

# PLIOCENE - PLEISTOCENE SEQUENCE STRATIGRAPHY IN BLOCK 05-2, NAM CON SON BASIN, OFFSHORE VIETNAM

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## Summary

Sequence-stratigraphic investigation using high-resolution 3D seismic data allows recognition of the detailed stratigraphic features of the Pliocene and Pleistocene succession such as incised valleys or channels and basin floor fans. They are excellent evidences for recognition of the lowstand system tract. Integration of seismic attributes and well data was used to predict their distributions as well as lithofacies. This article concentrates on sequence stratigraphy interpretation of seismic and well log data for prediction of the depositional environments of each sequence.

**Key words:** Channel and basin floor fan, depositional environment, seismic attribute.

## 1. Introduction

Block 05-2 is located in Nam Con Son basin, a rift basin in Vietnam, near the Mekong River system. The river system plays a significant role in transporting sediments into the basin, as the study area is about 260km from the current shoreline of Vietnam (Figure 1). The general stratigraphy and structure were recorded as the pre-rift stage during Eocene to Early Oligocene, the first syn-rift stage from late Early Oligocene to Late Oligocene, the subsidence stage during Early Miocene; the second syn-rift stage up to Middle Miocene and the post-rift from Upper Miocene to recent time [1].

Eight sequence boundaries namely S1, S2, S3, S4, S5, S6, S7 and S8 were interpreted based on the terminal seismic reflections such as downlap, onlap and truncation features as well as surfaces associated with incised valleys (IV) and/or canyon imbricates (Figure 2). By integration of seismic data and well log data, the system tracts within each sequence were defined to understand the detailed depositional processes.

Incised valleys and basin floor fan deposits are controlled by variations of

relative sea level, sediment input, tectonics and internal channel cuts or their development mechanisms.

This paper focuses on the following objectives:

- Interpret 3D seismic patterns integrated with well data in order to understand the depositional processes.
- Define the system tracts of each sequence from Pliocene to recent time.

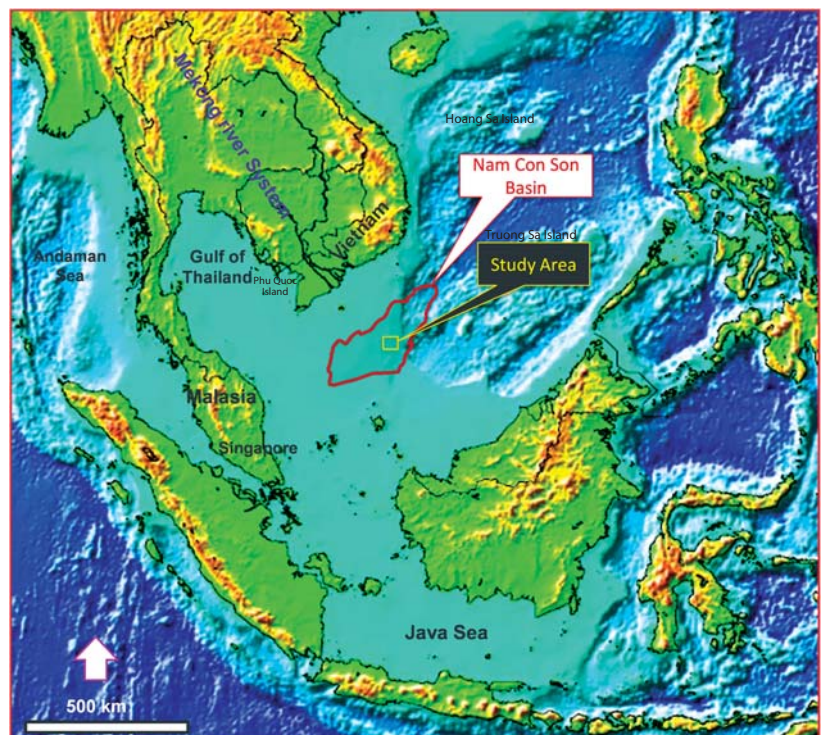


Figure 1. The study area (Yellow square) is located in Nam Con Son basin

- Correlate the variations in relative sea level, sediment supply and subsidence rate to the depositional processes in the area.
- Understand the evolutions of these channel cuts/incised valleys and basin floor fans deposits and their relationships within each sequence.
- Construct the Gross Depositional Environment (GDE) map for each sequence.

