SEQUENCE STRATIGRAPHIC STUDY AND SEISMIC IMAGING OF PLIOCENE LOWSTAND DEPOSITS IN OFFSHORE VIETNAM

Phong Van Phung

Petroleum Geoscience Program, Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand
Corresponding author email: phongpv8@gmail.com

Abstract

Channels and basin floor fans are not only excellent evidences for analyzing the lowstand system tract but also common objectives in the oil and gas industry. Incised valleys or channel cuts and basin floor fans of this study area were observed and interpreted based on general 3D seismic data. Combining of seismic attributes and well data are used to predict their distributions as well as their lithology. In addition, evolutions of channels and basin floor fans through time were determined by using time slices or horizon slices of the seismic attribute cube association by shifting a window above a surface and displaying it as the RMS (root mean square) of amplitude over a specific interval. This study concentrated on sequence stratigraphy in terms of combining all data such as seismic and well log data to understand the processes and depositional environments of sequences. The sequences were interpreted by looking for channels or incised valleys and basin floor fans development from Pliocene to Recent time of this area. This research also discussed about primal factors, which affect depositional principles. There are relationships of relative sea level, sediment loading and subsidence rate to these sequences. In addition, relative ages of sequence S3 and S4 could be correlated with the published sea level curve of Wornardt et al., 2001. Channels and basin floor fans are displayed on the Gross Depositional Environment map. The maps are used to demonstrate the processes controlling the channels and basin floor fans.

Keywords : Channel and Basin floor fan, Depositional Environment, Seismic attribute

1. Introduction

The area of study is located near the Mekong River systems, which play an important role on transporting sediments into the basin. The main data used is a 3D seismic cube and interpretations are based on seismic and well data like seismic facies and terminal reflections. The study area was defined and interpreted nine sequence boundaries such as S1, S2, S3, S4, S5, S6, S7, S8 and Seabed boundary. Based on seismic data and well log data, the system tracts within each sequence were defined to understand more depositional processes through time.

2. Database and methodology

Data sets were used in this study: 3D seismic, one well with some main log curves such as GR DT, LLS, LLD and the checkshot data to convert time maps to depth maps.

The 3D seismic, which covers an area of 1500 km2, is very good quality data with high resolution. The dominant frequencies are from 40 Hz to 60 Hz. Seismic data were used to define sequence boundaries. The attributes of the reflection surfaces, including amplitude, Incoherence, combining with root mean square (RMS) attributes were used to interpret and predict channel cuts or incised valleys and distributions of basin floor fans deposited.

Well data were not only used to define systems tracts based on log characters and predict lithology of each package but also forecast sand/shale ratio of basin floor fans.

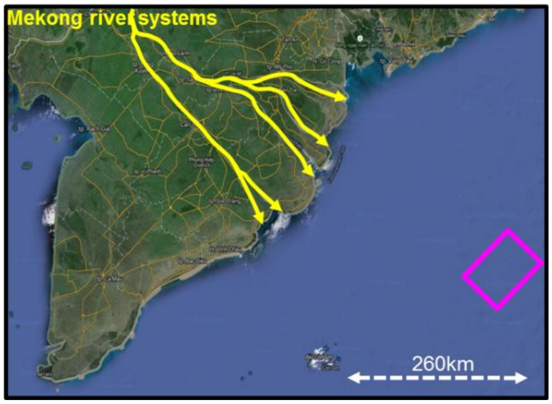

Figure 1. The location of the study (Pink square color)

The main works of sequence stratigraphic study focused on seismic sequence stratigraphy and well log analysis. For seismic sequence stratigraphic analysis, it was accomplished in several steps such as 1- Determinations of seismic sequence stratigraphic unit – Recognition and Picking; 2 – Sedimentary processes interpretations based on seismic pattern; 3 – Understanding of external processes that affect stratigraphy.

3. Discussions and results

The study area was interpreted into nine sequence boundaries, including S1, S2, S3, S4, S5, S6, S7, S8 and Seabed boundary as well as definitions of systems tracts within each sequence based on seismic data such as seismic facies, termination reflections and well log characteristics as figure 2 and 3.

