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Applying Multi-Point Statistical Methods to Build The Facies Model for Oligocene Formation, X oil field, Cuu Long basin

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Abstract:
Multi-point statistic method (MPS) can overcome the inherent disadvantages of traditional method based on Variogram and Object modeling, simultaneously allows the modeling progress becomes more flexible and rational. The algorithms based on variogram and gridding geological model are able to control the final result under the collection of samples data (well data) and another corresponding data (seismic). Though, these methods have trouble in modeling the shape of geological features. Then, object modeling method can generate digitized geological features with responsible shapes, conversely a final result in accordance with an input data is difficult to achieve. Combining the advantages of two mentioned methods, MPS describes the relationship of data in space based on the group of adjacent points or has a certain relationship, it allows the generation of digitized geological features corresponding with responsible shapes, moreover it is able to control the final result under a collection of input data (whose nature is still the pixel-based).

The Oligocene reservoir, X Field was formed in fluvial/ lacustrine, sedimentary mainly deposited in Northwest – Southeast, which is primarily affected by latitude – sub-latitude faults system. An Oligocene facies model of X Field is built based on MPS, it will show the geological features more clearly than the existing one. It also shows the remarkable ability on control the final result. MPS allows to combine a lot of different data (geology, seismic, outcrop,…) with the geological viewpoints are shown by training image, itself proves the superiority over traditional methods. Duration of each model simulation is approximately 3000 seconds and huge size (over 15 million cells), it is better while compared with 1717.8750 seconds in case of sequential simulation by SISIM method and default properties.

Keywords: Multi-Point Statistic, Facies Model, Training Image, Sedimental Environment, Sequential Indicator Simulation.

INTRODUCTION

Based on assessing the shortcomings of X field's current facies model, multi-point statistics method was used to generate X field facies model because of the following reasons:

- Multi-point statistics is a graphically modeling method which allows controlling resulting model effectively [1].
- Multi-point statistics is a graphically modeling method which allows controlling resulting model effectively [1].
- Training image is a more advanced algorithm than variogram in describing the spatial relationship of data,it also allows geological ideas to be added into the model (which has not been fully utilized in current facies model) [3].
- Basically, multi-point statistics method is well-known as a pixel-based method allowing a better control of the resulting model with well data [3].

In this study, authors focused only on clarifying and generating facies model for Upper Oligocene - C Reservoir.

X field facies characteristic analysis

Data base and Research method

Data base

Studying on characteristics of X field is based on the following data:

- Researched results on Cuu Long basin depositional environment charateristics.
- 3D seismic data of X field in deep zone **(**Time Domain**)**.
- Seismic interpretation results of C reservoir's top and bottom in deep zone.
- Well log data , from 1X to 7X in X field.
- Core sample analysis data of OligoceneX field.

Reseached method

- The process of facies analysis in X field has been conducted from a narrow to a wide range, illustrated by Figure 1:

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- Research on facies characteristics - depositional environment of Oligocene reservoir in Cuu Long Basin in general and block 16-1 in particular.
- Restore the ancient terrain of C reservoir's formation to determine anancient flow direction.
- Analyze and evaluateseismic attributes for signs of geological formations.
- Analyze the core samples data to determine such individual sedimentary facies in wells.
- Calibrate well log data with core analysis data to interpretethe sedimentary facies along the well.

Geological study

Geological studies of Cuu Long Basin showed the depositional environments in Late Oligocene were lakes and rivers [8]. In Block 16-1, studies indicated that during the formation period of C reservoir, the depositional environment is predominantly Fluvial Plain, into a saltwater or nearby sea [8]. A good interpreted image data within exploratory wells showed that depositional orientation was about 165^0. Based on the structural map of the main layers, the authors performed the restoration of paleo-geological features for the beginning and the end of the C reservoir 's formation process. Based on these results, it should benoted:

- The topography during C reservoir's formation period was markedly steep toward southeast. Specifically, the depositional orientation during this period was 165^0following the interpreted imaged result.
- At the beginning of C reservoir's formation process, there was a very steeply sloping strip spreading along the southeastern part of the study area (Figure 1). This part was no longer visible at the end of Late Oligocene (Figure 2). This is where a sudden reduction of flow energy appeared, which might represent the transitional area of depositional environment lakes and rivers.

In global, the literature review for most of lakes and rivers environment showed some relationship in size between depositional environment as follows [7]:

- Thickness ratio: The average width of the channel has a meandering degree of about 1:50 (Figure 3).
- Width ratio: crevasse splay thickness is less than 1500.
- Length ratio: The average thickness of crevasse splay is less than 2000.

This information will be used during generating training image and sequencing modeling.

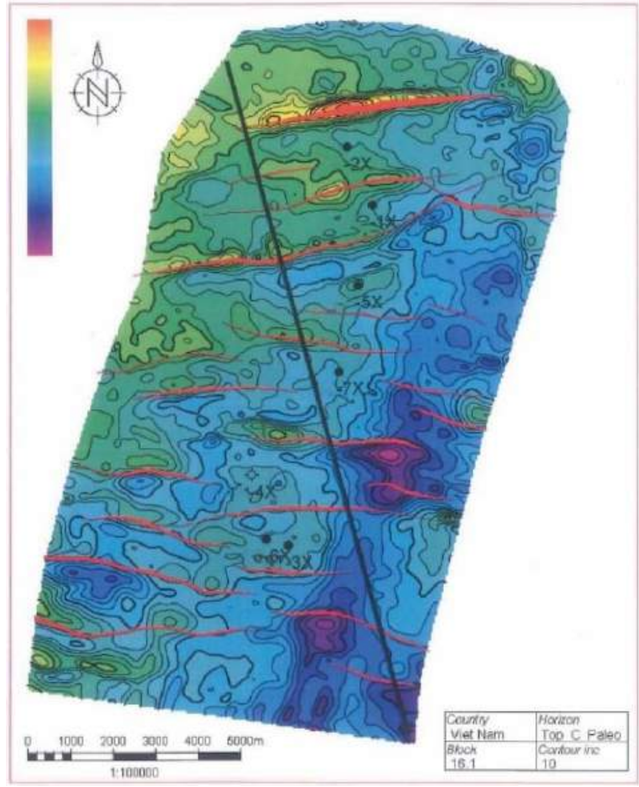

Figure 1. Topography map of early formation period of C reservoir

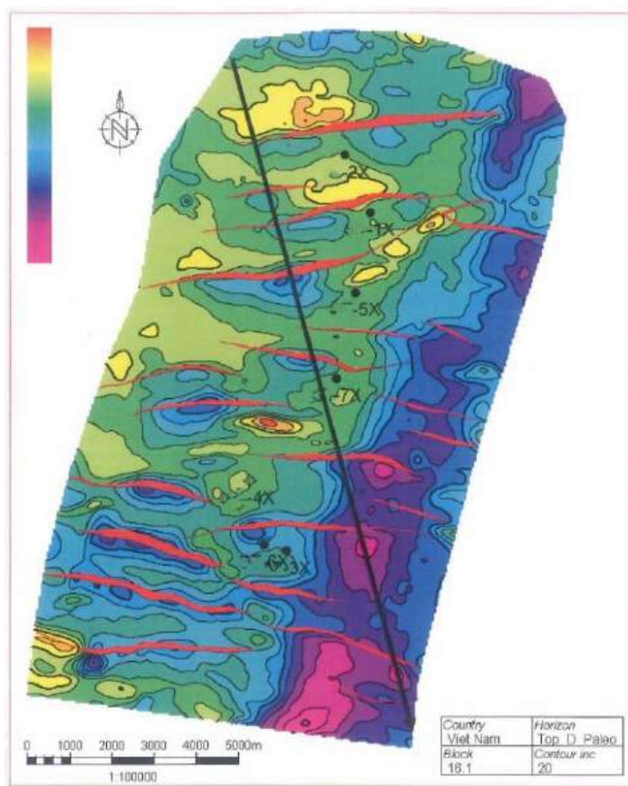

Figure 2. Topography map of late formation period of C reservoir

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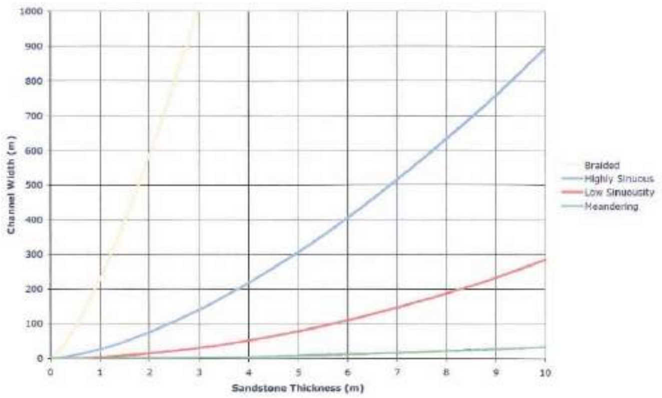

Figure 3. Emperical relationship between thickness and width of Channel[7]

Core analysis

In general, the C reservoir depositional environment is defined as a river-lake. Based on modern sedimentary description, sedimentary facies of the lakes and rivers include seven typical sedimentary facies: Channel Fill, Levee, Crevasse Splay, Mouth Bar, Sheet Flood, Soil, Overbank. The core sampled only in 4X well, at depths of 3144.5 -3171 mSSTVD. The environment is defined as alluvial plain, with 6/7 of these typical sedimentary facies recorded (Figure 4):

- 3144.5 - 3152.7 mSSTVD: This is explained as a set of thin sheet flood layers, overlaid on a fill channel and fine-grained overbank.
- 3152.7 - 3157.15 mSSTVD: This is interpreted as a coarse-to-fine channel fill, covering the soil.
- 3157.15 - 3163.65 mSSTVD: This is a set of channel fillings covered by overbank and localized by soil. Soil in depth 3159.15 SSTVD has the appearance of calcite cement, which may be a sign of a long period without sedimentation.
- 3163.65 - 3168.7 mSSTVD: This is interpreted as sheet flood due to the presence of unspecified sandstone, depositing very rapidly. This flood sheet is topped up by overbank, with some signs of chiselling.
- 3168.7 - 3171.0 mSSTVD: This is interpreted as sandstone channel fill.