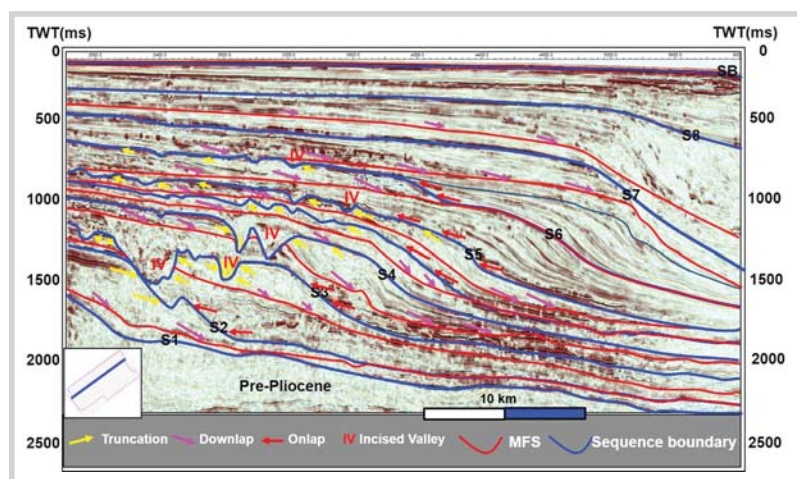
## 2. Database and methodology

The datasets used in this study include high-resolution 3D seismic data, one well with main log curves such as GR, DT, LLS, LLD and the check-shot data. The 3D seismic data, which cover an area of approx. 1,000km<sup>2</sup>, are of very good quality with high resolution, inline and crossline spacing of 12.5 x 12.5m. The dominant frequencies are from 40Hz to 60Hz. The seismic attributes including amplitude, and incoherence, combining with root mean square (RMS) amplitude were used to interpret and predict distributions of channel cuts or incised valleys and basin floor fans.

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 determination of seismic sequence stratigraphic unit - recognition and picking; interpretation of sedimentary processes based on seismic patterns; and understanding of external processes that affect stratigraphy.

- Determination of seismic sequence stratigraphic unit - recognition and picking:

Eight sequence stratigraphic units were interpreted by recognition of sequence boundaries. A sequence boundary was picked by truncation, onlap, downlap or concordance as well as internal and external geometries. They were mapped and labelled as S1, S2, S3, S4, S5, S6, S7, S8 (S-Surface) and SB (Seabed) (Figure 2).



**Figure 2.** Seismic reflections terminations are used to define sequence boundaries and to illustrate incised valley (IV) as well as basin floor fan

- Interpretation of sedimentary processes based on seismic patterns:

Seismic parameters within each seismic unit framework, including reflection configurations, amplitude, continuity and frequency, were analysed to understand the sedimentary processes. These parameters can be used to interpret the lithology, bedding spacing, fluid contents, contacts and depositional environments, and the paleo-topography. Figures 2 and 3 show reflection terminations and seismic facies.

- Understanding of external processes that affect stratigraphy in the area:

Sediment supply, relative sea level and subsidence rate were discussed in order to understand the external processes, which influenced the basin architecture.

Sediment supply depended on both the fluvial drainage and the mechanical erosion [2] and is one of the fundamental variables that determine the type of depositional trend in all fluvial to marine environments [3].