There are three basic controls to a sequence developed: 1 – Subsidence rate; 2 – Sediment supply rate; 3 – Eustatic sea level change.

The rates of the subsidence are determined by two primary factors: 1 - Tectonics and 2 - Sedimentary loading. However, in this case, the rates of the tectonic subsidence have not played an important role to total subsidence rates of the basin because it has been stable during Pliocene to Recent time (the post rift stage of the basin). Therefore, only rates of sedimentary loading subsidence have been discussed, considered and interpreted through sequences based on observations of seismic lines through internal - external seismic features and isopach maps.

Normally, sedimentary subsidence could change from margin to slope and down to basin-ward. In fact that sedimentary loading subsidence is not exactly the same at margin, slope or basin position. However, this study area is too small to compare with the whole basin. Therefore, it is assumed that the sedimentary loading subsidence rates at shelf or slope or basin position of the study are uniform. Vertical changes in stacking patterns and internal seismic geometries along the margin of the basin represent temporal variations in subsidence rate. Through sequence 1 up to sequence 4, a lot of incised valleys/ channel cuts were observed across the shelf, which might support low subsidence rate during these intervals. More progradational developments at the slopes, aggradation configurations along the shelf during sequence 5, 6 suggest the rate of subsidence is higher these times. The youngest sequences 7 and 8 are characterized by thick developed aggradations/ progradations to basin. These mean that low subsidence rate or high sediment supply are controls during these times (Figure 2).

The sediment supply rate in any locations can vary significantly through time and there will be large lateral variations within a basin at any one time. It depends on both the source to basin relief, which in general terms is dictated by tectonics as well as by the climate. The climate also controls the nature of the sedimentary fill of a basin. Differences in lithology can lead to significant differential compaction, sedimentary processes during deposition (G A Kirby and D J Evans, 1995).

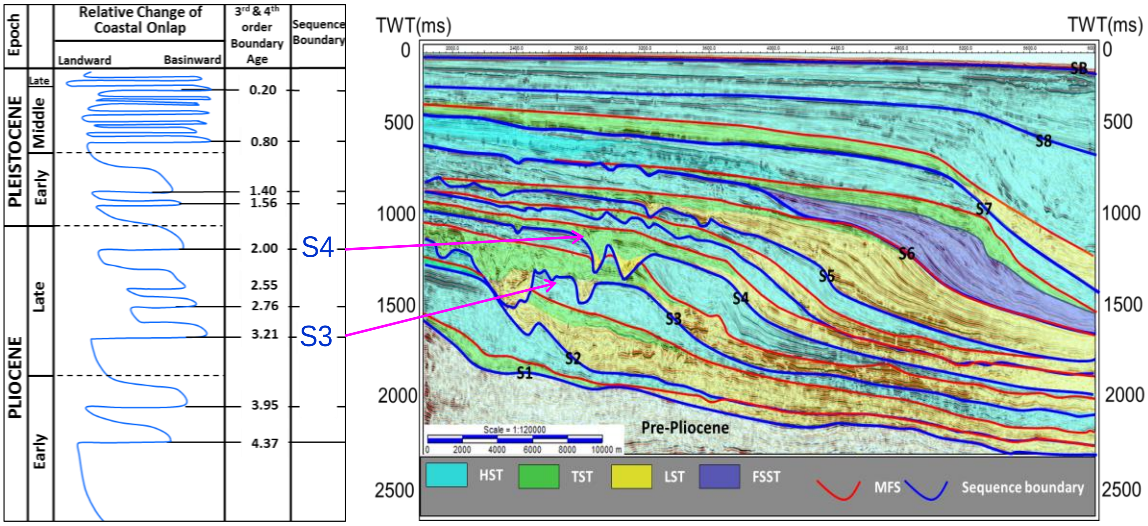

Figure 2: The correlation of the relative sea level change with sequence boundaries: S3, S4 and System tract definitions are interpreted based on seismic section.