In general, Soil and Overbank have the same characteristics with the medium-poor reservoir, exclusive the degree of change after sedimentation. For the sake of simplicity, they are considered as one, collectively referred to as Overbank, to refer to fine-grained sediment deposition outside the Channel Fill, formed by a large water-spillage process that pulled fine particle sediment. In addition, with the fine particle size of the channel and the development of Soil, the study area is located in the meandering channel.

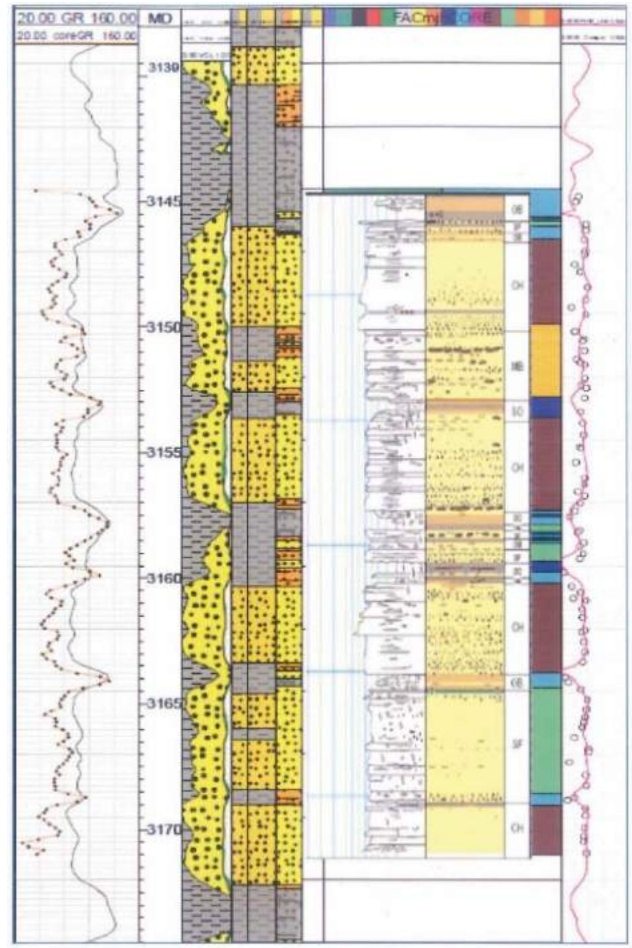

Figure 4. Core analysis result of C reservoir in 4X[7]

Seismic attribute analysis

Because X field has thickness below the resolution of the seismic wave, the volume-based attribute is not available used. Thus, the grid-based attributes were examined in an attempt to identify sedimentation features.

Based on the result of the analyzed seismic attributes, the Sum of Negative Amplitude attribute showed the sign of the Fann and Crevasse Splay in the southern part of the field (Figure 5). This result is quite consistent with the Splay Crevasse interpreted in C reservoir 4X, some important notes are:

- Channel's flow is generally North West – South East, in line with the general sedimental orientation within area. However, it is strongly influenced by the latitudinal fault system, so the near faulted zone tends to flow in the direction of West - East.
- The relative size of the geologic features: Channel Fill is about 700meters, Crevasse Splay is 2000meters long, 3000meters wide.

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- Channel is likely to expand toward East, with a maximum width of about 900meters. The expanded channel location coincides with the boundary between the two rivers and transboundary areas. The trend widen the flow in the river-lake transition zone to observe modern sediments, typically the Lago Poopó-Peru area (Figure 6), reinforces this view.

Because they are seismic attributes based on grid cells, they can not be used directly in facies model. However, these results also provide the size and direction of the Channel distribution within the study area. These information are useful when building scale and angle models later.

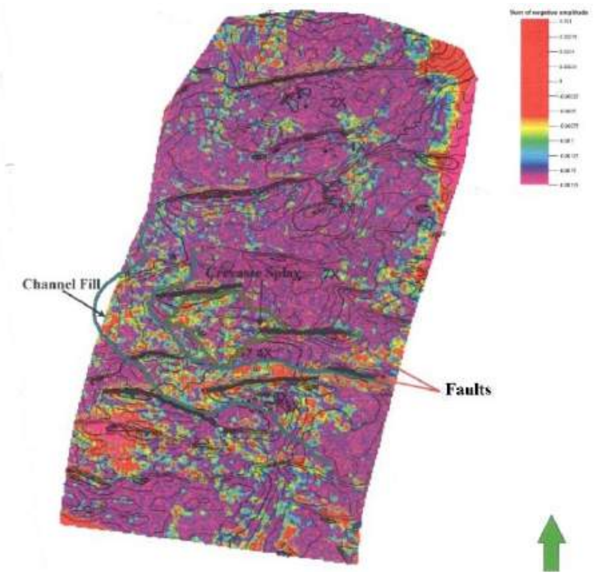

Figure 5. Channel image recorded by seismic attribute

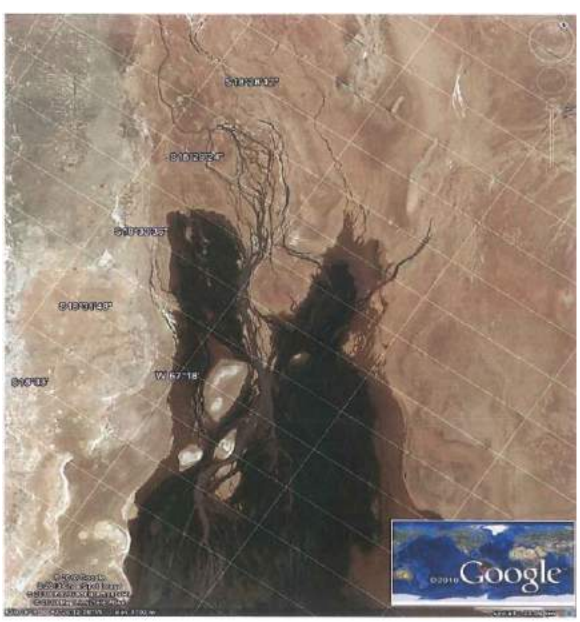

Figure 6. An example of flow expansion in the river-lake trasition area, observed at Lago Poopó Lake, Peru

Analysis and interpretation well log data

Although the description of core samples is always the most reliable data in sedimentary facies, due to the limited number of core samples, information on sedimentary facies

based on core samples are localized and fragmented. For this reason, well log data is used to provide more information of sedimentary facies along the well. This will generate more reliable values along the well to control the model results.

According to the results of the core samples, the sedimentary facies of C reservoir are consistent with well log characteristics (Figure 7):

- Soil and Overbank have similar log characteristics, with high Gamma Ray values.
- Sheet Flood is usually laminated between Overbank deposits, characterized by a Gamma Ray reduction.
- Channel Fill is characterized by an increase in Gamma Ray value.
- Mouth Bar is characterized by a gradual reduction in Gamma Ray value, lies above or laminated between Channel Fills.

Based on these characteristics, the corrections and the interpretation along 4X and from the other wells are conducted (Figure 8). According to the sedimentary facies recorded from the core samples, Crevasse Splay is interpreted, due to its presence on the seismic attributes. Crevasse Splay is characterized by a gradual reduction in Gamma Ray laminated between Overbank.