Based on log curves such as GR, DT and Resistivity, the transgressive surface (TS), flooding surfaces (FS), and maximum flooding surfaces (MFS) could be recognised. The maximum flooding surface is defined as a surface between the fining upward of the TST and the coarsening upward of the HST. The transgressive surface is interpreted by a surface between the coarsening upward of the LST and the fining upward of the TST (Figure 5). Commonly, some system tracts cannot be seen on seismic data at the well location even with very high resolution as the current seismic data; however, they could be defined on well log curves because of the higher resolutions of well log data.

There are three basic controls to a sequence developed: subsidence rate; sediment supply rate; and eustatic sea level change.

The rates of the subsidence are determined by two primary factors:

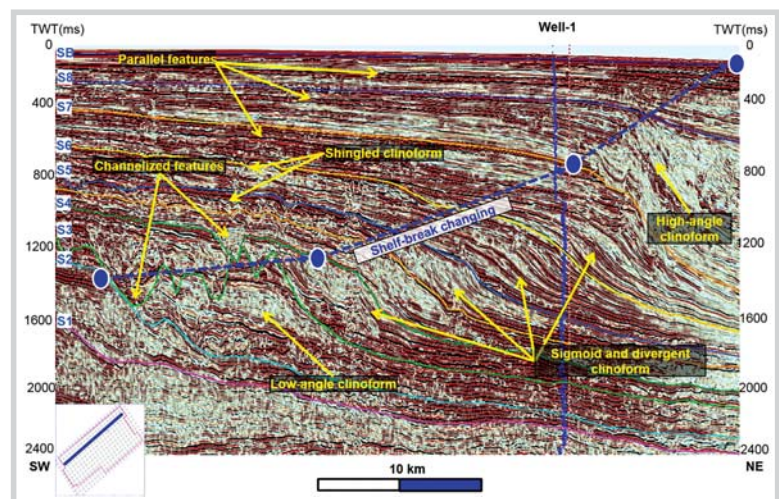
tectonics and sedimentary loading. However, in this case, the rates of the tectonic subsidence have not played an important role to total subsidence rates of the basin because it has been stable during Pliocene to recent time (the post-rift stage of the basin). Therefore, only the rates of sedimentary loading subsidence have been discussed, considered and interpreted through sequences based on observation of seismic lines through internal - external seismic features and isopach maps.

The sediment supply rate in any location can significantly vary through time and there will be large lateral variations within a basin. It depends on both the source to basin relief, which in general terms is dictated by tectonics as well as by the climate. Climate also controls the nature of the sedimentary fill of a basin. Differences in lithology can lead to significant differential compaction and sedimentary processes during deposition [4].

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 eustasy 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 [4].

### 3. Results and discussions

Generally, the sedimentary subsidence rate could vary from margin to slope and down to basin-ward. In fact, the 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 in the study area are uniform. Vertical changes in stacking patterns and internal seismic



**Figure 3.** Demonstrations of seismic facies through sequence to sequence. The blue line has meaning of shelf break variation due to changing of subsidence rates

geometries along the margin of the basin represent temporal variations in subsidence rate. Through sequences 1 - 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 sequences 5 and 6 suggest the rate of subsidence was higher these times. The youngest sequences 7 and 8 are characterised by thick developed aggradations/progradations to the basin. These mean that high sediment supply was controlled during these times (Figures 2 and 3).

In terms of the higher sediment flux, the larger the volume of sediment entering the basin, the thicker the resultant succession will be. Based on Figure 2, the thickness of upper sequences S6, S7 and S8 reflects the periods of high sediment supply in the study area. Conversely, the lower the sediment flux, the thinner the resulting succession will be as the sections of sequences S1 to S5 showing the periods of the low sediment supplied.

