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SEISMIC SEQUENCE STRATIGRAPHY OF THE PLIOCENE DEPOSITS, CENTRAL TARANAKI BASIN, NEW ZEALAND

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ABSTRACT

A seismicsequence stratigraphic study of the Pliocene age sedimentary rocks was conducted in thecentral part of Taranaki basin, which is located offshore in the western coast of TaranakiPenisula, New Zealand. The study areaisapproximately 217.4.km^{2}consisting of an anticline cut by some faults in the southeastern part of the study area.The purpose of this study was to identify the seismic faciesand to determine the seismic sequence stratigraphic boundariesof the Pliocene deposits.Ten seismic sections and three wells were used in this studywhere manyseismic facies were detected such as parallel, sub-parallel, continuous, sub-continuous, wavy, free reflection, chaotic, high amplitude-high frequency and high amplitude-low frequency. Based on reflection terminations and seismic facies two sequence boundaries with their chronostratigraphic unitswere determined.Sequence boundary 1 (SB1) separates Giant Foresets Formation upper and Giant Foresets Formation middle formations. While sequence boundary 2 separates Giant middle and Giant lower formations.Syntheticseismogram was developed from density and sonic logs and was correlated with the seismic section for locating the sequence boundaries. SB2 is characterized by erosional truncation as shown by the presence oftoplaps and downlapsreflection terminations in the central part of theseismic section. A low-amplitudehigh-frequency reflection was observed above sequence boundary SB1 while high amplitude-low frequency reflection was observed below SB2.

Keywords:
Taranaki basin, sequence stratigraphy, seismic facies and system tracts.

INTRODUCTION

A sequence stratigraphic analysis of the Pliocene age wascarried out in thestudy of central part of Taranaki basin which is located west of Taranaki Peninsular (Figure 1).The study area is about 217 km2 and geologically consisting of a big anticline with some faults striking towards the southeast part of the study area. The Taranaki Basin lies onthe western boundary of the proto-New Zealand Island. Taranaki Basin occupied an area of about l00 000 km2and is located along the west coast of New Zealand's North Island[1]. The basin is essentially a subsurface feature where much of the basin is in the offshore area, which means that the information description involved in our study is based on geophysical and geological interpretation of well data and available seismic sections1. Several tectonic events havedeformed and modified the basin.

The Taranaki Basin considered as the first sedimentary basin in New Zealand and was explored for hydrocarbons and is currently the only New Zealand's oil producing domain [2]. The Taranaki Basin is approximately separated into two structural regions namely the Western Steady Platform and the Eastern Movable Belt. The Western Steady Platform has endured somewhat calm ever since Cretaceous times, and is categorized by "layer-cake" and progradation deposition on an un-faulted, sub-horizontal and locally subsiding sea floor [3]. On the other hand, the Eastern Movable Belt shows a complex morphology due to the tectonic associated with the NeogeneKaikoura Orogeny[4].

Analysis of the interior construction of the progradational Giant Foresets Formation deposited during the Pliocene in northTaranaki Basin, gives the chance to know how a slope to basin clastic depositional system developedas a result of the various factors that control depositional constructions. This setting could contribute to the development of reservoir architectural models for quicklyprograding margins.

The investigation of the Giant Foresets Formationhas focused on the framework of stratigraphic elements in a shelf-slope-basin succession,thus, several fundamental building blocks of the deposits in the study area of centerTaranaki Basin have been addressed, including unconformities, fan, and channel incision. The depositional appearances of the Pliocene deposits (Giant Foresets Formation), imaged on eleven seismic sections covering the study area, have been variously affected by sediment flux, basin structure, local subsidence, and eustatic sea level change, giving rise to a variation of slope sub topography and deeper water depositional elements.About 2000 m thickness of muddy Giant Foresetes sediments built up most of the recentContinental shelf and slope resulted by the rapid progradation together with active down-faulting. The Giant formation is part of the anticline affected by many faults in the southeast part of the study area[3, 6].