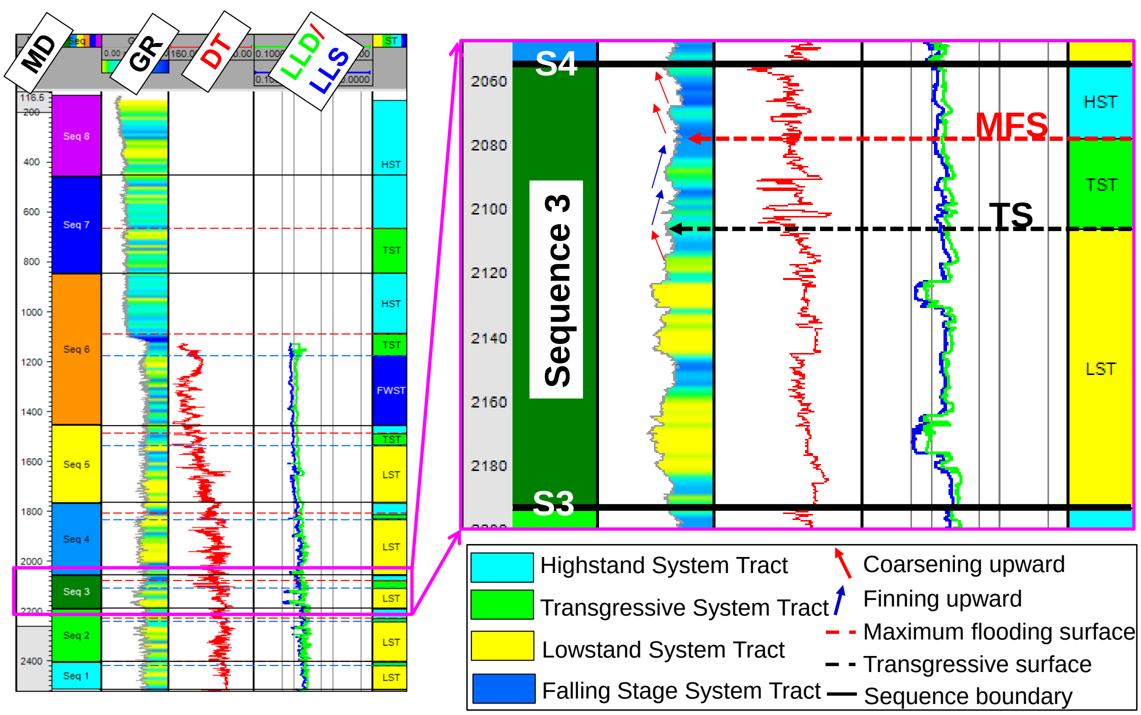

Figure 3: System tract definition on well log are defined when combining with sequence boundaries from seismic.

In term of the higher sediment flux, the larger the volume of sediment entering the basin, the thicker the resultant succession will be. Based on figure 6, the thickness of upper sequences S6, S7 and S8 reflects the periods of the high sediment supply into the study area. Conversely, the lower the sediment flux, the thinner the resulting succession as the sections of sequences S1 to S5 showing the periods of the low sediment supplied.

Eustatic sea level and subsidence interact to produce or remove space in which the sediment supplied into the basin can accumulate. This space is called accommodation. A curve describing the variation of total accommodation through time in a basin can therefore be constructed by adding successive incremental changes in eustacy to the cumulative subsidence curve. This curve is, in consequence, the same as the relative sea level curve. Therefore, the relative sea level curve plays an extremely important role in order to understand not only the development of sequences, but also their components (G A Kirby and D J Evans, 1995).

Normally, when relative sea level falls below the former shelf edge, the sediments of the lowstand system were deposited. However, when relative sea level is above the former shelf edge, the sediments of the highstand were built. The third division of strata of a sequence were known as the transgressive deposits when relative sea level initially floods the former shelf. During this time, the shoreline moves landwards, although this may be in a step-wise fashion being interrupted by periods of basin ward progradation (Figure 2).