Normally, when relative sea level falls below the shelf edge, the sediments of the lowstand systems 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 4). In this study area, a relative sea level curve has not been constructed because of lacks of data and tools. Therefore, the published relative sea level curve of Wornardt et al [5] completed by observations of the stratigraphic unit in the Gulf of Mexico was used to understand how to match the sequence boundaries with the relative sea level change. It is clear that sequence S3 has a good tie with 3.21Ma of relative sea level. Another sequence (S4) is the second good candidate for

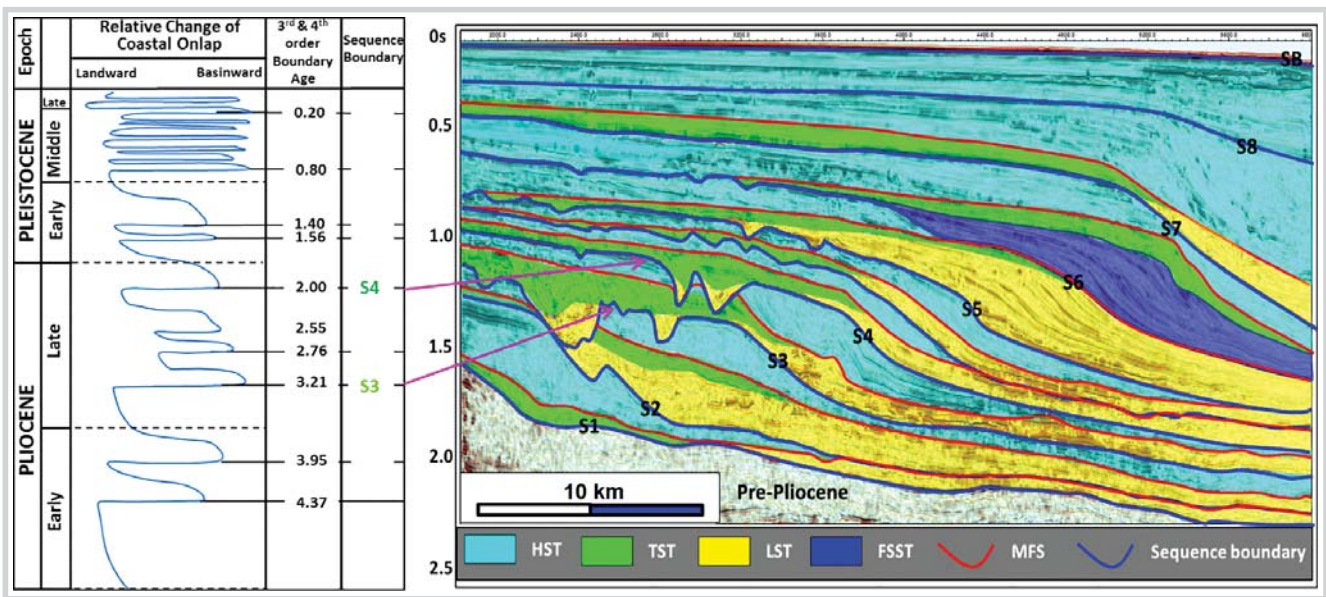


Figure 4. The correlation of the relative sea level change with sequence boundaries: S3, S4 and system tract definitions are interpreted on seismic section

matching with 2.00Ma of the relative sea level (Figure 4).

Based on seismic sections and seismic attributes, canyon systems/channels/incised valleys and basin floor fans (BFF) features can be interpreted. They can be seen clearly from sequence 1 to sequence 6, and it is quite difficult to identify channels in upper sequences, such as in sequences 7 and 8, due to their thickness below seismic resolution or channels may lie outside the seismic survey area.

For sequences 1 and 2, almost all sediments were deposited at slope and basin positions. This means channel features are associated with basin floor fans, both long and short drift fans, due to variation of flow energy.

In sequences 3, 4, 5 and 6, the channel/canyon/incised valleys 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 basin-ward. They develop through time with multiple stages and overlap together. Both long and short drift path basin floor fans can be seen in these intervals, which were controlled by different energy of channels of each stage of evolution. Therefore, grain sizes of sediments of basin floor fans can vary from fine (mud) to coarse (sand) grain as GR signature.