Geologically, the study area consists of twolithostrataunits of the Pliocene age which areGiant upper formation and Giant lower formation. Basically, Giant formation is a part of prograding deposits during Pliocene (latakapitean to early magapanian) [6].TheGiant foresets group is an informal name for the Pliocene found in the west and north of the

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Taranaki basin[7]. It is characterized by large scale foreset bedding, readily apparent on seismic lines over the area. As such, the unit is primarily has been defined on seismic evidence. In witiora-1, the Giant forsets group has been also divided into upper, middle and lower units on both seismic and lithologicalevidence. The upper unit (263 m to 710 m depth) is distinguished on seismic as flat lying topset units overlying the lower unit, which displays marked sedimentary dip of about 20 to the northwest. The upper unit comprises soft unconsolidated muds, silts, and sand in roughly equal proportions. Over the entire interval shell fragment is common[8].

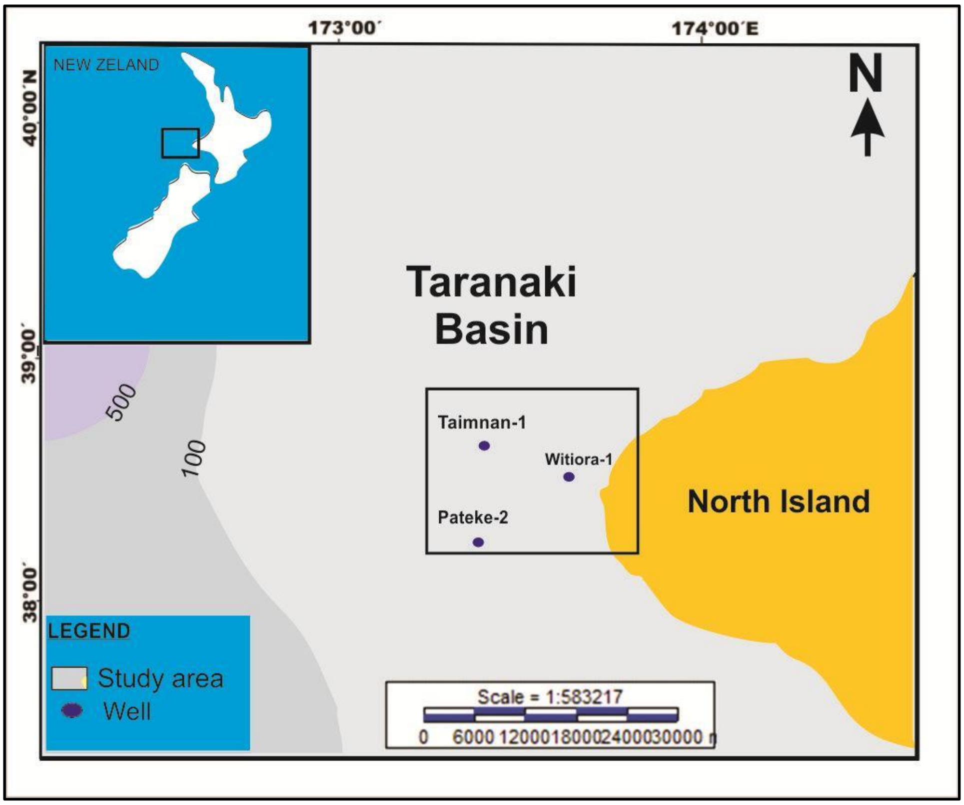

FIGURE 1. Location of the Taranaki Basin and the study area.

Pliocene deposits constitute the middleGiant, lower Giant. Themiddle giant unit (from700 m to 935 m depth) displays sedimentary dips of 20 degrees at the top, increasing to about 50 degrees around the well. Some lines show about 30 degrees dip with manychannels.Thedips are determined from the seismic lines near Witiora-1where the deposits commonly displays hummocky diffractions indicative of channeling. In the well, thetop of the unit is picked on markedinflections on both gamma ray sonic and synthetic seismogram curves. The interval comprises mudstones and siltstones with minor sandstones.The argillaceous lithology isnon-calcareous to slightly calcareous and contains abundant foraminifera. Below 1050m depth the sands become glauconitic, increasingly so towards the base[8].