In this study area, a relative sea level curve has not constructed because of lacks of data and tools. Therefore, the published relative sea level curve of Wornardt et al. (2001) completed by observations of stratigraphic unit at the Gulf of Mexico was used to understand how to match the sequence boundaries with relative sea level change. It is clear that the sequence S3 has a good tie with 3.21 Ma of relative sea level. Another sequence S4 is the second good candidate for matching with 2.00 Ma of the relative sea level (Figure 2).

Based on seismic sections and seismic attributes, Canyon systems/ Channels/ Incised valleys and basin floor fans (BFF) features can be observed. They can be seen clearly from sequence 1 to sequence 6, and it is quite difficult to identify channels in upper sequences such as sequence 7 and 8 due to their thickness below seismic resolution.

For the flow of channels as well as the directions of basin floor fans, the flow of

For sequence 1 and 2, almost all sediments were located in slope and basin places. That means channel features are associated with basin floor fans both long and short drift fans. These interpretations were observed on seismic sections and some attribute seismic maps. Based on well data, special GR curve, lithology of basin floor fans is sandstone interbedded with shale (pelagic sediments).

In sequences 3, 4, 5 and 6, the channel/ canyon/ incised valley develop strongly. They can reflect extreme relative sea level change during this interval. In addition, basin floor fans can be created after channels bring products of erosion to basin-ward. They develop through time with multiple stages and overlap together. Based on seismic facies and seismic attributes, they can be separated and distributed. Both long and short drift path basin floor fans can be seen in these intervals, which was controlled by different energy of channels of each stage evolution. Therefore, grain sizes of sediments of basin floor fans can vary from fine (mud) to coarse (sand) grain as GR signature. Combination of Root Mean Square (RMS) maps with well log, sand/shale of basin floor fans of each sequence can predict (Figure 4).

By moving up with a certain window of RMS above these surfaces, the evolution of channels/incised valleys on shelf can be seen on RMS maps and on the different time slices. In addition, evolution of basin floor fans can be predicted and mapped through time (Where A, B, C: source points and i, ii, iii: the evolutions of BFF (Figure 5).

Coming to sequence 7 and 8, it is not easy to see channel/ incised valley features within intervals, even having the high seismic resolution or it can understand that the thickness of channels/ incised valley is below seismic resolution. Addition to basin floor fans, they cannot be observed within these intervals of study area.

channels can be determined based on their geometries with their evidences on seismic sections. Almost all channels developed through time have a main flow from west to east direction, except the channels within sequences S4 and S5 have a trend from north to south. On the other hand, basin floor fans have a main direction from west to east as figure 4.