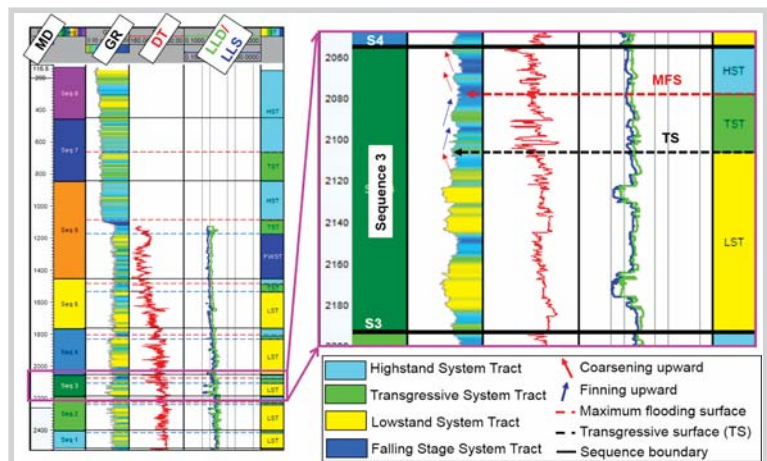


Figure 5. System tract on well log is defined when combining with sequence boundaries from seismic. Within Sequence 3, the LST contributes by floor fans with sharp blocky characteristic of GR log, the TS reflects by fining upward trend and the HST was undertaken by coarsening upward trend

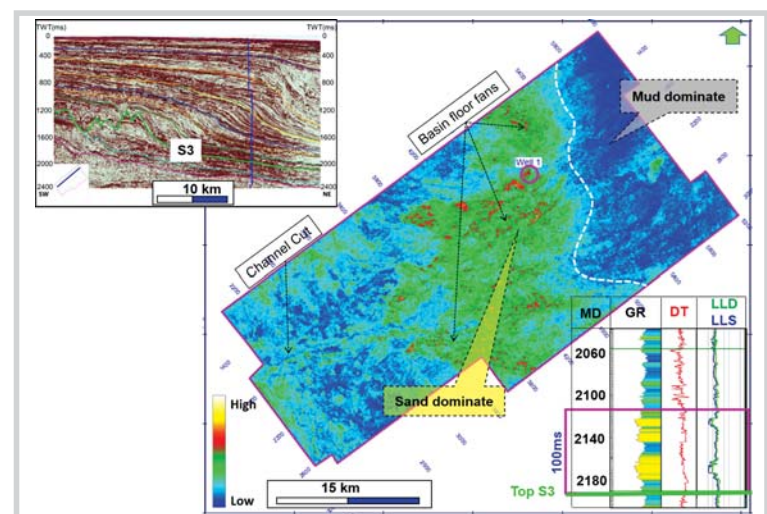


Figure 6. A root mean square attribute map of 100ms window above S3 surface shows channel and basin floor fan distribution and lithology of basin floor fans

