A proposed model of Width-Thickness Ratio for tidal shelf sand ridge reservoirs within Upper Cibulakan Fm. in the Ajata Field, Offshore Northwest Java Basin

Priantoro Kartika Dani Setiawan*, Amrizal, Yasinta Dewi Setiawati, Achmad Mansur

Pertamina Hulu Energy ONWJ

Corresponding author: priantoro.setiawan@pertamina.com

ABSTRACT

The Upper Cibulakan reservoir of the Ajata Field in the Northwest Java Basin represents tidal shelf sand ridges deposited in an open-mouthed shallow marine environment. One hundred fifty-three wells have been drilled to develop this reservoir since 1970. The average density of wells in the Ajata Field is 400-500 m, making it an ideal case for reconstructing tidal shelf sand ridges reservoir model. This study aims to determine tidal shelf sand ridges heterogeneity and geometry, especially through width-thickness ratio, in the Ajata Field and to identify similar reservoirs in other fields or basins. The data used in this study are 900 ft conventional core data, 74 Routine Core Analysis (RCA) data, 152 well logs, and 3D seismic data.

Tidal shelf sand ridges conventional cores analysis shows six lithofacies in the Upper Cibulakan Formation, namely: claystone-siltstone, lenticular siltstone, flaser sandstones, cross-bedded sandstones, non-calcareous massive sandstones, and calcareous sandstones. These six lithofacies are grouped into four facies associations and they reflect the tidal shelf ridge development stages: embryonic, immature accretion, mature accretion, and abandonment. These facies associations create a cyclicity pattern bounded by chronostratigraphic markers of marine flooding surfaces. Well-to-well correlation and seismic interpretation results show several trends and geometry of the tidal shelf sand ridges. Three zones of width thickness ratio (W-T) analysis in every parasequence are concluded in this study: Zone I (width: maximum 800 m; thickness: less than 25 ft), Zone II (width: 700 – 1300 m; thickness: 25 – 45 ft), and Zone III (width: 1000 – 1900 m; thickness: thicker than 45 ft).

Keywords: *Tidal shelf sand ridges, Upper Cibulakan, Northwest Java Basin*

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INTRODUCTION

Sandstone reservoirs from the Upper Cibulakan Formation are the largest oil producer in the Northwest Java Basin. More than 80% of the hydrocarbon production in the Offshore Northwest Java fields come from these reservoirs. Most sandstone reservoirs from the Upper Cibulakan Formation represent tidal shelf sand ridge deposits. The reservoirs were deposited in an open-mouthed shallow marine embayment with high control of tide current during deposition (Figure 1).

Lack of information about the basic concept of shelf ridges geometry becomes a significant problem in interpreting tidal shelf sand ridges reservoirs. The only published example of tidal shelf sand ridges deposits that formed in an open-mouthed, shallow marine embayment is from the Quaternary deposits in the Yellow Sea, China (Xu et al., 2017). Due to this condition, the Upper Cibulakan Formation in the Northwest Java Basin can be another example to develop tidal shelf sand ridges deposit geological models.

The Ajata Field is one of the most significant oil fields in the Northwest Java Basin, with most of oil production derived from the Upper Cibulakan Formation's reservoirs. In this field, one hundred fifty-three wells have been drilled to develop this reservoir since 1970. The average wells density in the Ajata Field is 400-500 meters. As a giant oil field in the Northwest Java Basin, the Ajata Field has a complete subsurface database and high well data density. This condition allows the Ajata Field to be a suitable location for constructing a model on the tidal shelf sand ridges deposit (Figure 2).

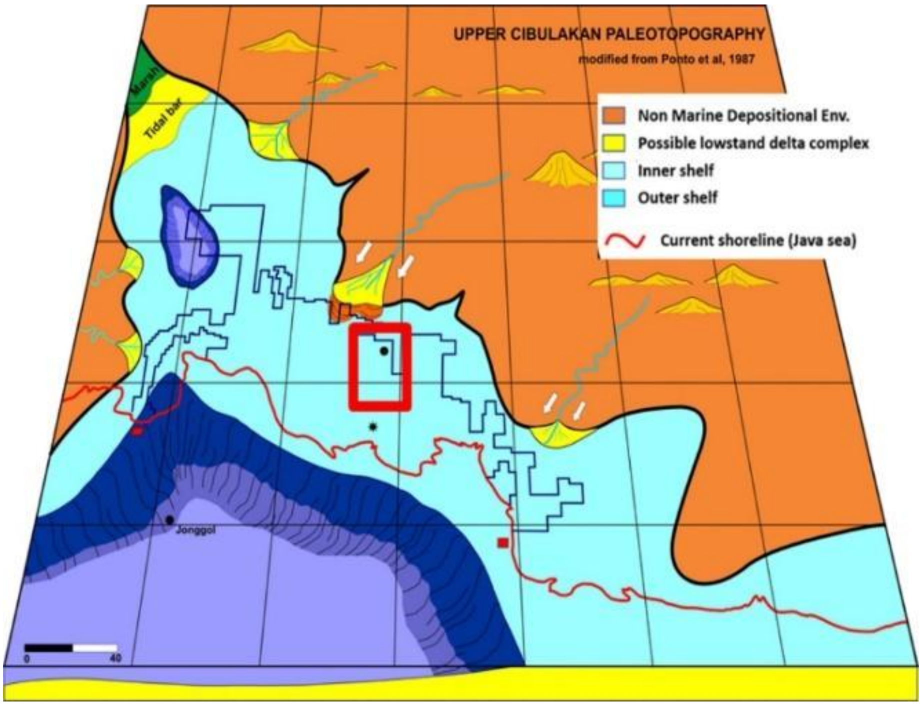

Figure 1: *Upper Cibulakan paleo-topography reconstruction (modified after Ponto et al., 1987).*

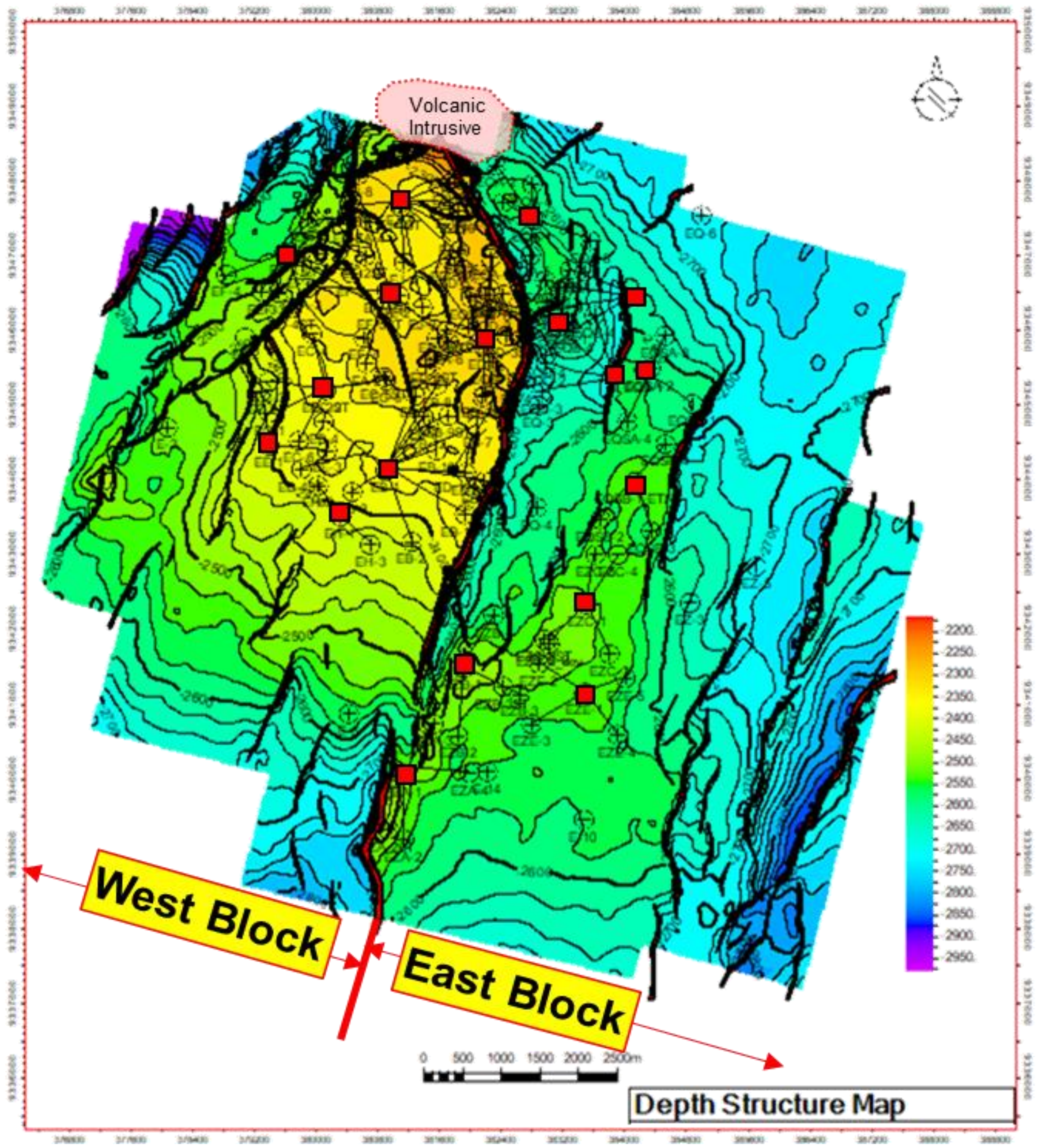

Figure 2: *Ajata Field Depth Structure Map.*

DATA AND METHODOLOGY

The study aims to determine tidal shelf sand ridges heterogeneity and geometry, especially through width-thickness ratio, so that it can become analogue for other fields or basins having similar reservoir type. The data utilised in this study are 900 ft conventional core data, 74 RCA data, 152 well logs, and 3D seismic data.