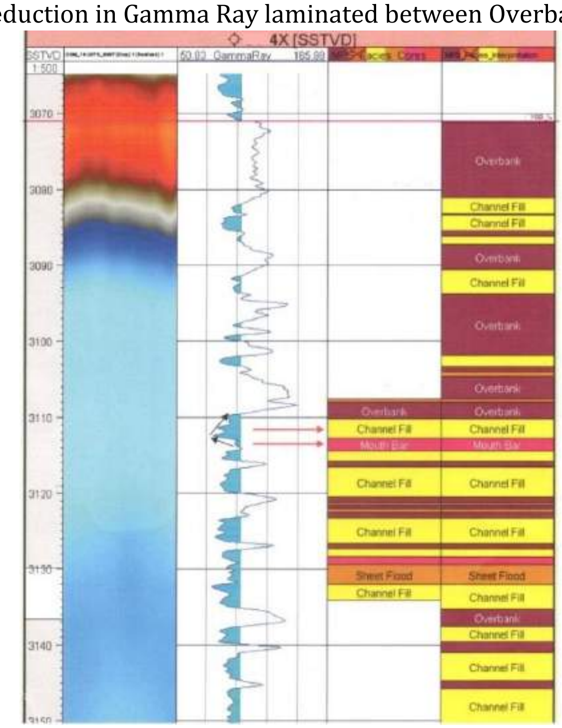

Figure 7. Comparision in facies interpretation result in 4X based on core data and Gamma Ray curve

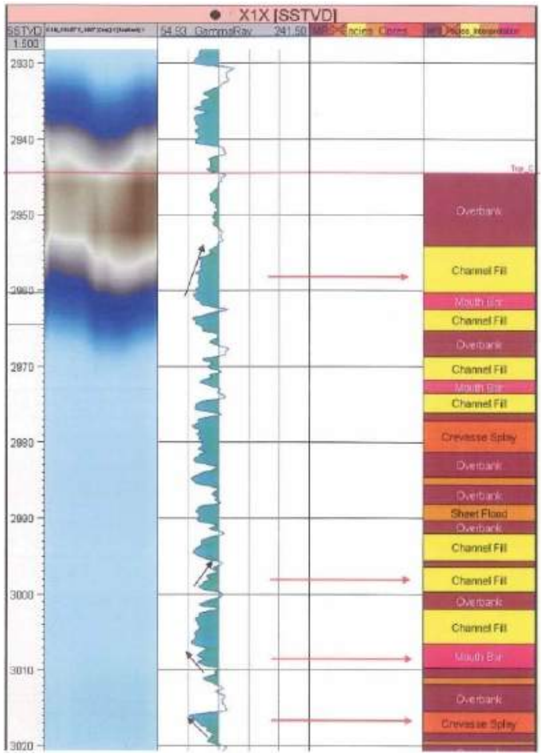

Figure 8. Facies interpretation result in 4X based Gamma Ray curve

Summary of Xstructural model

Fault system and stratigraphy model

Unlike the current X field geological model , in order to describe the distribution of sedimentary facies, the author decided to model the whole range of the field.

C reservoir fault model within X field is quite simple, including 23 parallel and subparallel faults, built on the basis of seismic interpretation. These faults mostly distributed independently, with only a few cases of intersection (Figure 9). This fault model serves as a framework for the structural model.

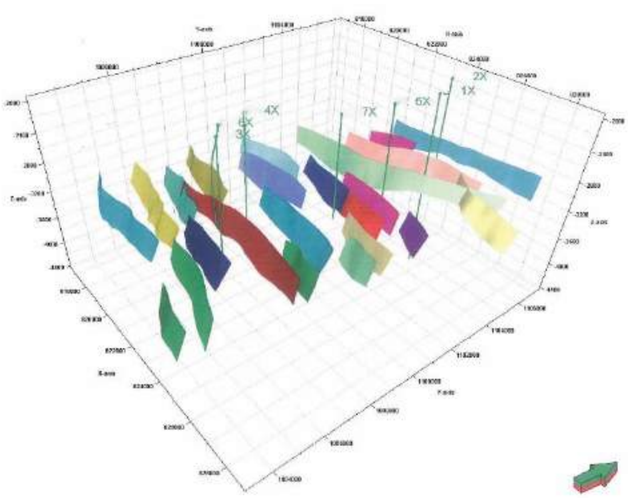

Figure 9. Fault model of C reservoir X field

Gridding

In horizontal plane, the model is divided into 100x100m grid cells (Figure 10). This grid size ensures the required level of detail of the model and has the number of grid cells to match the computing power of the computer.

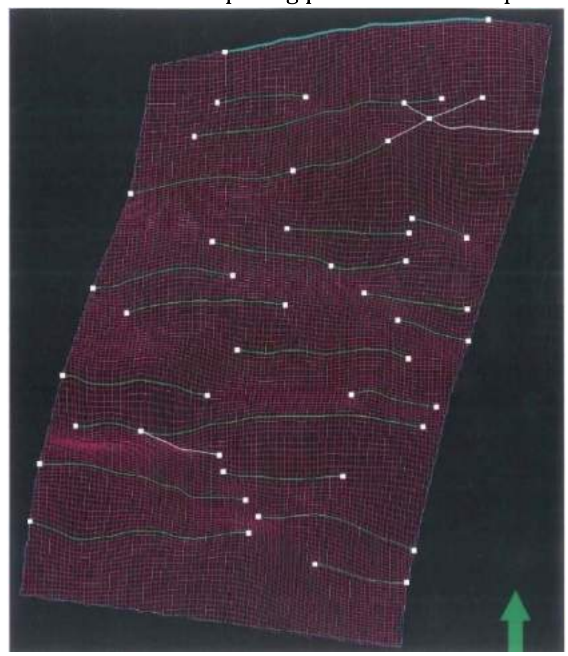

Figure 10. 100mx100m grid used in structural model of C reservoir X field

Modeling stratigraphic and layers

The stratigraphic model was generated based on the intepreted seismic result of layers C and D, calibrated with the well data. The results of the fault and stratigraphy model are compared and calibrated with the seismic data (Figure 11).

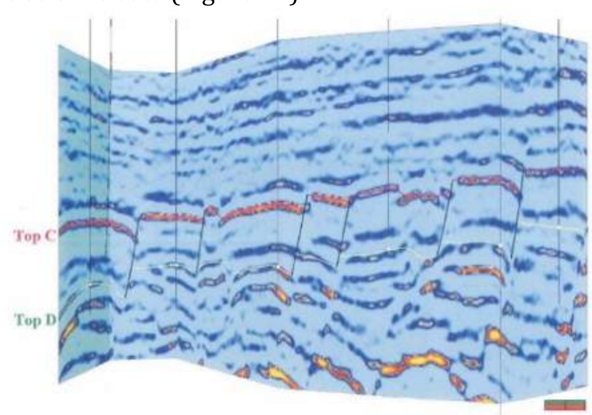

Figure 11. Comparison between facies and stratigraphy model to seismic data

In vertical plane, in order to select the thickness of the grid, several different parameters were conducted, then assigned the interpreted facies values along the 4X well to evaluate the heterogeneity retention capacity of facies corresponding to each thickness value. Accordingly, the selected grid thickness was 0.3 meters because this parameter well-matched to the detailed level of facies interpretation in the well (Figure 12), with the changing rate of each facies less than raw data (Figure 13).

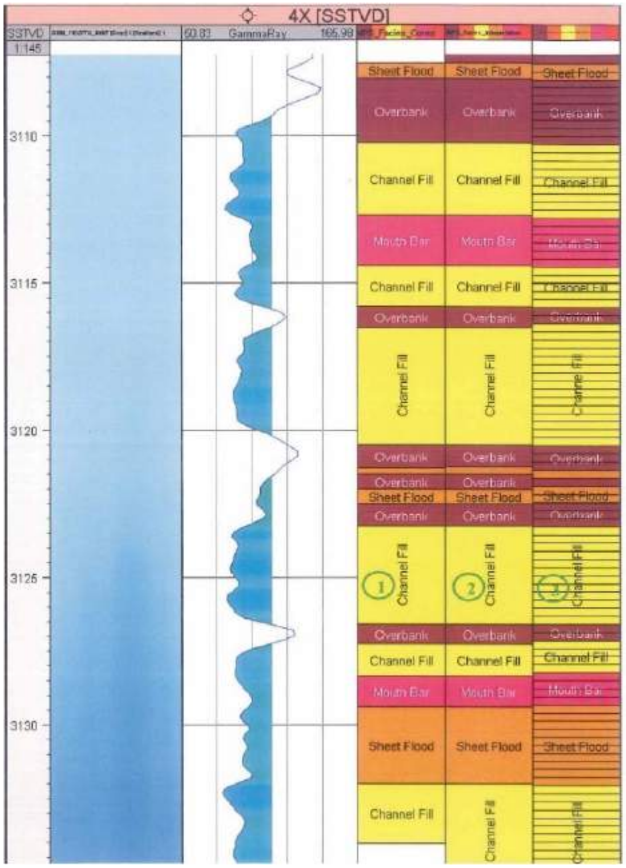

Figure 12. Comparison of facies in well by core (1), after interpretated by Gamma Ray (2) and after assigned in model (3)

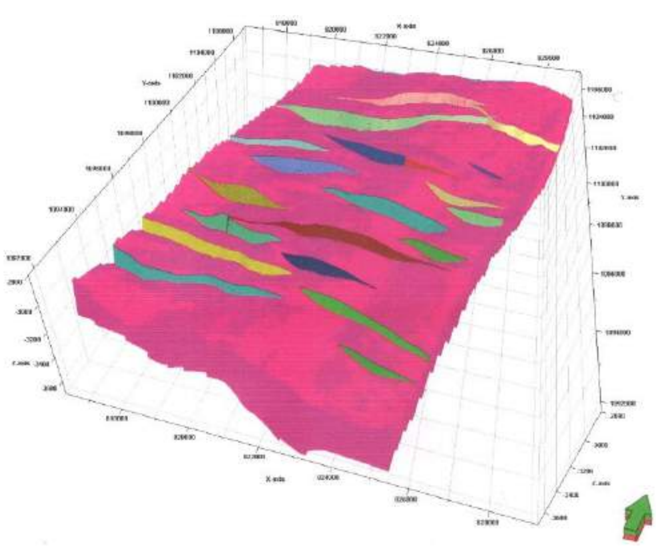

Figure 13. Structural model of Upper Oligocene X field

Data processing and running model

The process of generating facies model using multi-point statistics method includes the following basic steps (Figure 14):

- Develop a theoretical model for the distribution of facies in the study area (conducted above);
- Demonstrate the theoretical model by training image;
- Build a search tree using the search mask that scans the training image to capture the pattern of the theoretical model and probability of corresponding occurrence;
- Develop a regional division model;
- Develop models of proportions and angles,
- Sequential simulation based on well data and recorded multi-point statistics probability, combined with other supporting models.