Sequence stratigraphy is a studyto understand the relationship between rocks and stratigraphic evaluation. In terms of seismic facies, the traditional methods are based on the observation of seismic facieson the sections and their distribution to construct a subsurface model[9]. Seismic reflection packages are divided up into seismic sequences and system tracts to understand depositional processes, the application of sequence stratigraphy in seismic interpretation has proven to be Fundamentally important to guess traps positions distribution of reservoir, source rocks and also in the basin analysis.

Eleven seismic section and three wells were used in the analysis as shown in Figure 2.All the data used in this analysis are provided by New Zealand Petroleum and Minerals (NZPM). The Obtainable data directory contains the adjusted SEGY files that were loaded into the Kingdom software. The objectives of thestudy are to identify the seismic facies of Pliocene age (Middle and lower Giant foresets formations). The second purpose was to detect the sequence stratigraphic boundaries and determined the system tract (lowstand, transgressive and highstand).

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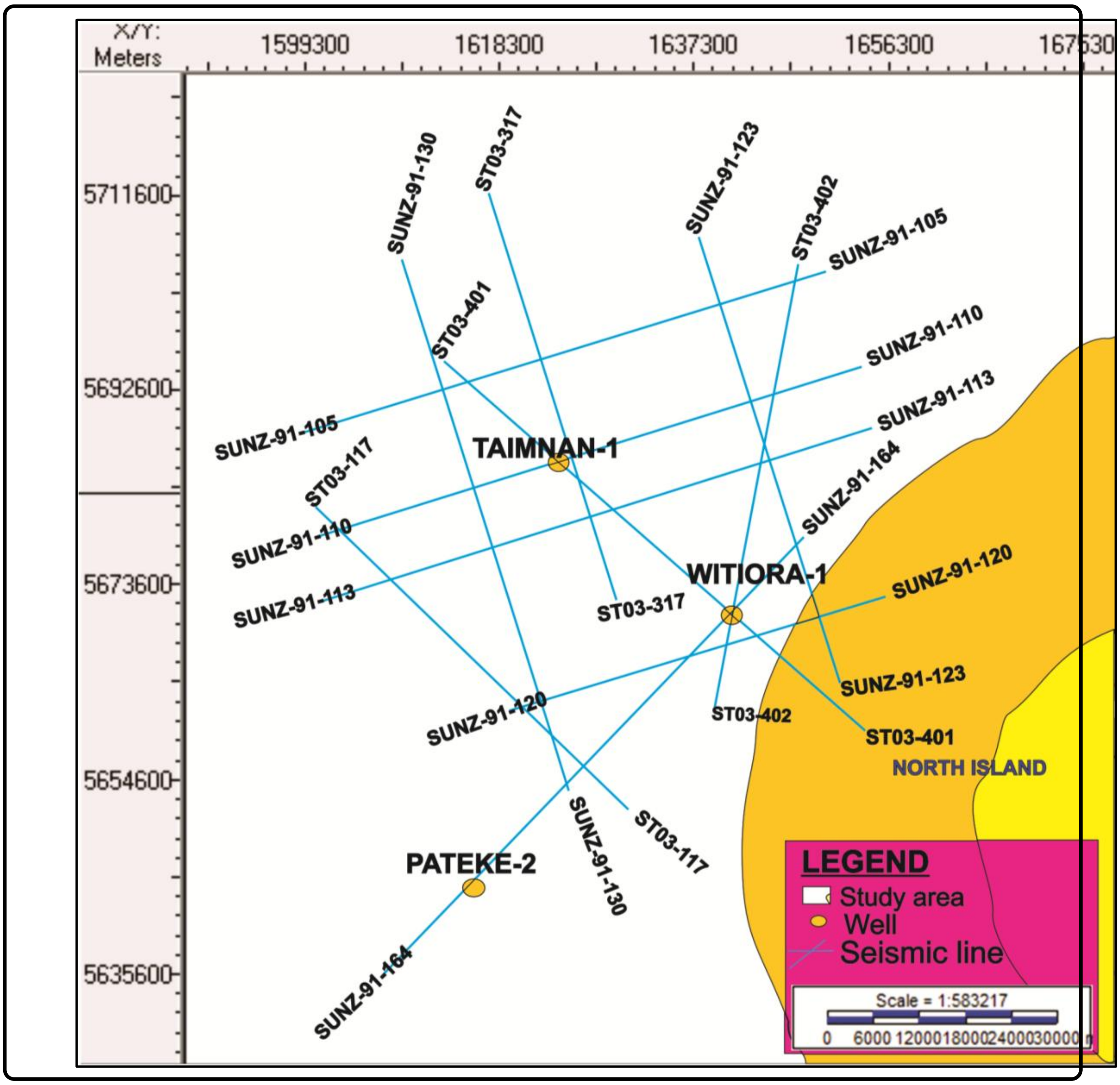