The research methodology used in this study involves sequence stratigraphy approach, which consists of dividing rock relationships within the geological time framework and identifying genetically related facies units. The objective of this concept is to identify geometry of strata

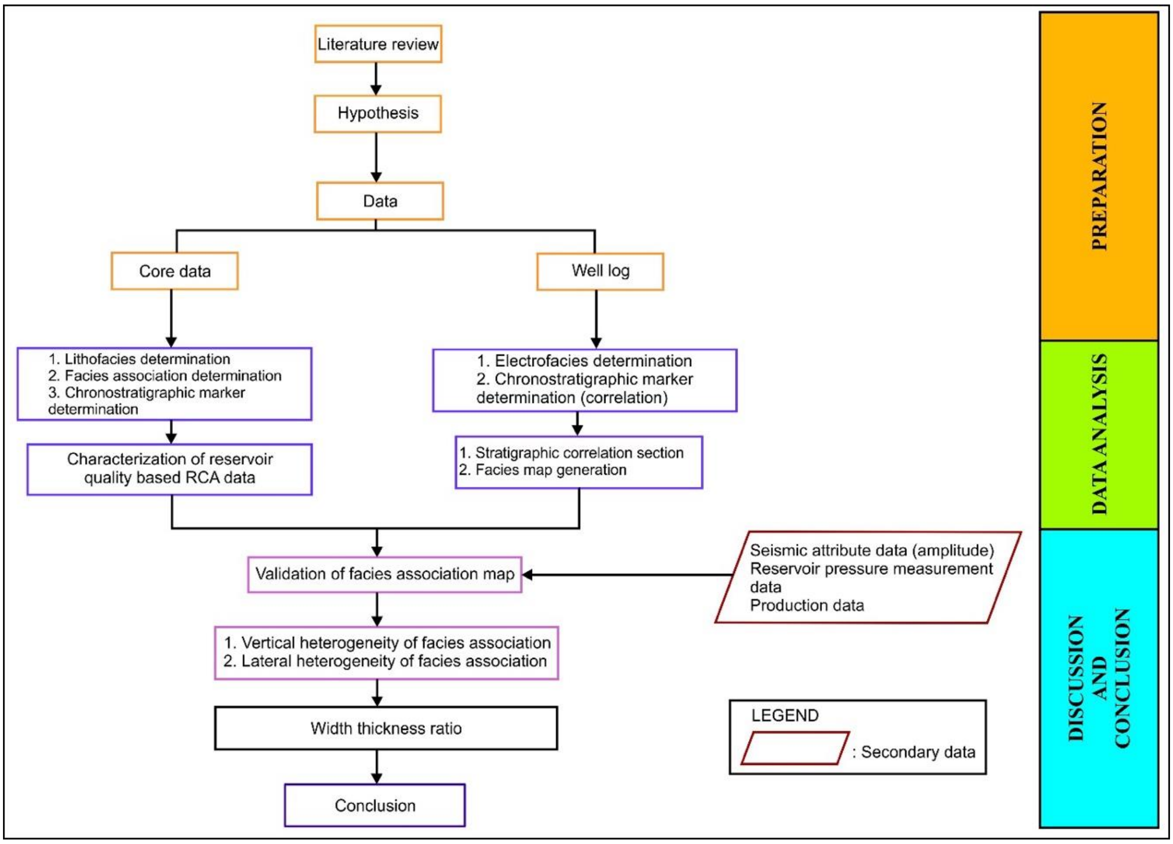

Figure 3: *Study Workflow.*

and facies patterns within sedimentary basins and to analyse the distribution of hydrocarbon accumulation areas. The high-resolution sequence stratigraphy approach in this research helps in analysing sedimentary units at a parasequence scale, allowing to determine the geometry, distribution, and characteristics of reservoir facies (Figure 3).

In this study, facies association of tidal shelf sand ridges is analyzed using pie chart method. A depositional parasequence cycle of tidal shelf sand ridges begins with the presence of the Transgressive Surface (TS) marker and ends with the flooding surface. In some conditions, the presence of the TS marker is challenging to be identified, as the marker is overlapped with the flooding surface. In the pie chart method, the thickness of the parasequence is reflected as the circle's diameter, while the percentage within the pie chart represents thickness ratio of each facies association to the measured total thickness. Afterward, the integration of pie chart method and qualitative seismic interpretation is conducted to define the trends of each tidal shelf sand ridge. The distribution of each facies association will be controlled by the trends of each ridge, especially for facies with good reservoir quality (Figure 4).

Posamentier (2002) interprets the deposition of the Upper Cibulakan Formation sandstone as tidal shelf ridge morphology, which is a product of tidal solid influences. As a background, Lopez et al. (2016) subdivides the depositional sequence for tidal shelf ridge deposits into three (3) main stages: embryonic,