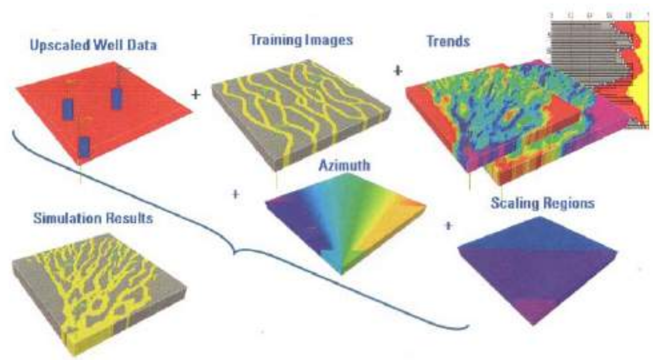

Figure 14. Diagram illustrates facies modelling process by multi-point statistics method[2]

Generating training image model

The training image was generated by directed drawing method on a grid of 102x102x30 with a square grid of 1x1x1m representing the understanding of the distribution andrelationship of facies in the study area.

Facies analyses and depositional environments show that the X field area has a gradual transition toward southeast between two depositional environments rivers and rivers-lakes. The sediment characteristics in these two areas are distinct, so it is necessary to develop two training images for each area.

For the river area

This area has meandering flows, developed facies such as Channel Fill, Crevasse Splay, Sheet Flood, Overbank and sometimes there is Mouth Bar**.** The denser apperance of the Mouth Bar is low due to the fact that the flow energy is still strong enough to form Crevasse Splay during the great flood period. Selected Channel size is the standard for the size of other sedimentary facies (Figure 15).

Facies	Characteristics					
	Shape	Length (grid)	Width (grid)	Thickness (grid)	%	Note
Channel Fill	Semicylinder	-	5	5	8.99	
Crevasse Splay	Cone	10-15	10-15	1-2	1.54	Thinner when away from Channel
Mouth Bar	Cylinder	6-8	3	2	0.46	Scattered along Channel
Sheet Flood	Sheet shape	Spreads out Channel Fill		1	5.04	
Overbank	The rest				83.97	

Table1. Features of geology in river area

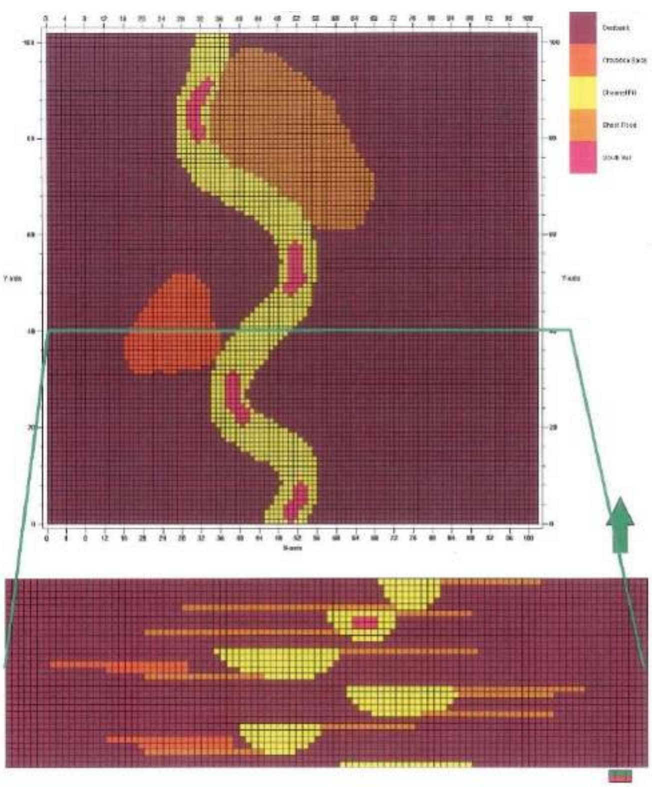

Figure 15. Training image for river area in cross horizontal and vertical section

For rivers-lakes trasition area

This area is marked by an expanse of flow, including Channel Fill, Mouth Bar, Sheet Flood and Overbank. Characteristic of this area is the denser appearance of Mouth Bar, as well as the disappearance of Crevasse Splay due to flow energy reduction. To ensure the stability of training image, Channel Fill in training image has a constant width (Figure 16). Channel Fill width existed on the real model will be multiplied to fit the above geological idea.

Facies	Characteristics					
	Shape	Length (grid)	Width (grid)	Thickness (grid)	%	Note
Channel Fill	Semicylinder	-	8	8	8.56	
Crevasse Splay	Not Exist				0	Thinner when away from Channel
Mouth Bar	Cylinder	8-10	Scattered along Channel	3	2.75	Scattered along Channel
Sheet Flood	Sheet shape	Narrower distribution in the river area			3.11	
Overbank	The rest				85.58	

Table2. Features of geology in trasition area

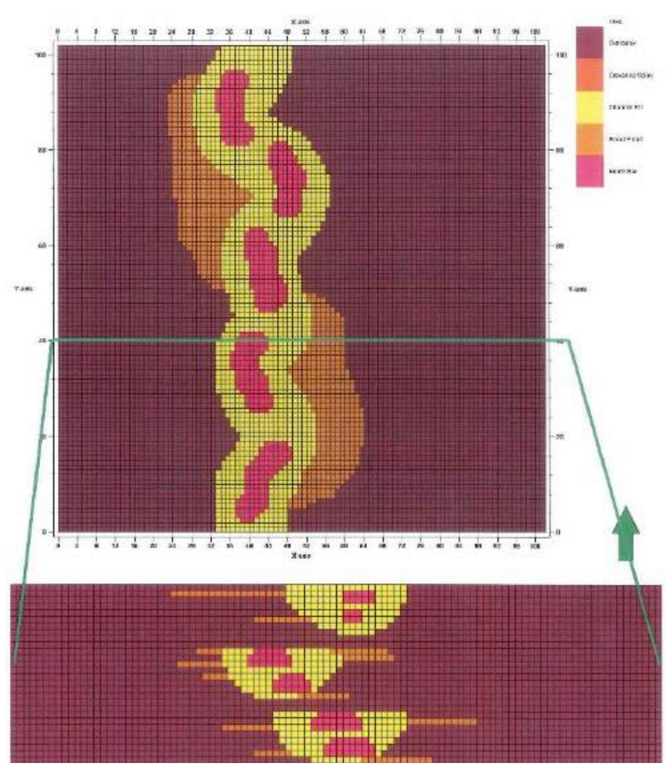

Figure 16. Training image for trasition area in cross horizontal and vertical section

Generating Search tree

Search tree is a data structure that records all the training image patterns that appear in search mask. When generating a search tree, the selection of the search mask size is very important, in accordance with the elements described in training image. If the search mask is too small, there will not be able to fully recognize all the patterns of training image, if the search mask is too large it will prolong the simulation time while the model's quality will not improve. [4]

Select the number of multi-grid

The usage of multi-grid is necessary to improve the efficiency of sequential simulations. Using less multi-grid will give the result not representing the training image [3]. In order to select the number of multi-grids required for the current training image, each multi-grid is visualized and evaluated visually for its ability to display the patterns of the corresponding training image. As a result, using 3 multi-grid is reasonable, as multi-grid 1,2 and 3 are capable of reflecting training image at different levels. From the 4th multi-grid, we can not recognize the training image pattern (Figure 17).

Select the search mask size and MNOIN parameter

Since the thickness of the Channel Fill in the training image is 5-8 grid cells with the presence of Mouth Bar, the height of search mask is set to 7 grid cells because the size is sufficient to record variables in vertical plane of Channel Fill. Other facies are thinner than Channel Fill, so it is also a good idea to use a 7-layer grid search mask.

To study the effect of search mask size on pattern quality in search tree, training image was scanned by 3 differentellipsoid search mask sizes 21x21x7, 21x31x7, 21x41x7 (Figure 18) then use these search trees to perform unconditional simulation on the same 3D grid. During unconditional simulation, the author tested different MNOIN parameters. The quality of these results models is the basis for selecting the appropriate search mask size.