FIGURE 2. Seismic lines and boreholes that used in this study.

METHODOLOGY

In this study, eleven seismic section and three wells were used in the analysis. All these data supplied by New Zealand Petroleum & Minerals (NZP & M). The study area covered an area of about 217.4km^2[2,6]. The analysis was started by generating synthetic seismogram by using sonic and density logs. The source wavelet used was Ricker with 30-40 Hz frequency. The synthetic seismogram with formation tops was then transported into the seismic section to determine the horizons corresponding to unconformities for the whole study area. In addition, reflection terminations such as toplap, downlap, onlap and erosional truncationwere determined associated with the horizons.Seismic facies and system tracts are also identified on seismic lines by analysis of reflection configuration such as frequencies, continuation, and amplitude. System tractssuch as highstand, lowstand and transgressive deposits between the horizons were then identified fromgamma ray well logs. The lithology, ages, depositional environment are derived from the geology report of the witiora-1.Para sequences wereidentified on the gamma ray log by recognizing the changing in gamma ray shape, whether the sediments trend fining upward or coarsening upward[10, 11].The shallowing upward sediment is marked by mudstone of deeper water overlying the beach or foreshore sandstone beds while the coarsening upward may consist of mudstone atthe base representing offshore deposition and overlain by sand deposits ofshore face, foreshore, and beach environment[12].

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RESULTS AND DISCUSSION

Figure 3 showsanon-interpretedexampleof a seismic sectionSUNZ-91-164 that was used in this study. This seismic sectionis trending E-W with 28 km length and containsa setof different reflection patterns which determineddifferent depositional types.This section has two-way time from 0.5 to 1.6 Secs with a depth range of 550m to 1500m thick of sediments.