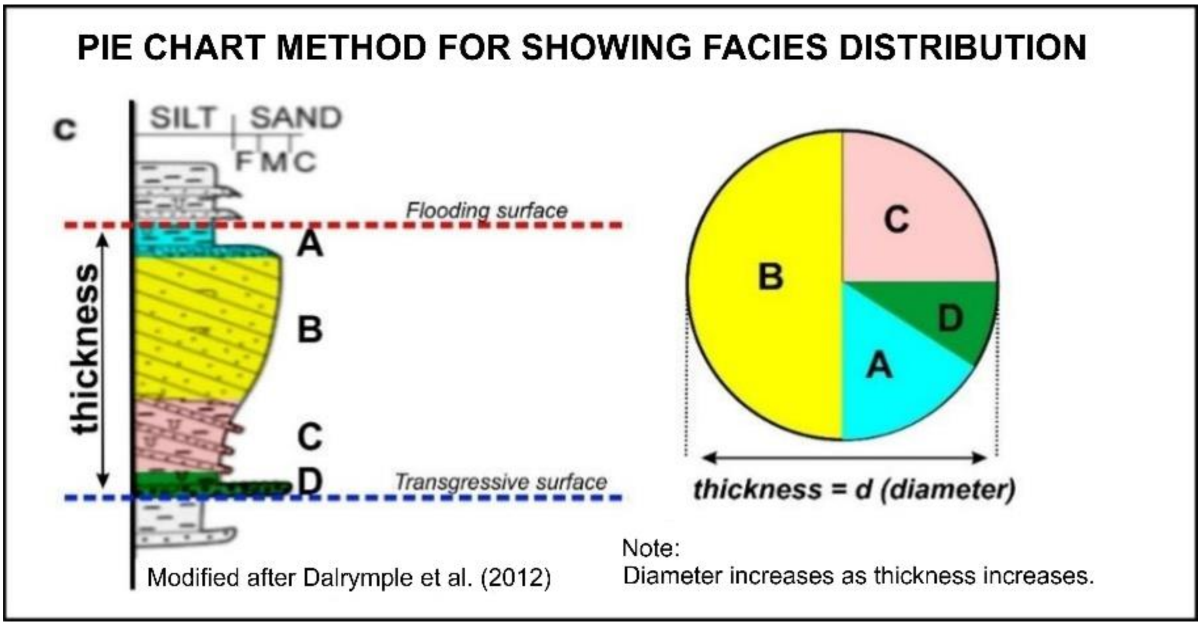

Figure 4: *Pie chart methodology applied used in this study.*

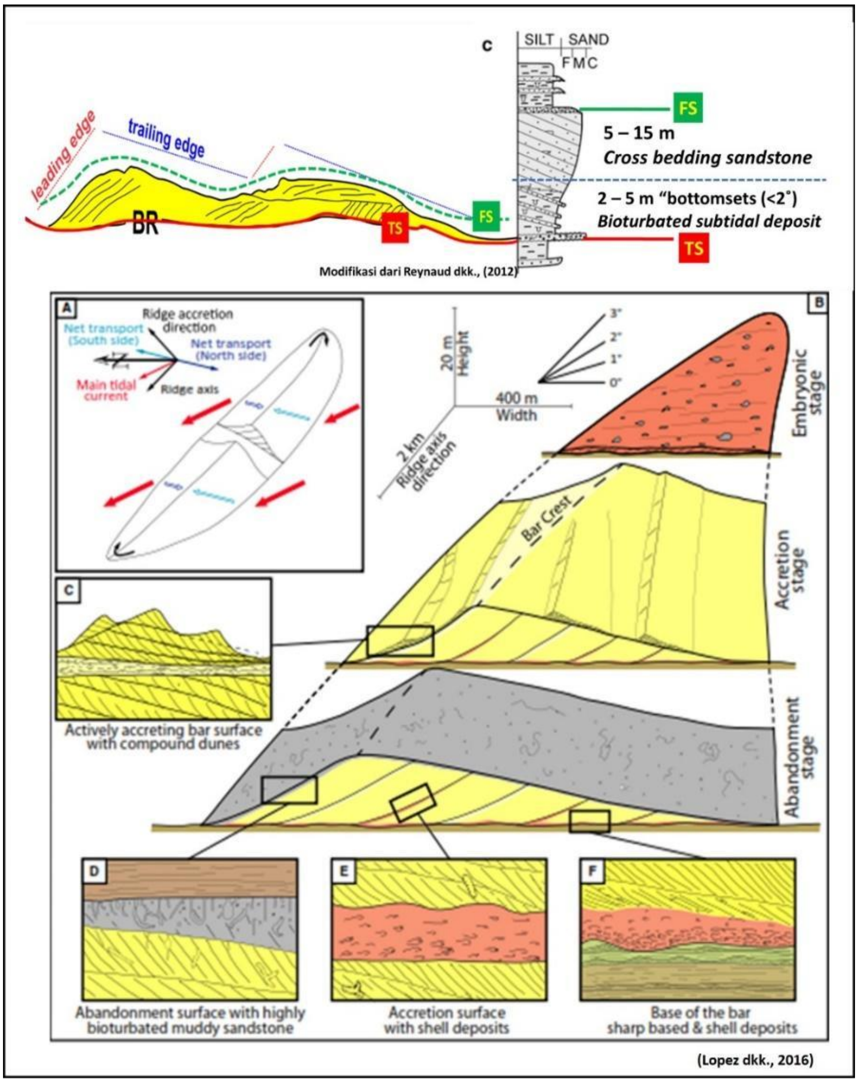

Figure 5: *Tidal Shelf Ridges Morphology and Development Stages (modified after Dalrymple et al., 2012 and Lopez et al., 2016).*

accretion, and abandonment (Figure 5). These three stages are represented by facies associations reflecting two fundamental aspects: reservoir quality and geometry of the facies associations.

RESULT AND DISCUSSION

Tidal Shelf Sand Ridges Lithofacies Interpretation

The description of the core data in the Upper Cibulakan Formation results in six lithofacies (Table 1): claystone-siltstone, calcareous sandstone, lenticular siltstone, flaser sandstone, non-calcareous “massive sandstone”, and cross-bedded sandstone.

Table 1. *Lithofacies “analysis result based on core data in Ajata Field*

No	Lithofacies	Characteristics	Remarks (ft MD)
1	Calcareous sandstone	Calcareous shell fragments; Siltstone-sandstone clastics	▪ LC-2: 2516’-2517’, 3304’-3305’, 3368’-3371’ ▪ LJ-1: 2437’-2438’, 2452’-2453’, 3328’-3330’ ▪ LQB-2: 4871’-4873’ ▪ LZC-2: 3319’-3201’
2	Claystone-siltstone	Massive; Bioturbation	▪ LC-2: 2513’-2515’, 3287’-3295’ ▪ LJ-1: 2446’-2451’, 2606’-2615’, 2570’-2575’, 2558’-2564’
3	Lenticular siltstone	Lenticular sedimentary structure; Bioturbation	▪ LC-2: 2448’-2452’, 2508’-2514’, 2683’-2685’, 3409’-3415’ ▪ LJ-1: 2444’-2446’, 2602’-2606’ ▪ L-3: 2421’-2423’, 2433’-2442’ ▪ L-2: 2260’-2262’ ▪ LQB-2: 4861’-4864’ ▪ LZC-2: 3452’-3455’
4	Flaser sandstone	Flaser sedimentary structure	▪ LC-2: 2446’-2448’, 2506’-2508’, 3281’-3287’, 3307’-3319’, 3381’-3385’, 3393’-3398’ ▪ LJ-1: 2443’-2444’, 2567’-2569’, 3293’-3295’, 3318’-3321’ ▪ L-3: 2420’-2422’ ▪ L-2: 2661’-2663’ LQB-2: 4879’-4886’, 4892’-4900’, 4857’-4861’ ▪ LZC-2: 3209’-3215’
5	Non-calcareous “massive sandstone”	Massive (>1 m); Structureless	▪ LC-2: 2434'-2446', 2466'-2492', 2498'-2506', 3230'-3279 ▪ LJ-1: 2438'-2443', 2453'-2466', 2547'-2555', 2578'-2585', 3279'-3292' ▪ L-2: 2255'-2260' ▪ LQB-2: 3320'-3326', 3388'-3400', 4278'-4303', 4847'-4853' ▪ LZC-2: 3202'-3209'
6	Cross-bedded sandstone	Cross-bed sedimentary structure	▪ LQB-2: 4238'-4245', 4252'-4265'

Tidal Shelf Sand Ridges Facies Association

The lithofacies analysis based on the core data from the Ajata Field mainly shows a facies association deposited in the shallow marine environments (from foreshore to offshore area). The determination of the facies association from the analysis in lithofacies obtained from the Ajata Field refers to the facies association subdivision based on Lopez et al. (2016), subdividing the tidal shelf ridge deposits in the shoreface-offshore environment into three stages of formation: embryonic, accretion, and abandonment (Table 2). The stages represent facies associations of their constituent lithofacies.

Table 2. *Relationship between lithofacies, facies association, and reservoir character.*

Lithofacies	Facies association (Lopez et al., 2016)	Remark
Calcareous sandstone	Embryonic Abandonment	Non-reservoir
Claystone-siltstone	Embryonic Abandonment	Non-reservoir
Lenticular siltstone	Accretion	Reservoir (poor quality)
Flaser sandstone	Accretion	Reservoir (poor quality)
Non-calcareous “massive sandstone”	Accretion	Reservoir (good quality)
Cross-bedded sandstone	Accretion	Reservoir (good quality)

In the Ajata Field, the embryonic stage's facies association consists of calcareous sandstone and claystone-siltstone lithofacies. The embryonic facies association represents the initial stage of the formation of tidal shelf ridges, starting with the deposition of transgressive lag deposits followed by the deposition of claystone-siltstone lithofacies. The accretion facies association is the main stage of the growth of tidal shelf ridge morphology, characterized by an increasing rate of sediment supply, resulting in the formation of lens-shaped claystone-siltstone lithofacies, flaser sandstone, non-calcareous massive sandstone, and cross-bedded laminated sandstone. The abandonment facies association marks the cessation of deposition of tidal shelf ridge due to a decrease in sediment supply rate, characterized by calcareous sandstone resulting from calcareous cementation at the top of the shelf ridge and claystone-siltstone lithofacies (Figure 6).