The results of the unconditional simulation are presented in Table 3 and Figure 19, whereby the larger search masks gave the better results, but the longer the simulation time would be. The MNOIN parameter also affects the quality of the resulting model. With the same search mask size, larger MNOIN parameters will result in better models, but simulation time is not necessarily slower. Table 1 shows that with the appropriately large search mask size, simulation time for 64 nodes is shorter than for 32 nodes. This can be explained by the fact that when controlling more nodes, the probability of a red jump is only found and calculated from a few branches of search tree, while when controlling fewer nodes, the probability will be found and calculated from more branches. This results in shortening the simulation time.

Based on the unconditional simulation results, the 21x41x7 search mask size for the river area and 21x31x7 for the transient area (corresponding to case 5 and 17) were selected, the results and the unconditional simulation time is acceptable.

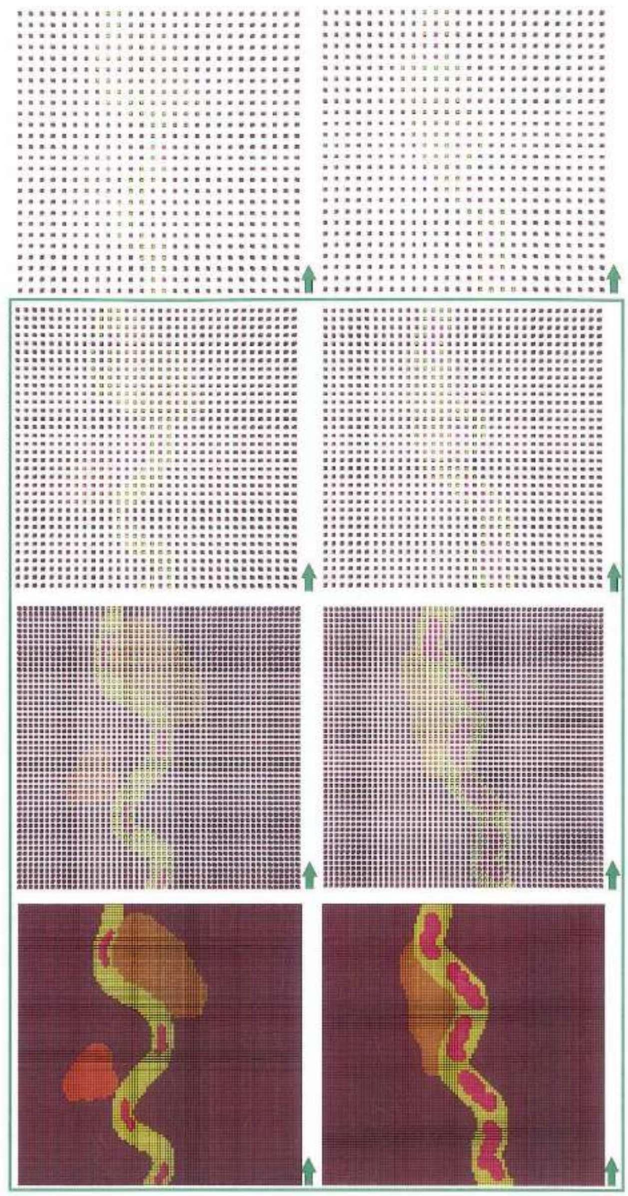

Figure 17. Training image corresponds to 4, 3, 2 and 1 multi-grid

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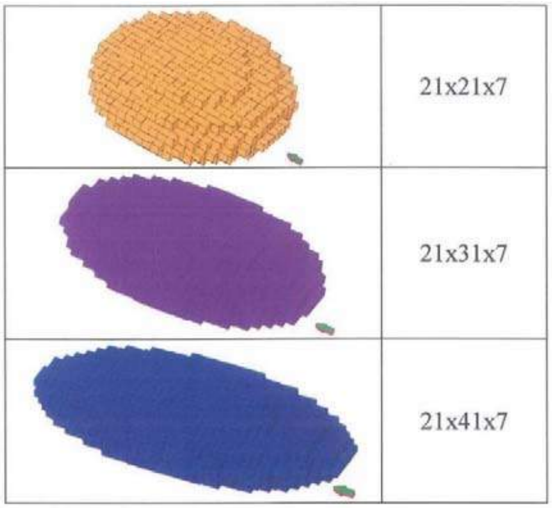
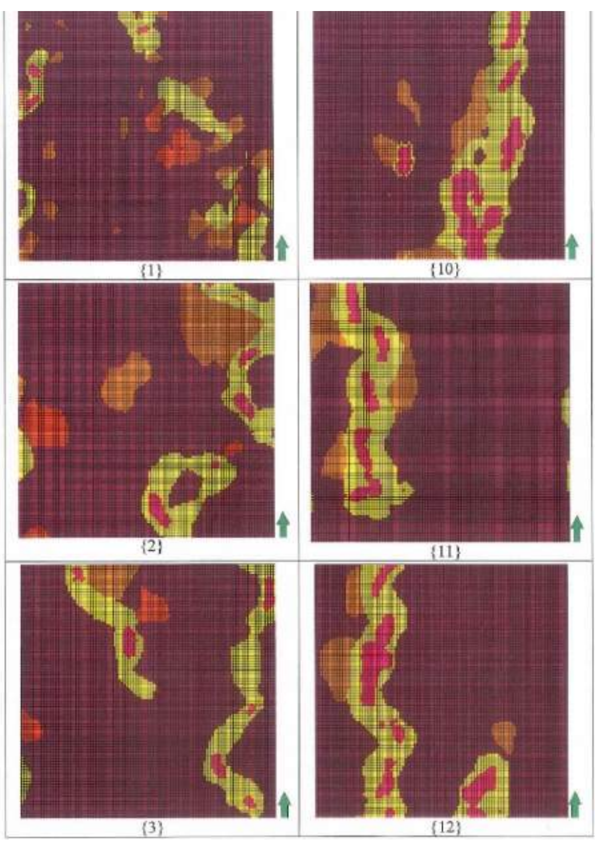


Figure 18. Search mask with different sizes are used

Search mask size		Sequentially unconditional simulation time (s)	
		River area	Transient area
21x21x7	32 nodes	223.500 {1}	253.7030 {10}
	64 nodes	290.4380 {2}	278.5320 {11}
	128 nodes	731.9680 {3}	352.2190 {12}
21x31x7	32 nodes	826.2030 {4}	407.4690 {13}
	64 nodes	705.8900 {5}	321.0470 {14}
	128 nodes	982.6560 {6}	639.8430 {15}
21x41x7	32 nodes	1045.1880 {7}	522.7340 {16}
	64 nodes	903.7970 {8}	476.4060 {17}
	128 nodes	1504.6090 {9}	742.6870 {18}

Table3. Unconditional simulation time with different sizes of search mask



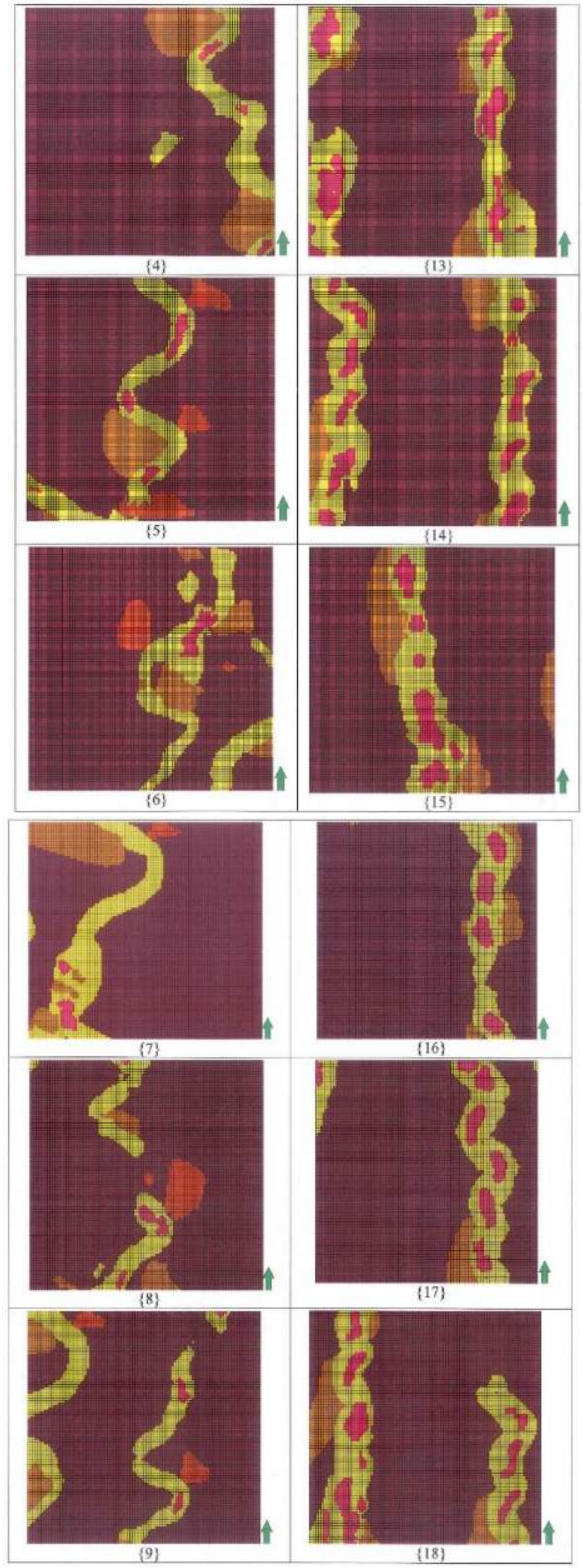


Figure 19. Unconditional modeling results with different sizes of search mask

There are two areas in the C reservoir that have different facies patterns, namely river and transition areas. The distribution of these two areas is determined on the model before applying sequential simulations for each area.

