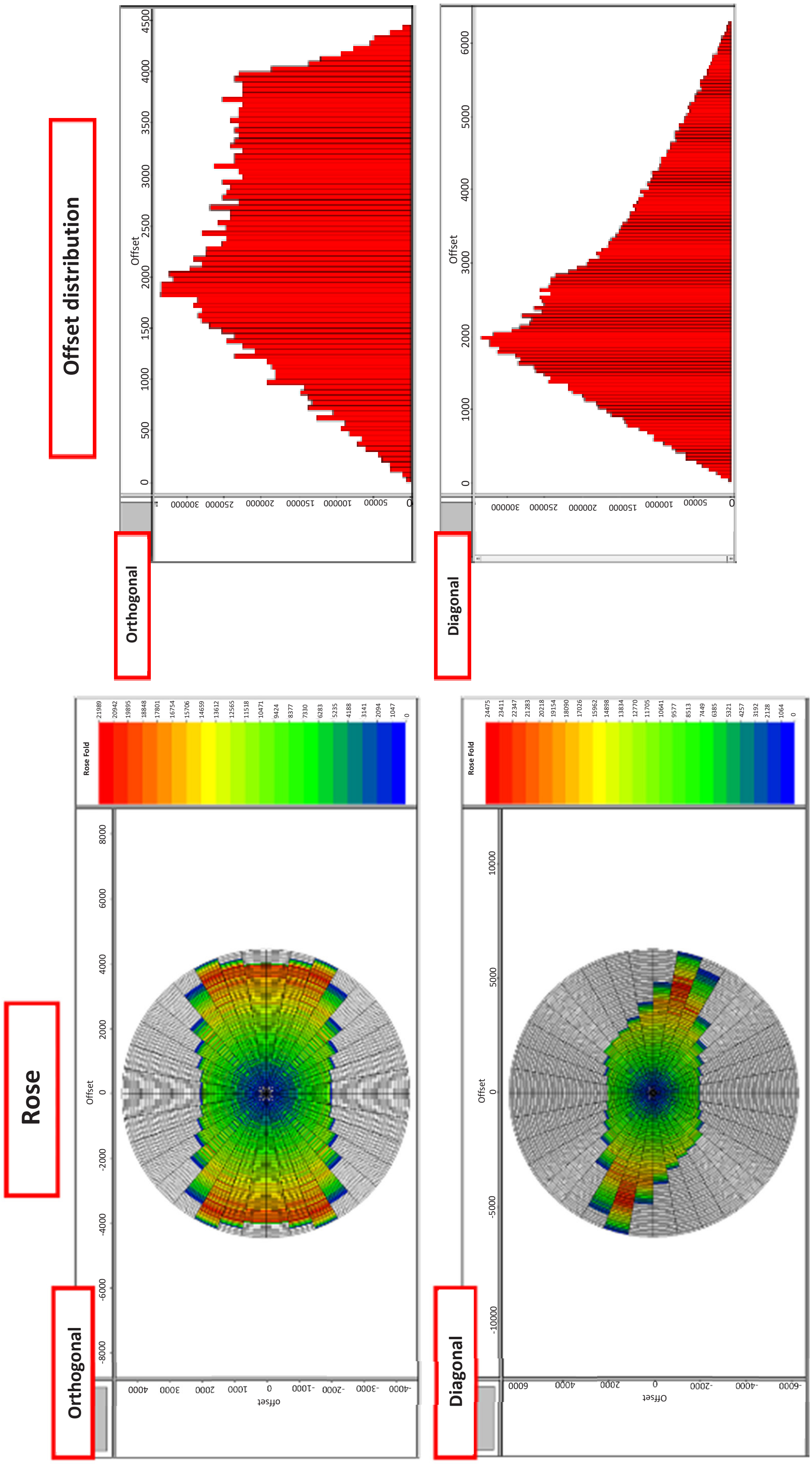

Figure 8
The azimuth distribution and offset of the orthogonal and diagonal shooting configuration

Proposal for the seismic processing sequences

Following the previous study on seismic wave simulation, modeling (Triyoso et al. 2018, 2020) the standard seismic processing for the marine seismic survey (Telford et al. 1990); (Triyoso et al. 2020), the following seismic sequence flow of (Dümmong et al. 2009); (Muhtar et al. 2021) processing step is then proposed.

Processing Sequences:

01. Reformat
02. Geometry setting
03. Time delay application
04. Bad trace editing
05. Gun/streamer static correction
06. Trace despiking
07. Low-cut filter
08. De-swell noise attenuation
09. Denoise
10. Deghosting
11. Spherical divergence correction
12. Deconvolution
13. 1st Velocity analysis
14. Radon demultiple
15. CRS (Common Reflection Surface)
16. 2nd Velocity analysis
17. Denoise in cdp and offset bin
18. PSTM for velocity analysis
19. 3rd velocity analysis
20. Full PSTM
21. Radon demultiple
22. NMO, mute, and stack
23. Post stack enhancement
24. TVF and TVS

CONCLUSION

Based on the results of this study, we propose two main alternative ideal source-receiver layout models of orthogonal and diagonal and the minimum prerequisites that are expected to map and characterize the shallow and deep target play type models in the South Walio Offshore area:

- It is recommended to use the orthogonal static design layout, which has a more prosperous or wider azimuth distribution and a relatively more uniform offset distribution. The bin size is 25m x 25m.
- The realization of the water-bottom data in this study is still based on free domain data; therefore, to ensure and validate the composition of the shot type and its quantity, it is necessary to conduct a bathymetry survey prior to seismic acquisition.
- The standard seismic processing flow is also proposed in this study. In addition, we add the Common Reflection Surface as an optional seismic processing flow that could be added to enhance the quality in case the lowest fold coverage acquisition geometry is preferred.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
DHI	Direct Hydrocarbon Indicator	
CRS	Common Reflection Surface	
PSTM	Pre-stack Time Migration	
NMO	Normal Move Out	

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