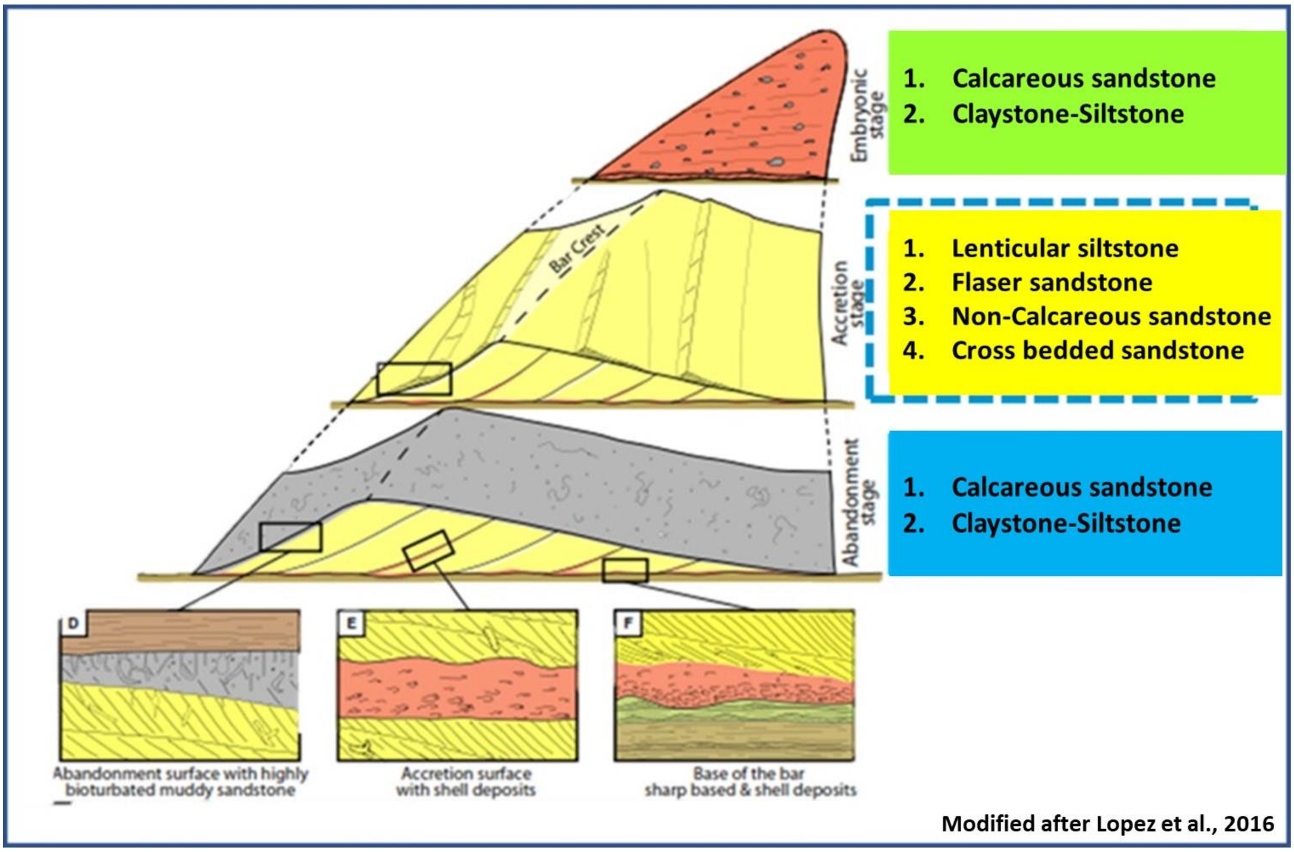

Figure 6: *Facies association determination and relationship (modified after Lopez et al. [2016])*

The flooding surface is the chronostratigraphic marker at the top of the abandonment facies association.

Depositional environment of the Northwest Java Basin during the deposition of the Upper Cibulakan Formation has a range of tidal currents with a macro to mega tidal type. It is reflected by the four lithofacies in this study area which comprise reservoirs: lenticular siltstone, flaser sandstone, non-calcareous massive sandstone, and cross-bedded sandstone. Lenticular siltstone and flaser sandstone indicate deposition dominated by tidal currents or tides. On the other hand, non-calcareous massive and cross-bedded sandstone are formed in a depositional environment with robust current systems due to wave action. These two depositional currents forming the Upper Cibulakan Formation indicate tidally modulated shore face (TMS) (Figure 7).

This study subdivides the accretion facies association of Lopez et al. (2016) into two categories: immature and mature accretions. Based on core data analysis, the deposition of the former facies' association is followed by the latter. Lithofacies constituting immature accretion facies association are lenticular siltstone and flaser sandstone, which are strongly influenced by tidal currents. This facies association is formed after the deposition of embryonic facies association and indicates an increase in sediment supply. Moreover, mature accretion facies association is deposited during intensifying fair-weather wave, and it is characterised by non-calcareous massive

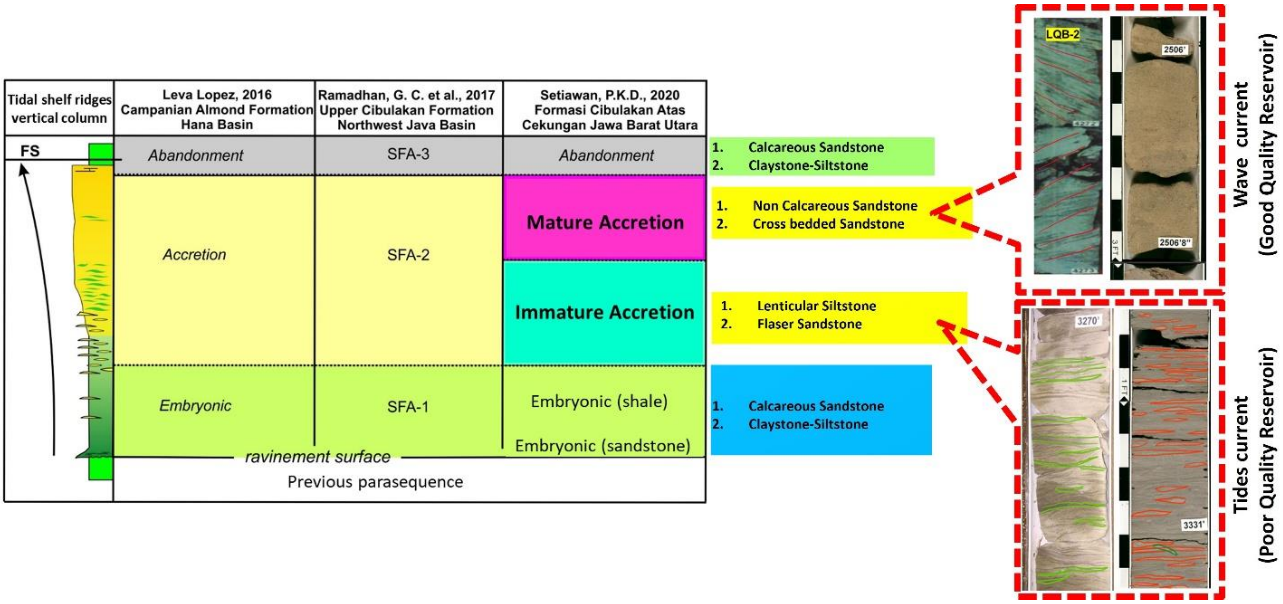

Figure 7: *Tidal shelf sand ridges facies association model compared with previous model.*

sandstone and cross-bedded sandstone lithofacies.

The immature and mature accretion facies associations show different reservoir characteristics. Immature accretion facies association displays high percentage of shale, resulting in poor quality reservoirs. Mature accretion facies association has good sorting and low mud content due to increased sediment washing, leading to good reservoir quality (Figure 7). Such sediment washing results from the combination of fair-weather waves, increased sediment supply, and macro to mega tides.

Tidal Shelf Sand Ridges Depositional Environment.

The depositional environment in the coastal area consists of several depositional environments controlled by the presence of wave and tidal currents. Dashtgard et al. (2012) subdivides the coastal environment into several zones: backshore, foreshore, upper shoreface, middle shoreface, lower shoreface, and offshore. Generally, the depositional environment developed during the deposition of the Upper Cibulakan Formation in the Ajata Field is the shoreface and depositional environments towards the land such as foreshore and backshore (Figure 8).

The embryonic facies association represents the initial deposition of tidal shelf ridges in the lower shoreface-offshore environment. The deposit of this facies association begins with subaqueous erosion during sea level rise in the lower shoreface area. The sediment supply rate during the deposition of the embryonic facies association is low, forming the domination of lithofacies with fine grain sizes, such as silty mudstone. The increased sediment supply rate and control from the tidal range lead to the deposition of the immature accretion facies in the middle shore face-lower shore face environment. The tidal process strongly influences from the lower to middle shoreface environment. The condition results in the formation of lithofacies with sedimentary structures characterized by tidal processes such as lenticular and flaser bedding. The continuous increase in sediment supply rate leads to the shallowing of the seabed. This situation leads to wave activity forming the mature accretion facies association. During the deposition of this facies association, the shoreface environment is mostly located in the upper shoreface-middle shoreface area (Figure 8).

Tidal Shelf Sand Ridges Total Porosity-Permeability Relationship.

There is a linear relationship between facies association, total porosity, and permeability as shown in the cross-plot in Figure 9. The mature accretion facies association has the best total porosity and permeability quality, followed by the immature accretion facies association. The immature and mature accretion facies associations are the main reservoir types in the Upper Cibulakan Formation. The embryonic and abandonment facies associations are categorized as non-reservoir facies associations.