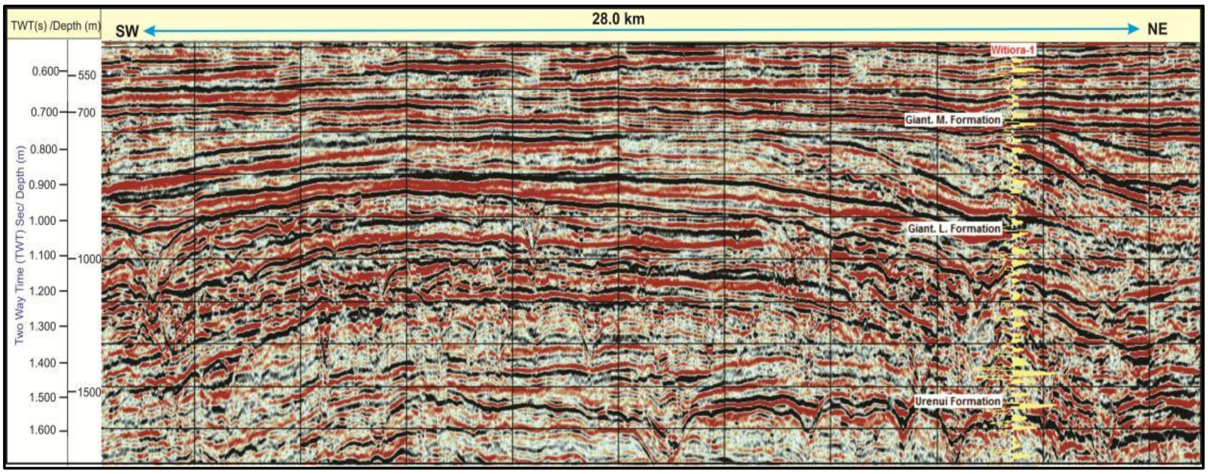


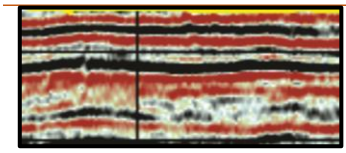
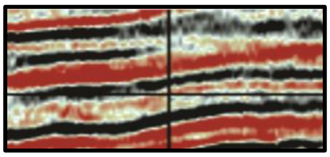
FIGURE 3. Uninterpreted seismic line with two-way time in seconds and depth in the meter.

Many seismic facieswere observed on this seismic section such as parallel, sub-parallel, continuous, sub-continuous, wavy, chaotic, high amplitude-low frequency and low amplitude- high-frequencyfaciesand the descriptions of the facies are as described in Table1. All facies were associated with the appropriate formations,ages, and lithology based on thewellcorrelations.

Figure 4, 5 and 6 show the interpreted seismic sections showing the chronostratigraphic units, bounded by sequence boundaries. The sequence boundaries are top Giant Foresets middle and top Giant Foresets Formations. The seismic Reflection terminations such as onlaps, toplaps, downlaps and erosional truncations were used to identify the sequence boundaries. Seismic facies detected depend on the reflection configuration in the seismic sections.

Gamma ray log (GR) involved in identifying the general lithology especially the sand and shale. The sequence boundary 1 (SB1) represent the top of middle Giant Foresets starting from 700 m to 935 m depth with sedimentary dips of 2 to 5 degrees at the top in the well. The dipping was as high as 30 degrees in some of the lines such as line STO3-317.the Giant middle formation is also characterized by the presence of many river channels. This sequence basically consists of two seismic facies such as parallel and sub-parallel as well as erosional truncation. A clear change of gamma ray log patterns of the sequence infers different types of sediment deposits such as mudstones, siltstones with minor sandstones as shown in Figure 4.

TABLE 1. Seismic facies and description.

Facies	Description
 Parallel	Middle Giant FormationPliocene, (Early Magapanian)Dominant mudstones and siltstones with minor sandstones and calcareous.
 Sub Parallel	Middle Giant FormationPliocene, (Early Magapanian)Dominant mudstones and siltstones.

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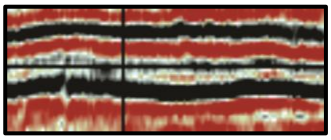
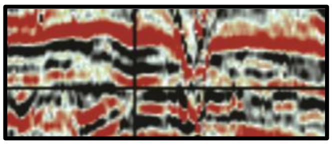
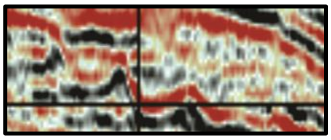

Continuous

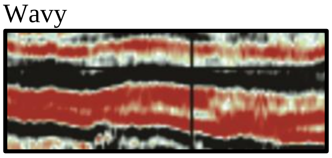
Middle Giant FormationPliocene, (Early Magapanian)Dominant mudstones, siltstones with minor sandstones and calcareous.


Sub-continuous

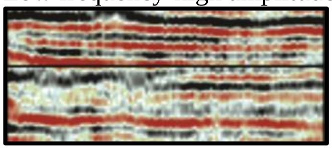
Lower Giant FormationPliocene,(late kapitean to early magapanian)Dominant with minor sandstones, calcareous and argillaceous lithologies.