Partitioning for the model was carried out using the Truncated Gaussian SIMulation (TGSIM) method, based on the trend in the analyzed river-lake transition area. The model division results show the temporal encroachment trend of the transition area towards North West (Figures 20 and 21).

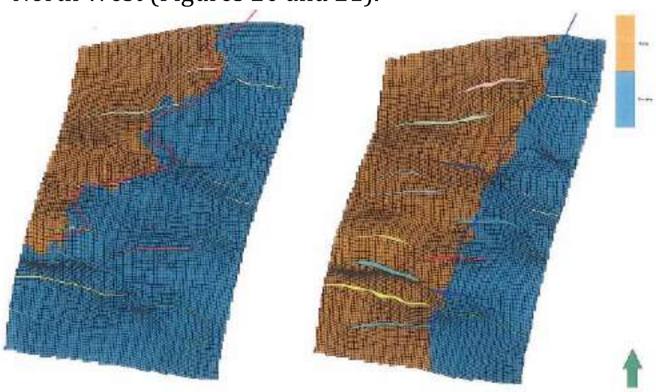


Figure 20. Area division in top (left) and bottom (right) of C reservoir

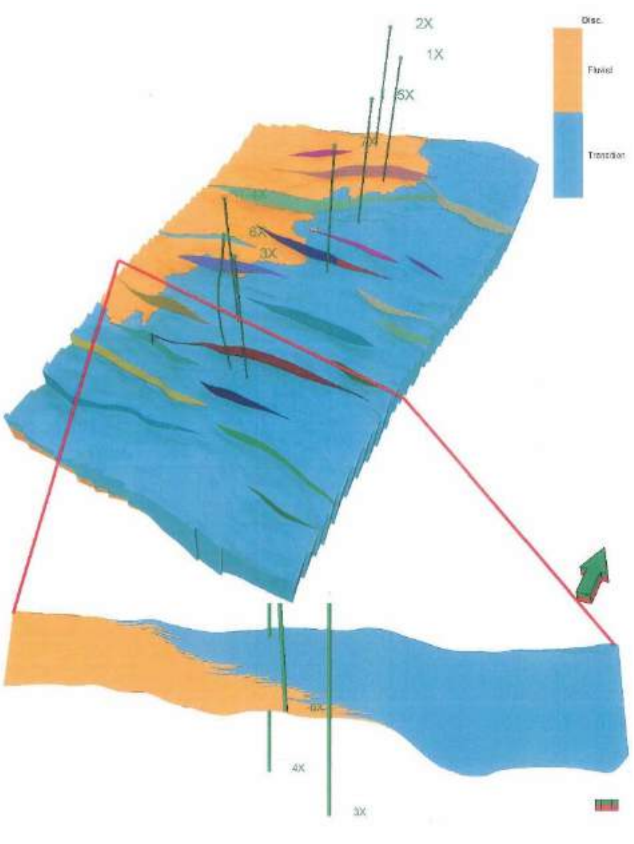


Figure 21. Area division model

Generating angle and propotion controlling models

The angle and propotion models are generated on simulated grid, providing information about the propotion and angle applied to search mask in each grid. The use of angle and propotion model to model for non-stationary areas [5],[6].

Propotional model

Training image is built on the basis of the fit size between facies so it is possible to derive a facies as a representation for studying the scale applied to the real model. In this case, Channel was selected as the comparison object.

In I-direction:

- Channel Fill width in the river area is about 700meters (Figure 5), equivalent to 7 grid cells. On training image of the river area, Channel Fill width is 5-grid-cell. In order to reach the required size, the ratio in the I-direction is 1.4 (Figure 22).
- In the river-lake transition area, due to the expansion of the river, the coefficient in I-direction must gradually increase in the flow's direction. Channel width in this area is defined as 800meters, equivalent to 8 grid cells. Compared with channel width on training image (8 gridlines), we need to apply a ratio of 1 to this area (Figure 22).

In J-direction

Correlation between the I and J-direction affect the continuity and shape of Channel. Therefore, the scale model of I-direction was similarly applied to J-direction.

In K-direction

Similar to the analysis above, channel on training image has 5-8-grid-cell thickness, and the relationship curve between the width and thickness of the Channel shows the average thickness of the Channel in ST field is about 8-10 m, equivalent to 27-33 grid cells. Thus, the K-direction propotion is estimated to be approximately 4-5.5 with a decreasing trend in the South East (Figure 23).

Angle model

The angle model represents the angle between the orientation of the channel pattern in the real grid and the sediment pattern on training image, which is standardized north of each grid. As for the ST facies model, although the flow direction determined from well images is 165^0, due to the effect of the subparallel fault system, the geological formations tend to be distributed in the direction of 90^0. The north of training image and real grid matched each other (0^0). So the angle model is taken as constant 90^0.

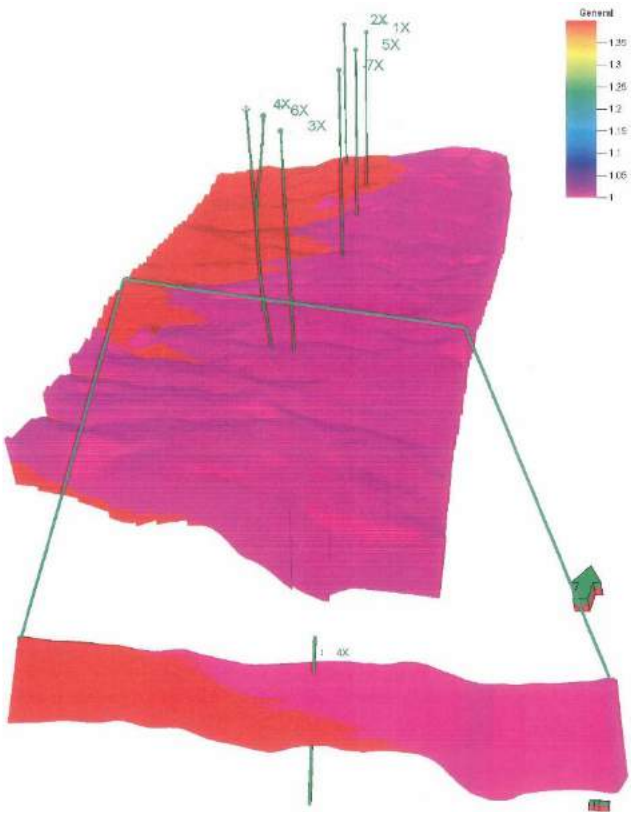


Figure 22. Model in I and J-direction

Figure 23. Model in K-direction

Sequential simulation is performed on the real simulation grid of X field, using search trees and parameters which are selected above.

Based on the above parameters and data, the sequential simulations were run for three groups of cases with the same estimated distribution of each facies, which changes the correction factor r (p. 44) respectively corresponding to control model calibrate with training image (r = 0), in accordance with the expected rate of distribution (r = 1) and mediating the two factors (r = 0.5).

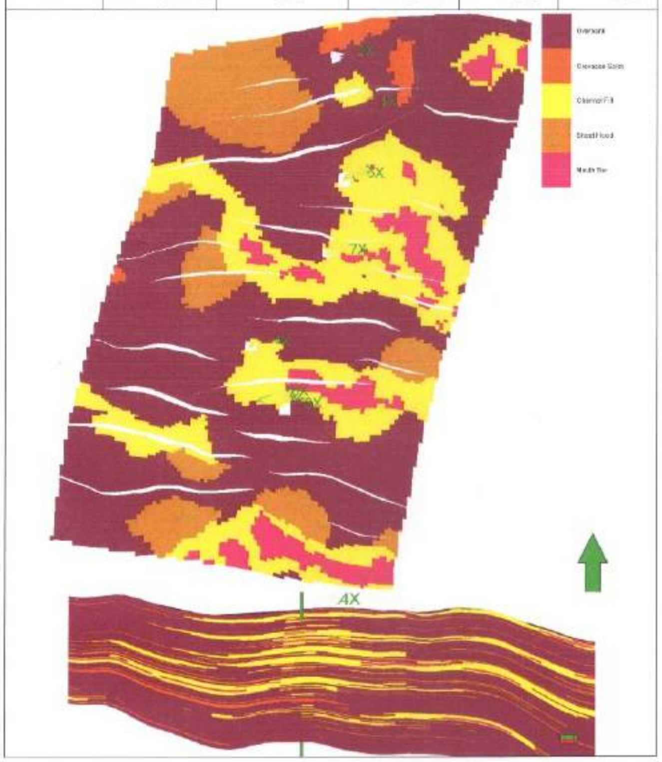
Case	Area	Expected rate (%)					Correction factor (r)
		Overbank	Crevasse Splay	Channel Fill	SheetFlood	Mouth Bar	
Training image	Fluvial	83.97	1.54	8.99	5.04	0.46	
	Transition	85.58	0	8.56	3.11	2.75	
R1_1	Fluvial	84	1.5	8.5	5.5	0.5	0
	Transition	85.5	0	8.5	3	3	
R1_2	Fluvial	84	1.5	8.5	5.5	0.5	1
	Transition	85.5	0	8.5	3	3	
R1_3	Fluvial	84	1.5	8.5	5.5	0.5	0.5
	Transition	85.5	0	8.5	3	3	
R2_1	Fluvial	76	3	11	8.5	1.5	0
	Transition	78	0	11	5.5	5.5	
R2_2	Fluvial	76	3	11	8.5	1.5	1
	Transition	78	0	11	5.5	5.5	
R2_3	Fluvial	76	3	11	8.5	1.5	0.5
	Transition	78	0	11	5.5	5.5	
R3_1	Fluvial	65	5	15	10	5	0
	Transition	70	0	15	7.5	7.5	
R3_2	Fluvial	65	5	15	10	5	1
	Transition	70	0	15	7.5	7.5	
R3_3	Fluvial	65	5	15	10	5	0.5
	Transition	70	0	15	7.5	7.5	