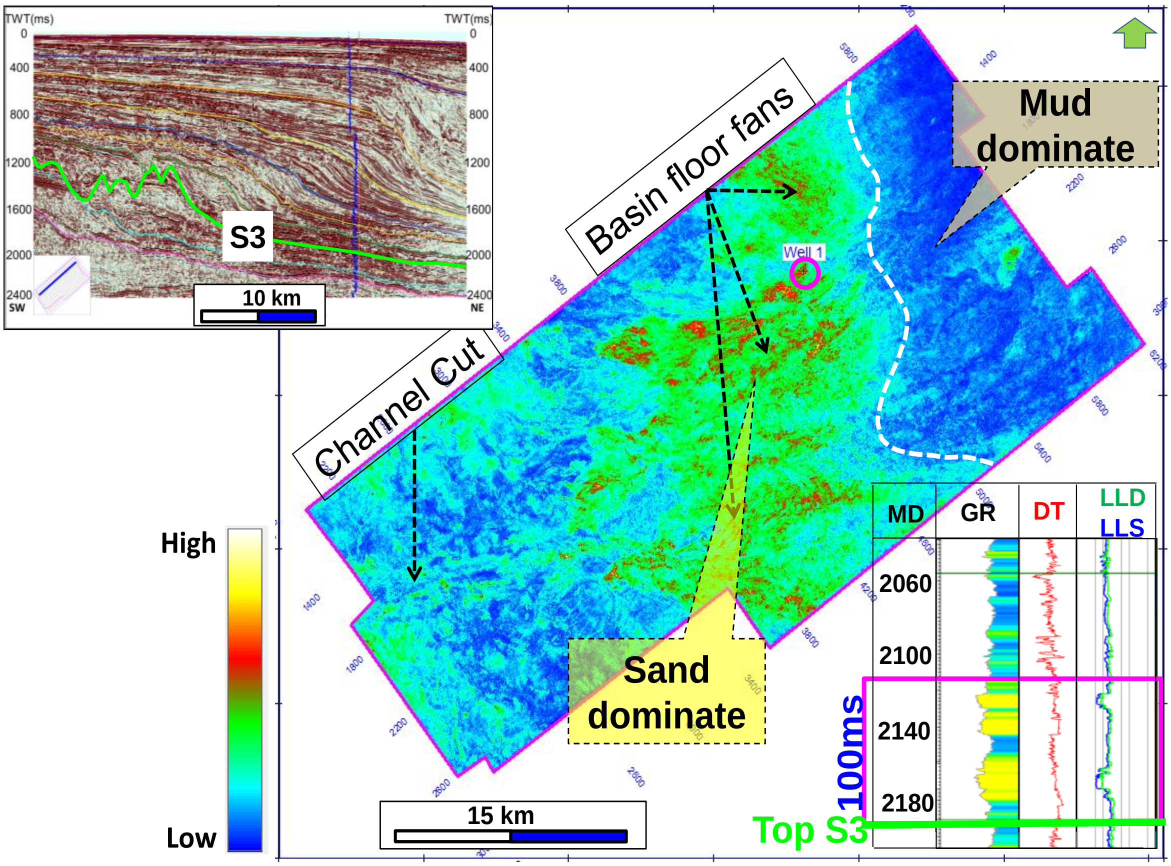

Figure 4: A root mean square attribute map of 100ms window above S3 surface shows channels and basin floor fan distributions and lithology of basin floor fans.

In term of finding exploration targets, geometries of channel or incised valleys and basin floor fans were defined based on seismic attributes. However, it is more important to predict lithologies filled in channels or all incised valleys and lithology of basin floor fans. From seismic attribute maps, almost all basin floor fans with thickness changing from 20ms (proximately 20m) of sequence 4, 5 to 100ms (proximately 100m) of sequence 1, 2, and special sequence 3 have sand dominated as high amplitude on RMS map. Therefore, channels and basin floor fans as stratigraphic traps become potential traps in future with pelagic sediments inter-bedded as seal rocks of basin floor fans during Pliocene sediments deposited when source rocks of young sediments are mature enough.