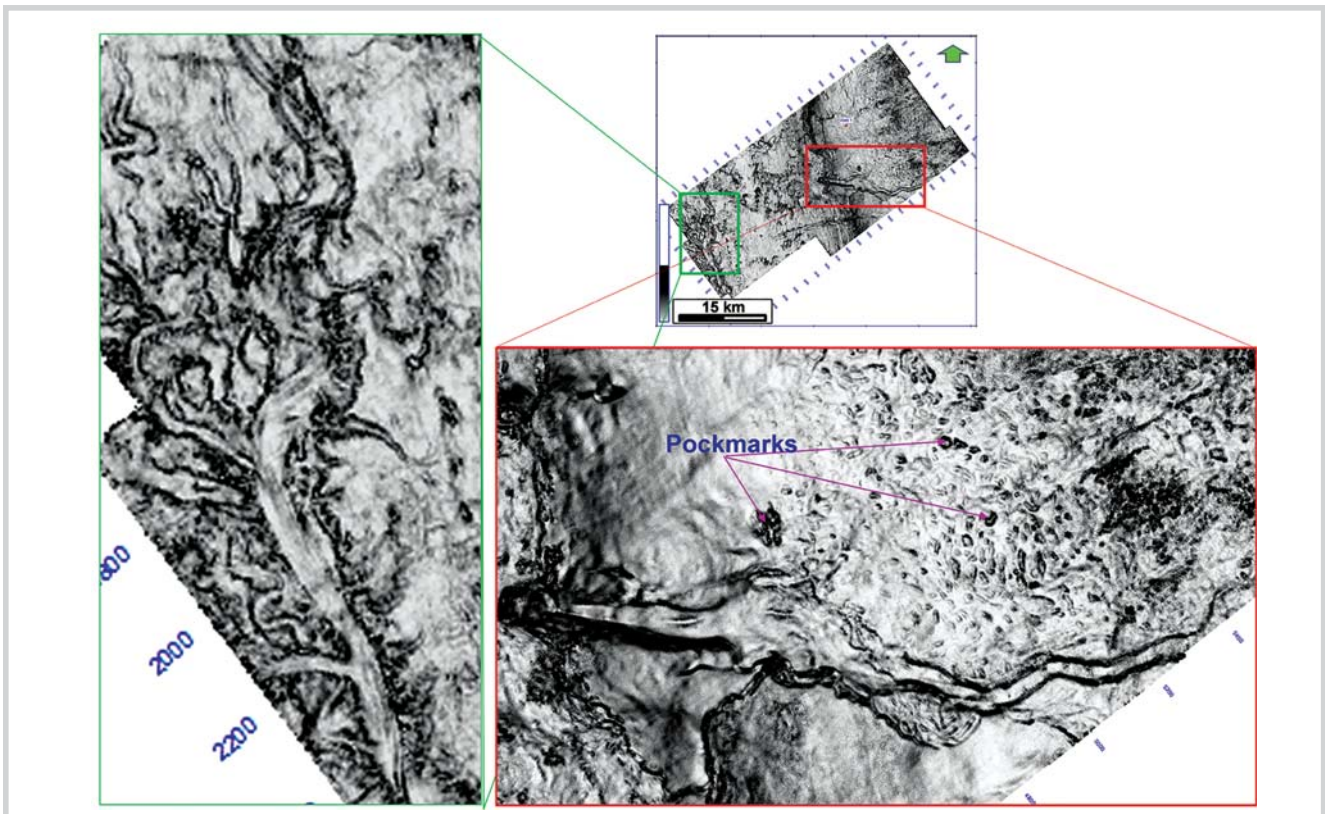


Figure 7. A root mean square attribute map of 30ms window above S5 surface showing the architectures of channels and basin floor fans; dark point could be gas pockmarks, channel migrates from North to South and basin floor fans are from West to East directions