Wavy

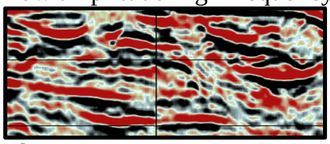
Lower Giant Formation, Pliocene,(latakapitean to early magapanian) Dominant with minor sandstones, calcareous and argillaceous lithologies


Low frequency-high amplitude

Lower Giant Formation, Pliocene,(latakapitean to early magapanian). Dominant with minor sandstones, calcareous, argillaceous lithologies


Low amplitude-high frequency

Middle Giant Formation, Pliocene, (Early Magapanian). Dominant mudstones and siltstones with minor sandstones and calcareous.


Chaotic

Lower Giant Formation, Pliocene,(latakapitean to early magapanian) Dominant with minor sandstones, calcareous and argillaceous lithologies

The sequence boundary two (SB2) which represent Giant lower formation was identified in the seismic section by thesametechnique as in the determination of sequence boundary SB1. The SB2 is characterized by a different seismic faciessuch as chaotic,parallel, subparallel,and there are many channelsobserved on the upper part of this sequence deposit. Hummocky and discontinuous reflection patterns were also observed especially in the lower part of the sequence together with wavy, parallel and sub-parallel seismic facies.

The synthetic seismogram and GR logs observed at the boundary of SB2 indicate a variety ofsediment deposits. Based on the Gamma-ray reading, sequence boundary two (SB2) can be interpreted as representingSandstones,siltstones and calcareous to calcareous and some argillaceous materials (Figure5). Strata separating the SB2 consist of sedimentary units of different ages as determined by borehole information and corresponding todifferent types of seismic reflection terminations and seismic facies.

Figure 6 shows the complete colorful and interpreted seismic section of theSUNZ-91-164seismic section that illustrates the sequence boundaries, seismic facies, systemtracts, reflection termination, andchannels.The gamma ray log of well witiora-1indicates acomplete depositional system includinghighstand, lowstand, and transgressive system tracts of the Giant Foresets middle Formation.

The lower part of Giant middle formation is marked by the presence of slope and floor fans which reflect the lowstand system tract (LST) environment of deposition.The upper part of the Giant middle formation indicatesthe presence of high stand system tract deposit (HST).The lowstand systems tract (LST) is characterized by a relatively low sea level and in the case of SB1, sea level falls below the shelf-slope break. Typical LST sediments comprise a basin floor fan with a slope fan developing during the sea level start to rise and ended with the development of a clasticlowstand wedge in a basinal position.

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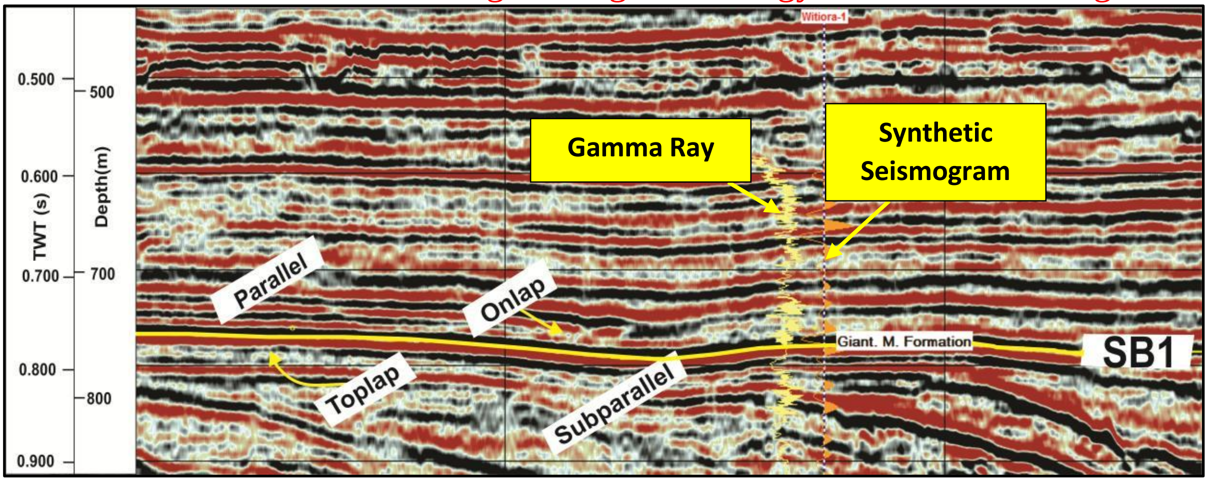

FIGURE 4. Interpreted seismic section with synthetic seismogram and GR log displays the SB1 position (yellow line).