The total porosity values in this study area range from below 15% to 38%, while the permeability is from 0.01 mD to 2000 mD (Figure 9). The mature accretion facies association has good reservoir quality with a range of total porosity from 21% to 38% and is dominated by a total porosity range from 31% to 35%. The permeability values based on RCA data in this facies association range from 100 mD to 2000 mD (Figure 9). The immature accretion total porosity range based on RCA data is 11% - 25%, with the most significant data dominance from 16% to 20%. The immature accretion facies association has permeability values below 100 mD (3 mD - 100 mD). The embryonic and abandonment facies associations are categorized as non-reservoir facies. These facies have the worst properties compared to the reservoir facies associations. The total porosity of the embryonic and abandonment facies associations is below

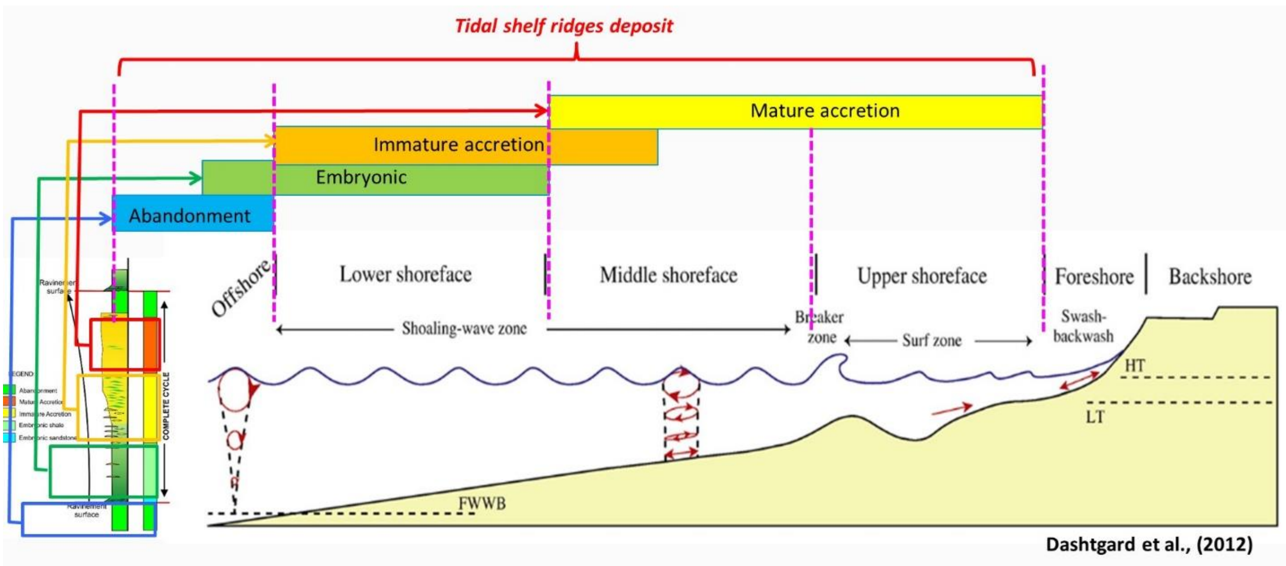

Figure 8: *Tidal shelf sand ridges depositional model (modified after Dashtgard et al. 2012).*

15% with permeability values of 0.01 mD - 5 mD (Figure 9).

Tidal Shelf Sand Ridges Vertical and Lateral Reconstruction.

The west-east stratigraphic section shows the morphology of tidal shelf ridge deposits, and it is perpendicular to the direction of sediment supply (Figure 10). The reconstruction of ridge morphology is conducted by flattening the chronostratigraphic markers below the reservoir interval, including transgressive and flooding surfaces.

The stratigraphic section of the tidal shelf ridges reservoir interval in the Ajata Field shows the configuration of several ridges. There are five to six ridges formed in each reservoir interval. The shelf ridges have widths ranging from 800 meters to 1,600 meters. The thickest part (leading edge) of each ridge has the potential presence of the mature accretion facies association, as found in the well sections LC-1, LC-2, LC-3, LB-1, LZ-3, and LZC-5. The thinnest area~~s~~ (trailing edge) between the ridges of the tidal shelf ridge deposits ~~are~~ dominated by the immature accretion facies association, as observed in well L-1, interval reservoir LRS-22A (Figure 10).

The reconstruction analysis in the LRS-22B interval shows the presence of five ridges constituting the LRS-22B reservoir. The mature accretion facies association appears at the uppermost part of the ridge. Mature accretion facies association of the tidal shelf ridge deposits indicates more intensive wave action during deposition. On the other hand, the immature accretion facies association mainly occurs in the thinnest part of the tidal shelf ridge deposits. This thinnest area represents the deepest area during deposition coeval with less wave influence

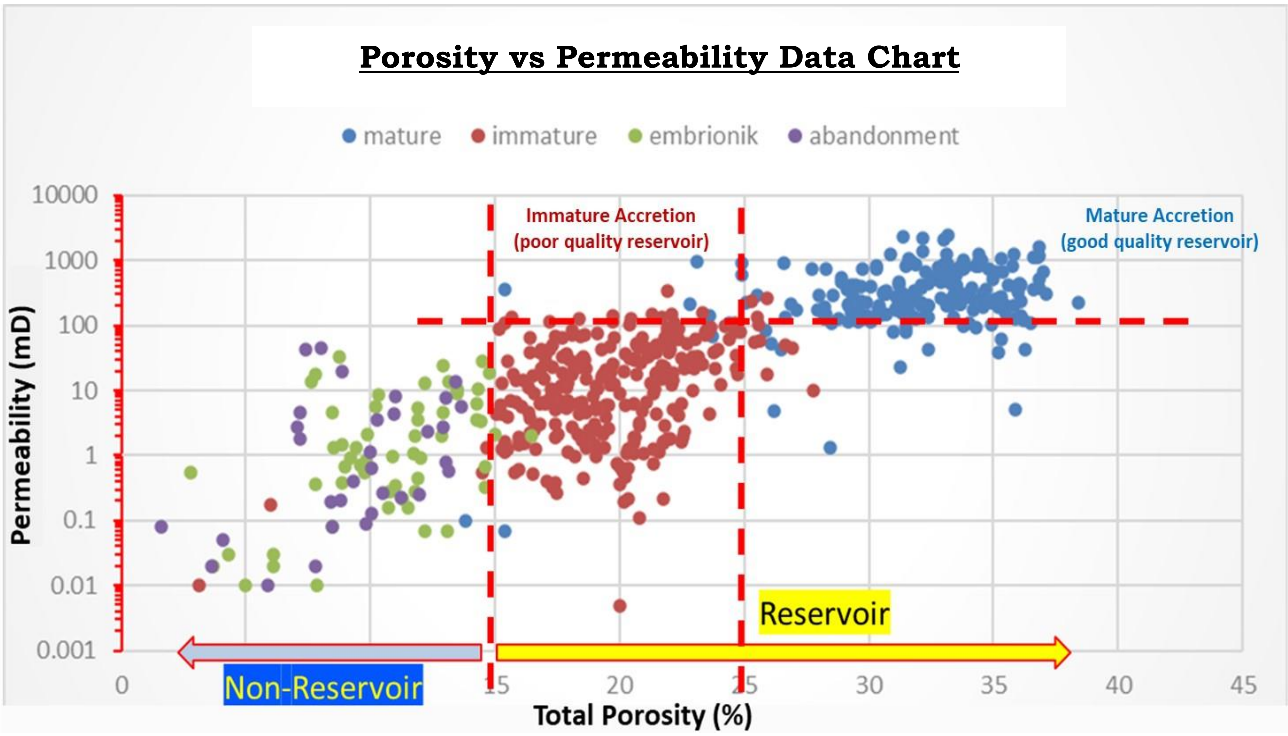

Figure 9: *Facies association, total porosity and permeability relationship based on RCA data in the Ajata Field.*