Table 4. Details of expected rate of each facies in each case

Case	Simulating time (s)
R1_1	3138.9040
R1_2	3022.8120
R1_3	3187.2330
R2_1	3124.4540
R2_2	3083.6240
R2_3	2746.5850
R3_1	2892.9640
R3_2	2761.2930
R3_3	2935.7060

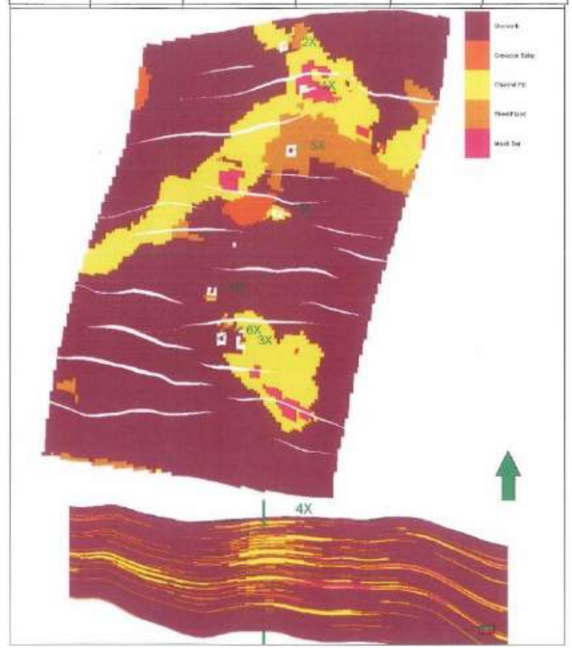
Table 5. Sequential simulation runtime

Real distribution of facies (expected)					
	Overbank	Crevasse Splay	Channel Fill	Sheet Flood	Mouth Bar
Fluvial	71.33 [84]	2.13 [1.5]	18.50 [8.5]	6.59 [5.5]	1.45 [0.5]
Transition	67.13 [85.5]	0 [0]	21.16 [8.5]	5.17 [3]	6.54 [3]



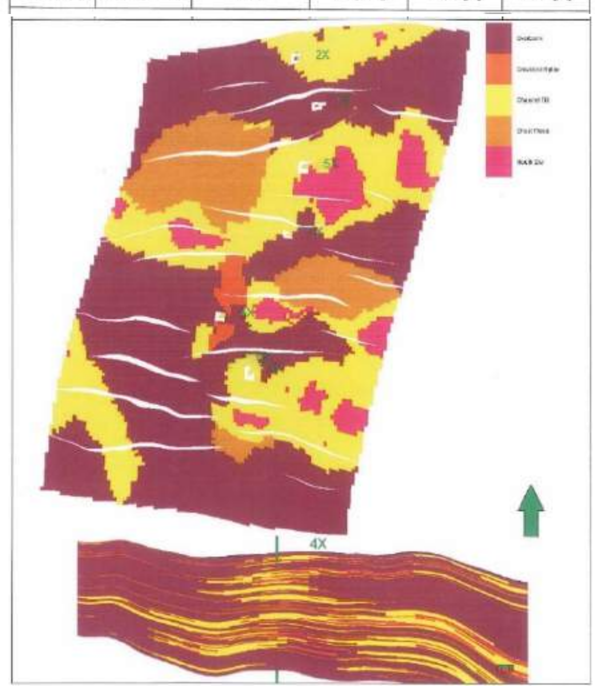
Firgure 24. Resulting model of case R1_1

Real distribution of facies (expected)					
	Overbank	Crevasse Splay	Channel Fill	Sheet Flood	Mouth Bar
Fluvial	83.93 [84]	1.52 [1.5]	8.53 [8.5]	5.46 [5.5]	0.56 [0.5]
Transition	85.48 [85.5]	0 [0]	8.54 [8.5]	3.03 [3]	2.95 [3]



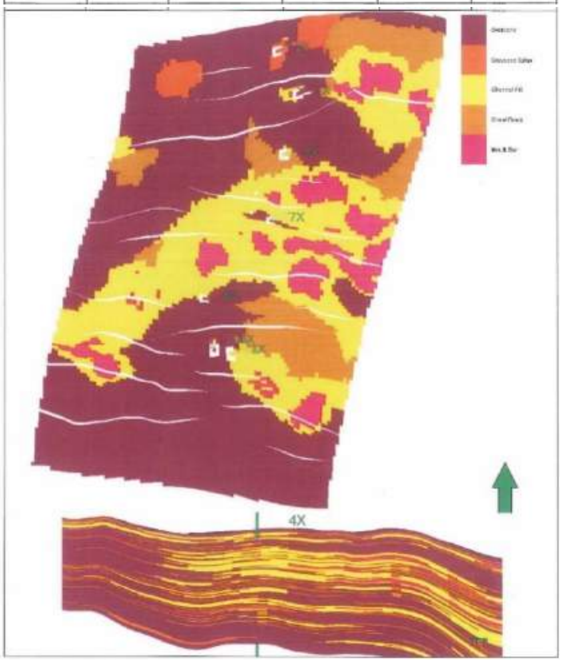
Firgure 25. Resulting model of case R1_2

Real distribution of facies (expected)					
	Overbank	Crevasse Splay	Channel Fill	Sheet Flood	Mouth Bar
Fluvial	77.87 [84]	1.94 [1.5]	14.78 [8.5]	4.34 [5.5]	1.08 [0.5]
Transition	77.32 [85.5]	0 [0]	14 [8.5]	3.96 [3]	4.72 [3]



Firgure 26. Resulting model of case R1_3

Real distribution of facies (expected)					
	Overbank	Crevasse Splay	Channel Fill	Sheet Flood	Mouth Bar
Fluvial	73.42 [76]	2.71 [3]	16.11 [11]	6.55 [8.5]	1.21 [1.5]
Transition	65.66 [78]	0 [0]	21.69 [11]	6.76 [5.5]	5.89 [5.5]



Firgure 27. Resulting model of case R2_1

Real distribution of facies (expected)					
	Overbank	Crevasse Splay	Channel Fill	Sheet Flood	Mouth Bar
Fluvial	74.45 [76]	4.56 [3]	12.56 [11]	6.99 [8.5]	1.44 [1.5]
Transition	78.04 [78]	0 [0]	10.93 [11]	5.58 [5.5]	5.45 [5.5]

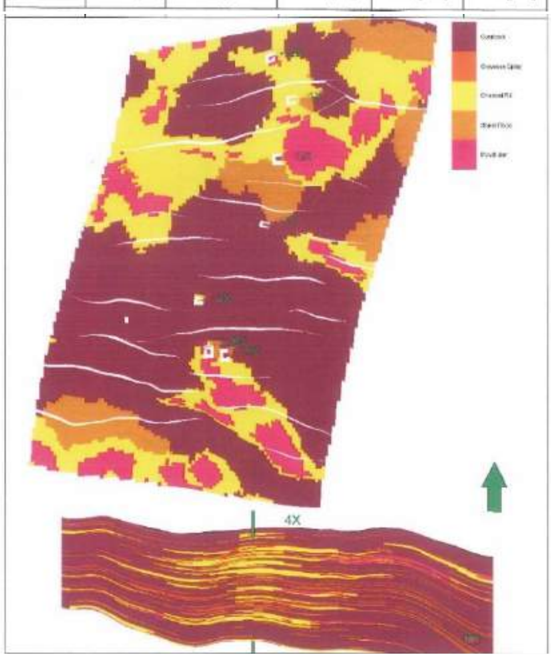
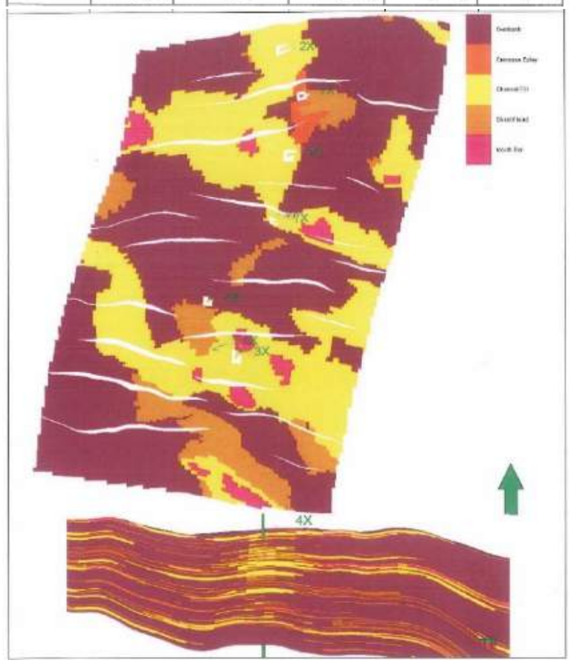