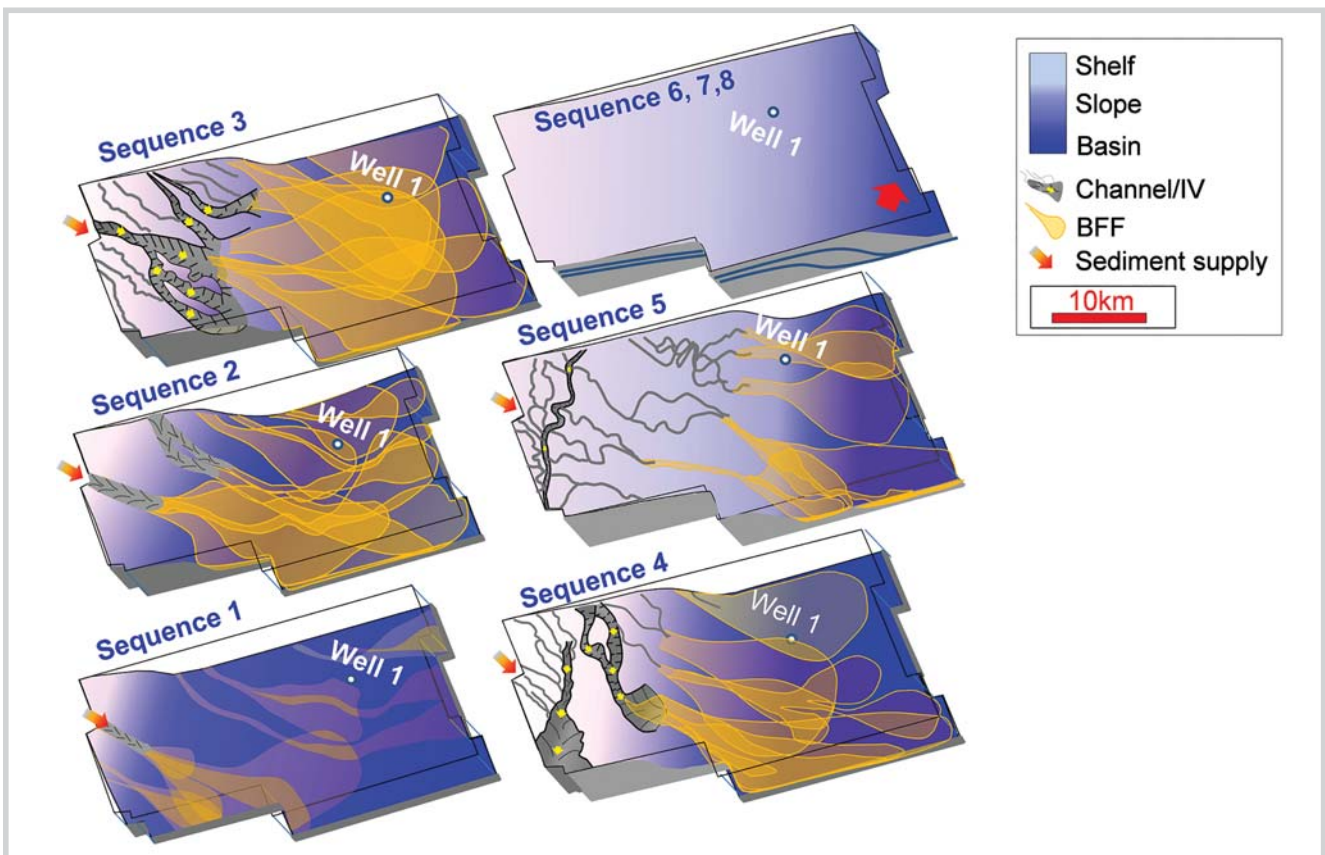


Figure 8. Channels and basin floor fans are displayed on the depositional environment map

By combination of root mean square (RMS) maps with well log, the sand/shale of basin floor fans of each sequence can be interpreted (Figure 6). The evolution of channels/incised valleys on shelf can be seen on RMS maps and on the time slices. In addition, the evolution of basin floor fans can be predicted and mapped through time (Figures 7 and 8).

Almost all channels developed through time have a main flow direction from west to east, while 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 of sediment supply from west to east as shown in Figure 8.

In terms 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 lithology facies 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 (approximately 20m) of sequences 4 and 5 to 100ms (approximately 100m) of sequences 1 and 2 and special sequence 3 have sand dominated as high amplitude on RMS map.

#### 4. Conclusions

Eight sequence boundaries within the Pliocene-Pleistocene sections were interpreted on integration of seismic and well data. The system tracts of each sequence were defined confidently. Based on seismic sections, maps and seismic attribute analyses, channels or incised valley systems and basin floor fans were detected and mapped. The Gross Depositional Environment map was also interpreted aiming for better visualisation of the process of how the sediments were deposited and developed.

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