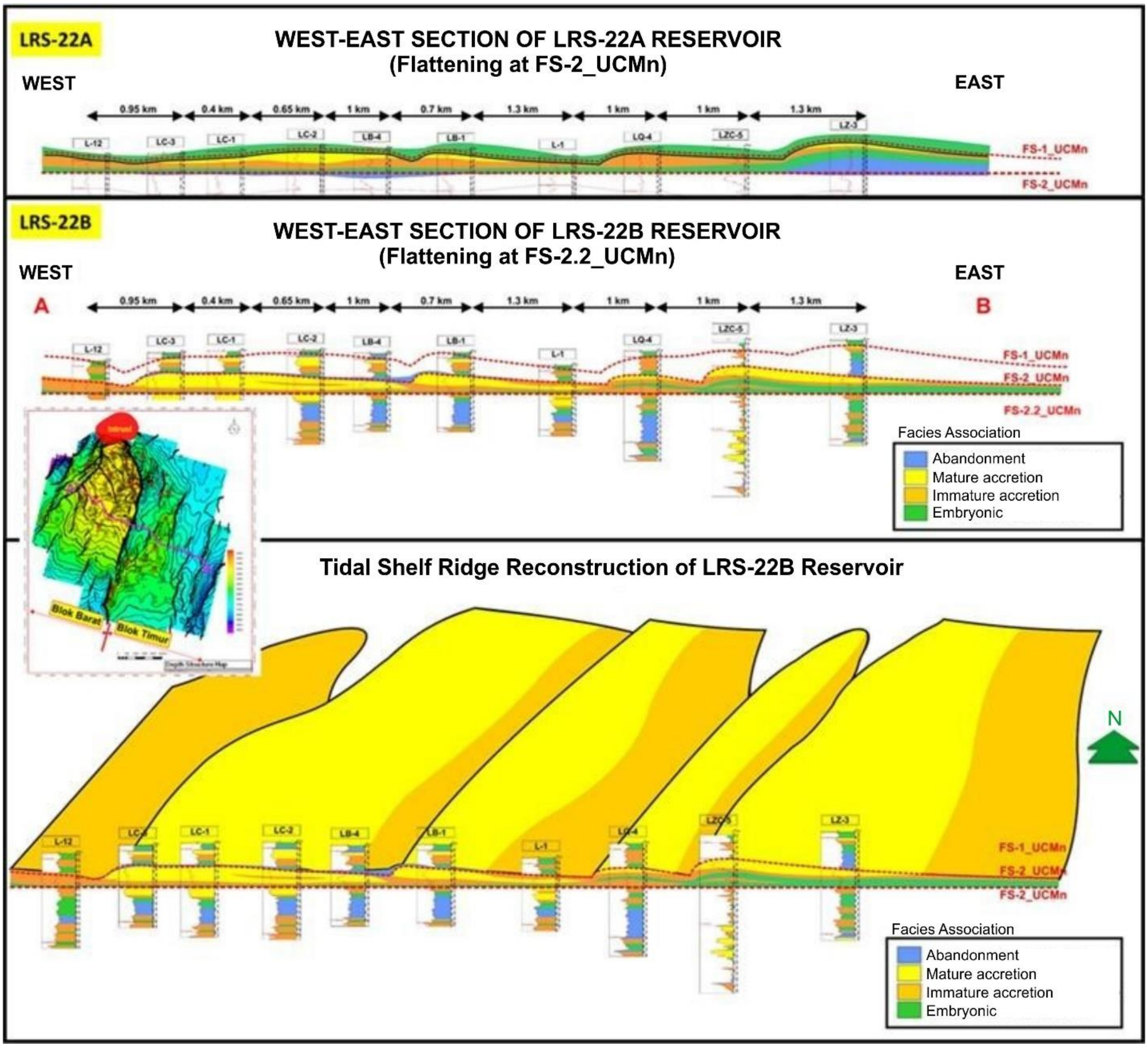

Figure 10: *Stratigraphic cross-section and tidal shelf sand ridges reconstruction in Ajata Field*

and more dominance of tidal currents. (Figure 10).

The reconstruction of the LRS-22A tidal shelf ridge sequence (Figure 11) is constrained by the chronostratigraphic markers at the bottom and top, which coincide with the top of the sandstone reservoir. The correlation results from these markers are presented as pie charts in each well penetrating the reservoir interval. The diameter of the pie chart reflects the vertical thickness or true vertical thickness (TVT) between the two markers that bound the reservoir interval. The filled color segments inside the pie chart represents the thickness ratio of each facies association of the parasequence. The tidal shelf ridge deposits are characterized by large-diameter pie charts at the crest of the ridges and small-diameter pie charts in the inter-ridge valleys.

The distribution map of the facies association pie charts (Figure 11) shows five prominent ridges that form the LRS-22A reservoir deposit. The dashed blue lines in the image represent the straight lines of the valleys that form the boundaries between the two ridges. The trend of the ridges is northeast-southwest with a slope angle of about N12°E. The width of each ridge ranges from 800 m to 1,500 m. The direction derived from the pie chart map is used to create the parasequence isopach map. The thickness of the parasequence ranges from 5 ft to 40 ft. The inter-ridge valley areas have thickness range from 5 ft to 15 ft, while the ridge crest has thickness from 30 ft to 42 ft (Figure 11).

The facies association ratios displayed by the color segments in the facies association pie charts are used to control the distribution of the LRS-22A tidal shelf ridge facies associations. In the Ajata

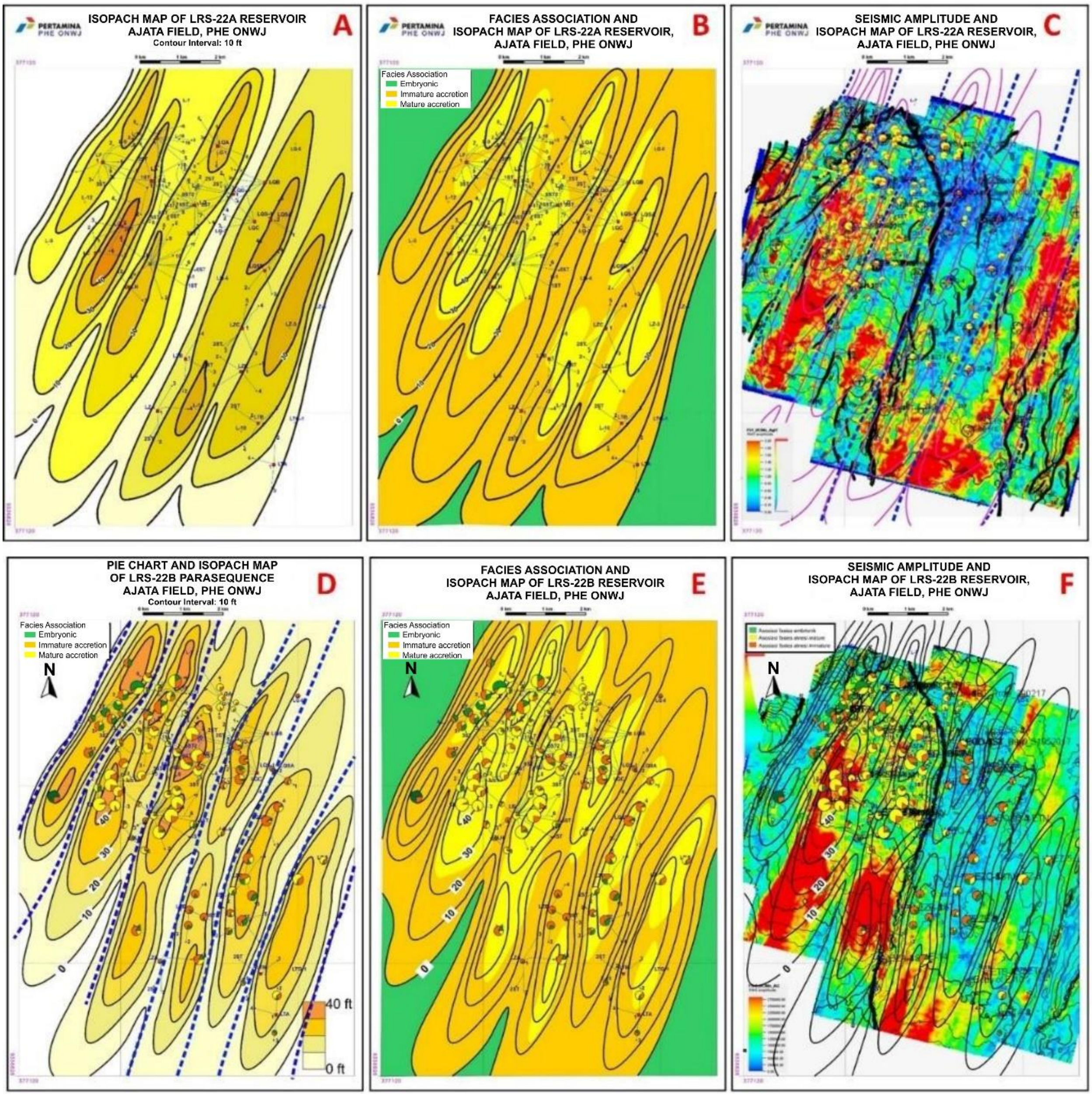

Figure 11: *Isopach and facies association reconstruction of tidal shelf sand ridges deposit in Ajata Field*

Field, the immature accretion facies association in the LRS-22A zone is widely distributed. The mature accretion facies association is mainly located at the crest of the ridges and does not extend into the inter-ridge areas. The distribution of the embryonic or non-reservoir facies association is interpreted to be located south of the study area or basinward. The distribution of the embryonic facies association in the western and eastern parts of the study area is interpretive due to the wells data absence in those areas (Figure 11).