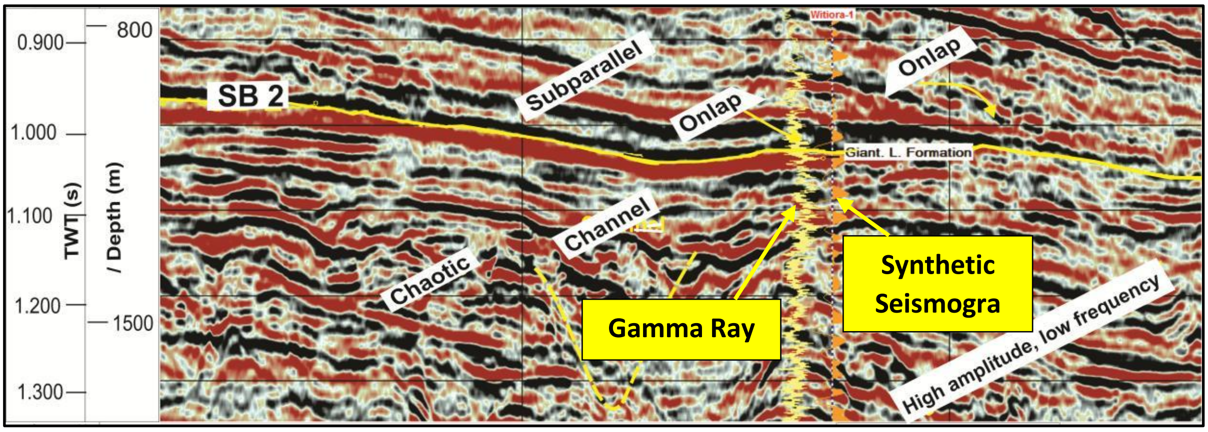

FIGURE 5. Interpreted seismic section displays the location of SB2 (Yellow line) with seismic facies and channels.

In seismic section (Figure 6), the LST is commonly seen as a wedge of sediment deposited on the basin floor and slope the basin. Clastic LST wedge deposits estimated about 100m thick is observed in the seismic section. The LST deposits also contain normal fault structures trending SE-NW as shown in the seismic. LST basically represent continental deposits caused by the river erosional process resulting in deposition of formations with channels during the sea level decrease. The bottom part of Giant Foresets middle Formation contains some river channels especially in other seismic lines in the study area such as ST03-317 located on the western side of Taranaki basin.

The TST starts by a rising of sea level where the sea water moves towards the continent by carrying the marine deposits. During the period of rising of sea level, the channels were cut to form the incised valley and filled by mostly sand deposit. The sand deposit during the rise of sea level is associated with parasequence set named as flooding surface (FS) characterized the starting of the transgressive system tract (TST). The TST surface developed above the LST and the TST surface were identified by the presence of the marine onlaps terminations in the seismic section.

Atransgressive system tract TST is produced when the Relative sea level is rising rapidly and the sea level has risen back onto the shelf. Thin, parallel, relatively deep water deposits or coastline proximal sediments are generated during this process. The base of the TST is the transgressive surface, where TST Reflectors are parallel in the middle part of the section and downlap onto the underlying LST deposits in a distal position and onlap onto the underlying sequence boundary in a proximal position. The upper surface of the TST is the maximum flooding surface (MFS) which separate between the TST and HST.

At the maximum rising of sea level, the supplied sediments are enough to outpace the rise in the sea level (accommodation) and start to prograde seaward as shown by the presents of the downlap on the top parts of Giant lower and middle. This progradation formed during high sea level rise is called the highstand system tract (HST). A new cycle of sea level falling is then starting again to form a new sequence on the top surface of the Giant middle formation by the erosional process that occur as unconformity surface which shown by the presents of erosional truncation. This episode of sea level fall produces the sequence boundaries and the sediment that remains between the sequence boundaries will show patterns of progradation, transgression, and Aggradation reflecting the sea level changes as determined by Gamma

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ray log analysis. A complete cycle of falling and rising sea level identified on the Giant middle formation and only LST and HST system were identified in the lower giant formation.