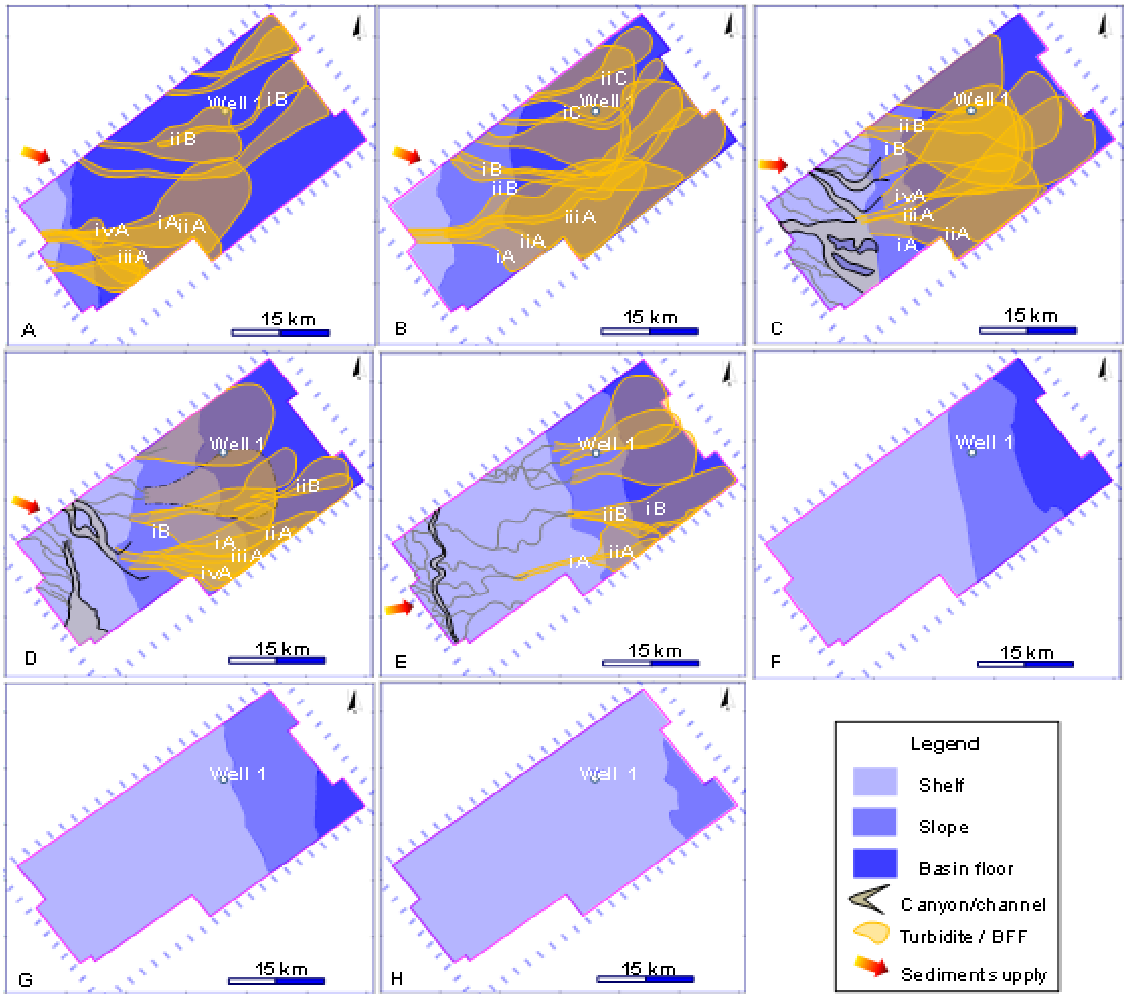

Figure 5: Channels and basin floor fans are displayed on the depositional environment map of each sequence (from A: Sequence 1 to H: Sequence 8) (where: i, ii, iii numbers are evolution of basin floor fan and A, B, C are source points)

4. Conclusions

The key findings and conclusions are summarized below:

- Nine sequence boundaries including seabed were defined and picked. Out of these nine sequence boundaries, eight sequences were used to generate isopach maps to look for stratigraphic features such as channels, incised valleys and basin floor fans within each sequence. Combining seismic data and well data, the sequence stratigraphy of the study area was clearly interpreted and detailed from defining systems tracts.
- There was an attempt to tie and compare all sequence boundaries to relative sea level curve (Pliocene to present) from the Gulf of Mexico, which was published by Wornardt et al. (2001). Sequence boundaries: S3 and S4 were assigned a relative age. Relative sea level change and the rate of sediment supply were considered and interpreted during this time interval. These two factors were reflected as various seismic facies and internal or external seismic geometries.

- Based on seismic sections, maps and some seismic attribute analyses, channels or incised valley systems and basin floor fans were detected and mapped. It is also useful to understand the evolution of channels and basin floor fans by using variations of time slices and the root mean square maps above the sequence. Normally, channels and/or incised valleys are produced when the sea level falls below the shelf edge.

- Moreover, Gross Depositional Environment map was interpreted based on the combination of seismic facies, structural and isopach maps, and seismic attribute maps. It aids readers to better visualize the process of how the sediments were deposited and identify the stratigraphic features such as channels and basin floor fans located and developed from Pliocene to present.

- Channels and Basin floor fans have been considered important stratigraphic traps, which are significant targets in petroleum exploration. Here the results of this study will be excellent models for geologists when they look for oil and gas fields similar areas. Basin floor fans with distributions of sand and mud areas will be especially useful for explorers.

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