Seismic amplitude attribute data from the LRS-22A sequence is overlain by the tidal shelf ridges thickness map to determine the qualitative relationship between the thickness (isopach) map and the seismic attribute data (Figure 11). Figure 11 shows that several ridge trends, such as in the western and eastern parts of the study area, coincide with seismic amplitude data. The overlay result shows several ridge trends of the LRS-22A tidal shelf ridges visible in the seismic amplitude data, such as in the western and eastern parts of the study area. The seismic attribute quality is good in the western-southwestern and eastern parts of the study area. Conversely, seismic data with poorer quality is observed in the central and northern parts of the study area due to the presence of closely spaced production platforms, which affected the seismic acquisition process conducted in 1996. Generally, the LRS-22A tidal shelf ridge distribution trend is towards NNE-SSW (north-northeast to south-southwest) with a trend angle of 12° relative to the north direction (Figure 11).

Tidal Shelf Sand Ridges Vertical Heterogeneity and Facies Association Cyclicity

The analysis of core data, RCA data, and well log data in the Upper Cibulakan Formation interval in the Ajata Field, Northwest Java Basin, shows the vertical variation of facies associations that make

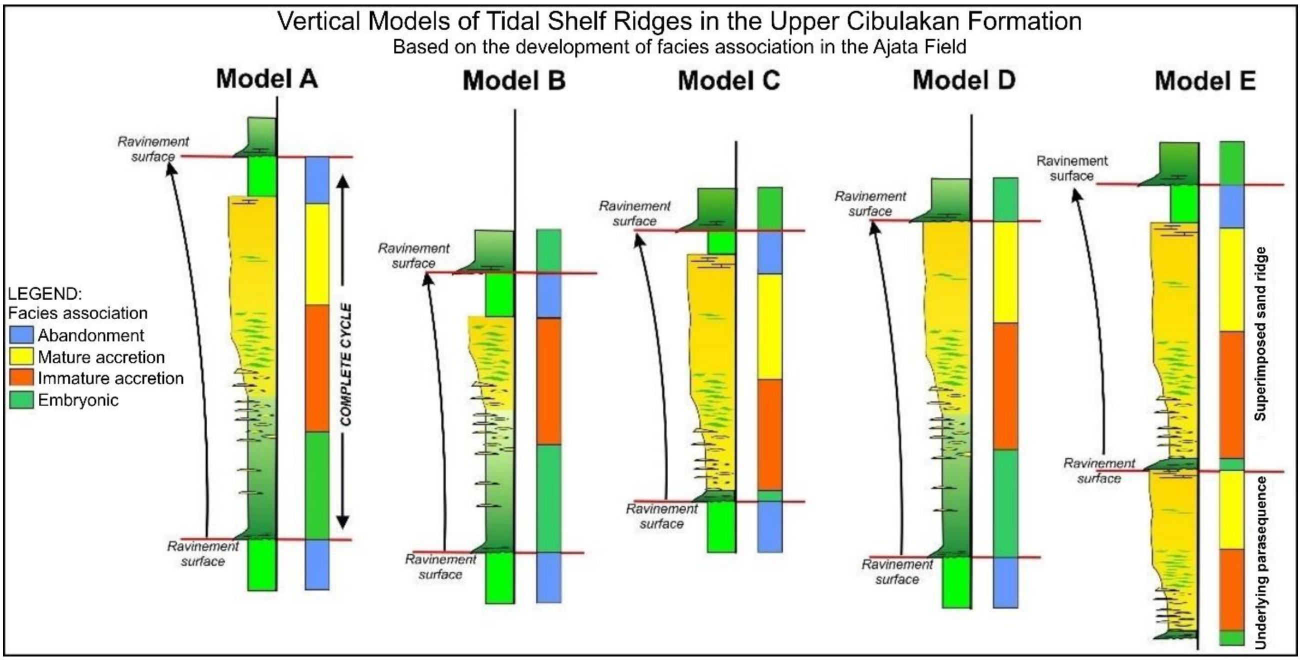

Figure 12: *The Upper Cibulakan Fm. tidal shelf sand ridges vertical cyclicity model in Ajata Field.*

up the tidal shelf ridges sedimentary parasequence. The four facies associations are embryonic facies, immature accretion facies, mature accretion facies, and abandonment facies associations. These four facies associations form cycles or sequences within the tidal shelf ridge sediment, starting with the presence of the transgressive surface (TS) and ending with the flooding surface (FS) chronostratigraphic markers. The vertical heterogeneity of the tidal shelf ridge deposits is reflected by these facies associations within each parasequence. The cyclicity of the facies associations in the tidal shelf ridge deposits reflects changes of currents during deposition, starting with tidal currents and ending with wave control at the crest of the ridges, while tidal currents occur in the inter-ridge valleys.

The results of facies association propagation based on un-cored wells in the Ajata Field (Figure 12) reveal five main models of vertical succession within each cyclicity of the tidal shelf ridge sedimentary sequence. Model "A" depicts a cyclicity with the accumulation of intact facies associations, starting with the presence of the embryonic facies association, followed by the immature accretion facies association, the mature accretion facies association, and the abandonment facies association as the top layer in each cycle. The "A" model parasequence occurs at the top or thickest part of each ridge because this area is more likely to be influenced by wave currents during deposition.

Model "B" shows incomplete accumulation within a tidal shelf ridge parasequence. The mature accretion facies association is missing in the parasequence body. Model "B" parasequence (Figure 12) reflects the absence of wave influence during deposition. The model possibly formed in several conditions, such as during relatively small sediment supply rate, deposition in basin-ward position, and deposition in the inter-ridge valley. Dashtgard et al. (2012) states that the absence of wave influence during tidal shelf ridge deposition reflects a tidally influenced shore face environment. Parasequence of model "B" forms reservoirs with poor quality.

Model "C" (Figure 12) represents the absence of the embryonic facies' association within the arrangement of tidal shelf ridge parasequence. This condition occurs when there is a significant sediment supply rate immediately after the formation of transgressive surface, resulting in the absence of fine-grained sediments. The possible location for this arrangement is the area close to the sediment supply (landward).

Model "D" (Figure 12) is characterised by the absence of the abandonment facies association as the top layer of the cyclic tidal shelf ridge parasequence. This model occurs when the deposition of the tidal shelf ridge parasequence ceases relatively quickly and is immediately overlaid by a new parasequence. The location that allows the formation of this model is in the high ridge area close to the sediment supply for the subsequent tidal shelf ridge parasequence or relatively landward.

Model "E" (Figure 12) is a combination of the "D" and "C" models, forming a vertical succession without the presence of the embryonic facies association as a separator between the parasequence. The

"C" parasequence will directly overlie the "D" parasequence. Posamentier (2002) describes this stacking model as a superimposed shelf sand ridge, and these two parasequences will form a single reservoir because they have vertical connectivity.

Tidal Shelf Sand Ridges Deposit Width-Thickness Ratio

The geometry of valleys and ridges firmly controls the lateral distribution patterns of tidal shelf ridges facies associations. The width of each ridge is determined by several factors, such as the rate of sediment supply, paleomorphology, and the depth of the fair-weather wave base (FWWB) during deposition. Embryonic facies associations form in a wide area. The immature accretion facies associations have a relatively extensive spread, forming ridges perpendicular to the shoreline. The geometry of mature accretion facies associations generally forms in the peak areas of the ridges. Abandonment facies associations are widely distributed and relatively thin out landwards.

The cross-plot analysis of the parasequence thickness data with the width of tidal shelf ridges in the Ajata Field can be seen in Figure 13. The cross-plot analysis shows a nearly linear relationship between the parasequence thickness data and the width of the tidal shelf ridges, with a correlation coefficient of 0.55. Based on the cross-plot, the equation for determining the width of the parasequence tidal shelf ridges in the Upper Cibulakan Formation is as follows:

$$Y = 17{,}482\ (X) + 385.2$$

Y represents the width of the ridges in meters.