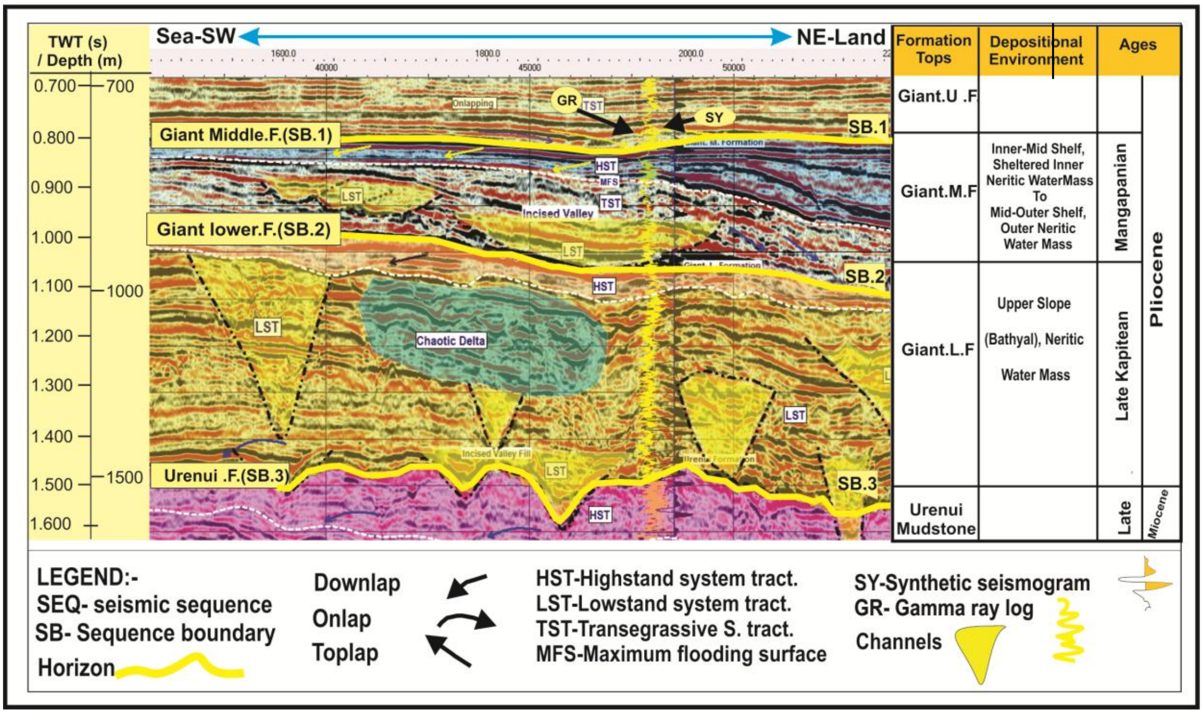

FIGURE 6. An interpreted seismic section displaying the sequence boundaries of SB1 and SB2 with associated formation top, age range, the system tracts, reflection terminations, GR log, synthetic seismogram and the channels.

CONCLUSION

Analysis of seismic section and thewell log has successfully been used in the determination of Sequence boundaries, Seismic facies, system tracts, river channels and depositional environment.Two sequence Boundaries separating three formations in the Pliocene age such asSB1and SB2 were identified. Eight types of seismic faciesand a complete cycle of sea level change occurred in the giant middle formation representing LST and HST system tracts. Seismic section reflection terminations also helped in the determination of system tracts representing different depositional environments such as Inner-Mid Shelf, Sheltered Inner Neritic Water Mass To Mid-Outer Shelf, Outer Neritic Water Mass in SEQ1 while in SEQ2 was upper Slope (Bathyal), Neritic Water Mass deposited environment.

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