Figure 28. Resulting model of case R2_2

Real distribution of facies (expected)					
	Overbank	Crevasse Splay	Channel Fill	Sheet Flood	Mouth Bar
Fluvial	74.17 [76]	2.32 [3]	14.09 [11]	8.14 [8.5]	1.29 [1.5]
Transition	72.06 [78]	0 [0]	16.98 [11]	5.22 [5.5]	5.75 [5.5]



Firgure 29. Resulting model of case R2_3

Real distribution of facies (expected)					
	Overbank	Crevasse Splay	Channel Fill	Sheet Flood	Mouth Bar
Fluvial	75.12 [65]	2.08 [5]	15.46 [15]	6.46 [10]	0.89 [5]
Transition	65.38 [70]	0 [0]	21.89 [15]	6.16 [7.5]	6.57 [7.5]

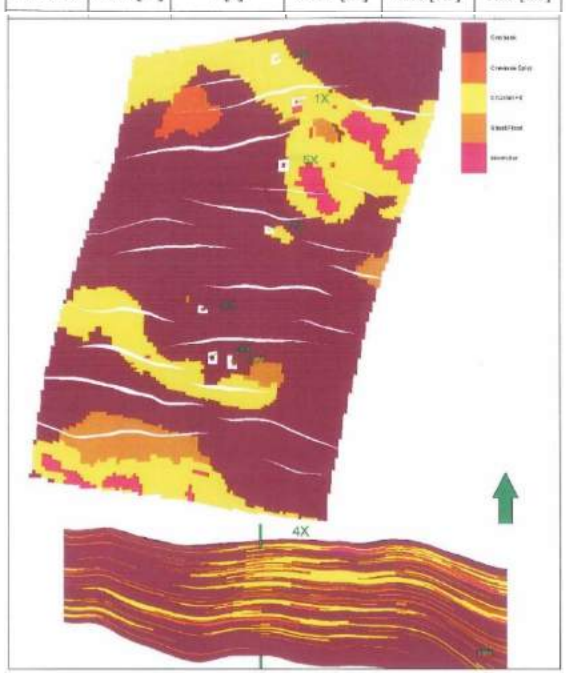
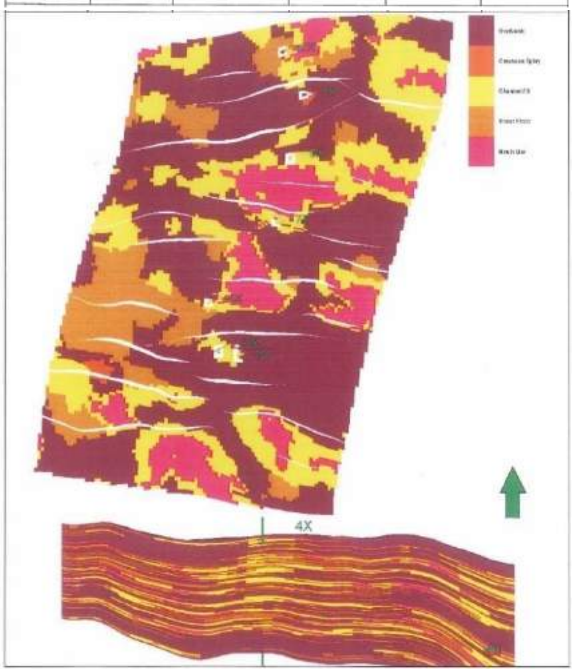


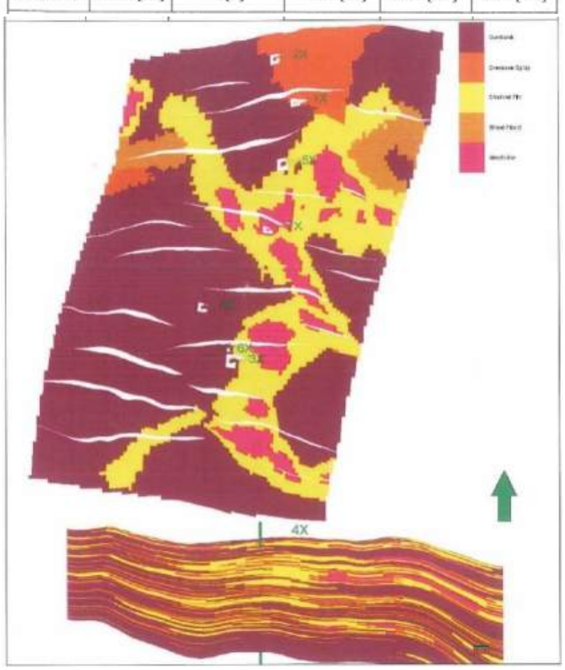
Figure 30. Resulting model of case R3_1

Real distribution of facies (expected)					
	Overbank	Crevasse Splay	Channel Fill	Sheet Flood	Mouth Bar
Fluvial	66.07 [65]	4.2 [5]	16.28 [15]	9.14 [10]	4.30 [5]
Transition	70.02 [70]	0 [0]	14.96 [15]	7.51 [7.5]	7.52 [7.5]



Firgure 31. Resulting model of case R3_2

Real distribution of facies (expected)					
	Overbank	Crevasse Splay	Channel Fill	Sheet Flood	Mouth Bar
Fluvial	67.36 [65]	3.44 [5]	17.02 [15]	9.00 [10]	3.17 [5]
Transition	66.39 [70]	0 [0]	20.30 [15]	6.71 [7.5]	6.60 [7.5]



Firgure 32. Resulting model of case R3_3

Comment on the results

The results of sequential simulations using multi-point statistics are shown in Figure 24 to Figure 32. Based on the model results, there aresome comments:

- In general, the resulting model matches the geological idea of training image. This shows that the MPS algorithm is capable of regenerating geologic ideas described on training image in a more flexible manner, which is totally consistent with the well results. The geological idea on training image is critical to the model's results.
- The rate of facies in the models R1_2, R2_2 and R3_2 is very close to the expected rate, suggesting that the multi-point statistics method is capable of controlling the resulting model to an expected proportional distribution.
- The higher the correction factor r, the better expected rate of the model will be, but the lower the image quality of the model (model R3_2), and vice versa. Therefore, in order to determine the correction coefficient, a consideration was taken between achieving the expected rate and reconstructing geological pictures from training image. In the ideal case, when the rate of facies on training image is similar to the real model ‘s one, then the model result will be the best and less dependent on the correction factor r.
- When the difference between the expected rate and training rate is high, it will be difficult to control model in expected rate. Observations in R2_2 and R3_2 resulting models show that assigning facies becomes localized in the near borehole area, to achieve the expected rate and not to reflect the geological picture of training image.
- The simulation time for each model is approximately 3000 seconds, compared to the big actual size of the model (over 15 million grid cells). This is an acceptable runtime. For simplicity of comparison, a sequential simulator was run by using the SISIM method with the default parameter, runtime was 1717.8750 seconds. This shows that the performance of the multi-point statistics method is quite good compared to SISIM.

In conclusion, Oligocene facies model on X field is constructed by multi-point statistic method which presents the geological picture more clearly than the current facies model and shows the ability to control very good resulting model. Multi-point statistics method allows to combine different sources of information (geological, seismic, field, etc.), plus the geological perspective shown by training image, has proved its superiority compared to other traditional methods.

Conclusion

Modeling facies requires the synthesis of studies from a variety of sources, from seismic to well geophysics; In many areas, ranging from basin scale to core scale and thin slab.

Multi-point statistics method is a breakthrough in the field of geostatistics in particular and facies modeling in general. This method uses a training image to describe the relationship of data in space, overcoming the limitations of traditional facies modeling methods, which allow a more flexible and reasonable way in facies modelling.

In order to apply multi-point statistics method, facies in wells should be interpreted in sedimentary form with clear viewpoints on the geological environment of the study area. For multi-point statistics methods, it is important to make a theoretical model of the geological environment in the study area.

The parameters used in generating search tree and sequential simulation have a great influence on the efficiency and accuracy of the model.

Oligocene reservoir of ST field is formed in the river-lake environment, the sediments in the direction of northwest - southeast, affected by the system of faults in the parallel - sub-parallel.

The facies model Oligocene reservoir ST field was generated by multi-point statistics method, combining information from various sources, reflecting the field geological picture in a reasonable manner, is a concrete demonstration for practicality of the method.

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