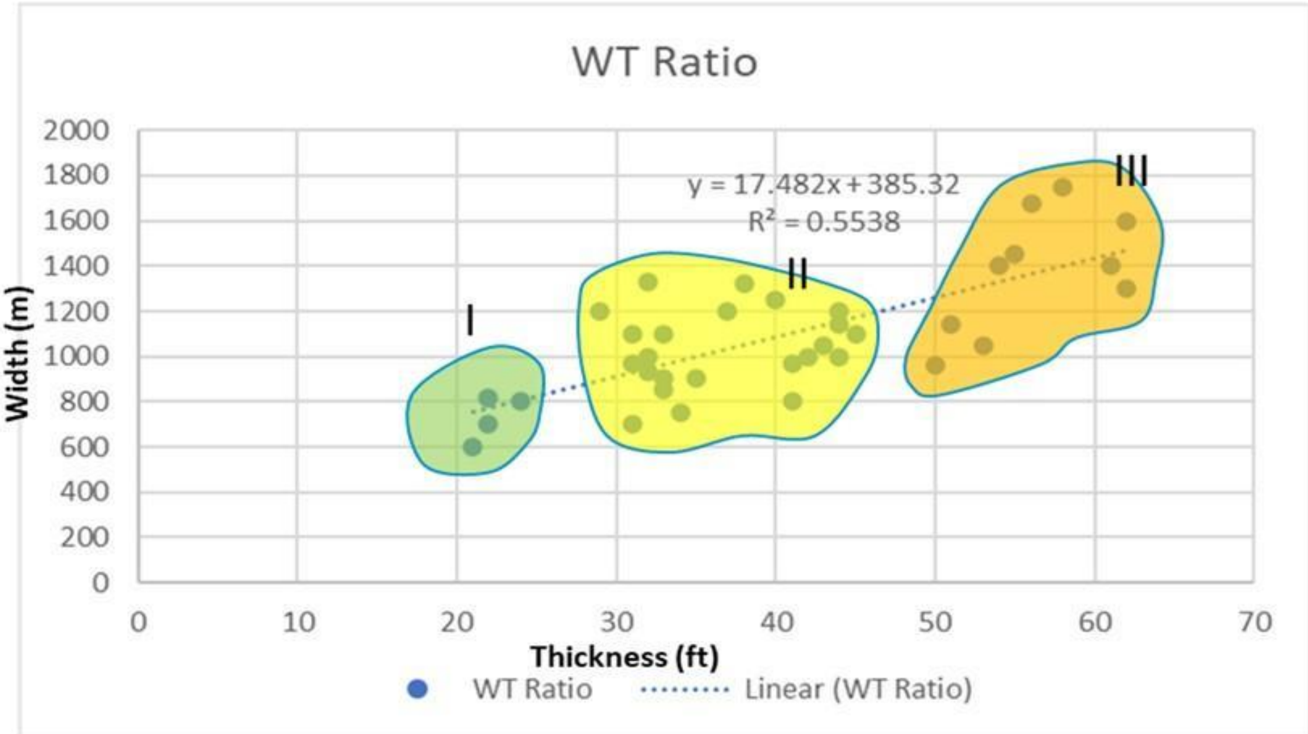

Figure 13: *Tidal shelf sand ridges width-thickness ratio in Ajata Field.*

X represents the thickness of the parasequence in feet (ft).

The equation can assist in analysing the tidal shelf ridges parasequence deposit in the Upper Cibulakan Formation that have limited well data or low-quality seismic attribute data. Based on the graph above, three main zones indicate the relationship between ridge width and parasequence thickness. Zone "I" is characterized by areas with parasequence thickness < 25 ft and ridge widths ranging from 600 m to 800 m. Zone "II" has parasequence thickness between 28 ft and 45 ft, with potential ridge widths ranging from 700 m to 1300 m. Zone "III" is the zone with parasequence thickness > 50 ft, and in this zone, the range of tidal shelf ridges width is from 1000 m to 1900 m. As the thickness of the tidal shelf ridge increases, the width of the ridges also rises (Figure 13).

The mature accretion facies association exhibits a distinct pattern, mainly found at the peaks of the ridges. The relationship between the thickness and width of the mature accretion facies association in the Ajata Field shows three trends (Figure 14): P90 (low case), P50 (best case), and P10 (high case). The correlation coefficients between mature accretion thickness and facies width have ranged from 0.81 to 0.90. These conditions indicate a strong relationship between thickness and width for each P90, P50, and P10 trend. The trends (P90, P50, and P10) can be used to determine the dimensions of the mature accretion facies associations in other fields with similar depositional settings. These formulas can also be applied to construct static uncertainty models for

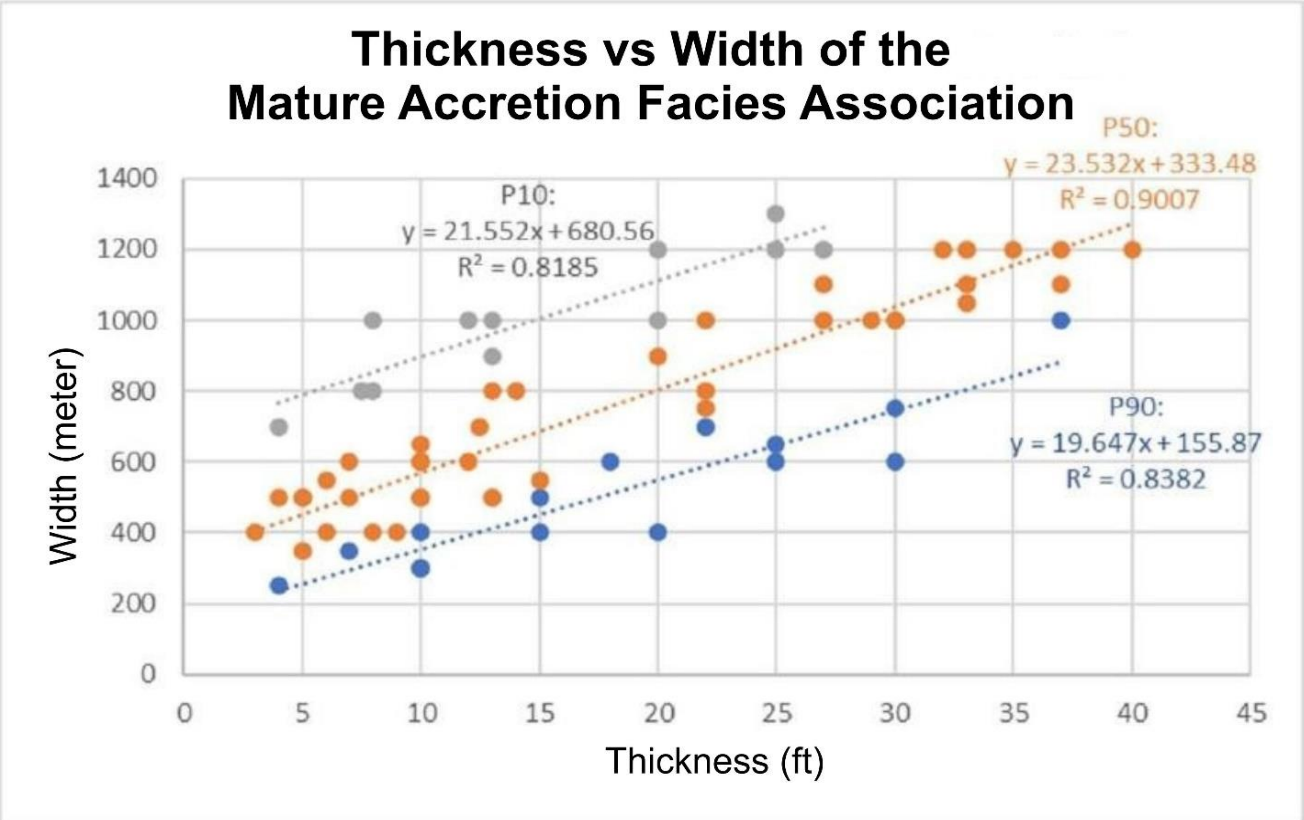

Figure 14: *Mature accretion facies association width-thickness relationship (x axes is thickness in ft, y axes is width in m)*

the same reservoir type in different areas (Figure 14).

CONCLUSIONS

Conventional core data of the tidal shelf sand ridges within the Upper Cibulakan Formation shows six lithofacies forming four facies associations.

The facies associations generating the deposits of parasequence tidal shelf sand ridges are embryonic, immature accretion, mature accretion, and abandonment facies association.

These four facies associations form tidal shelf sand ridge deposits and exhibit cyclic variations within each ridge.

The associations between immature and mature accretion facies form reservoir rock sequences in the Upper Cibulakan Formation. The immature accretion facies association creates low-quality reservoirs, while the mature accretion facies association constructs a good-quality reservoir.

There are three zones of width thickness ratio for the parasequence tidal shelf sand ridges, namely Zone I, II, and III. Cross-plot of the thickness and ridge width shows a relatively linear relationship.

Cross-plot between thickness and reservoir width of the mature accretion facies association reveals P90, P50, and P10 trends.

The zonation of width thickness ratio for the tidal shelf sand ridges parasequence and the thickness-width relationship trend of the mature facies association can be applied to predict sand distribution of similar deposits of tidal shelf sand ridges in the other fields or basins.

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