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Processing of an offshore new zealand complex tectonic environment taranaki basin, 2d seismic line

Maunde A.*, Haruna I. V., Raji A. S. and Halilu M.

Department of Geology, School of Pure and Applied Sciences, Modibbo Adama University of Technology, Yola, P.M.B. 2076, Yola, Nigeria.

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Norpac International crew #503 acquired 22.7 km of seismic line off the West coast of New Zealand's North Island in the Taranaki basin for New Zealand Oil and Gas industry in order to evaluate the subsurface stratigraphy of the basin. The seismic line trends east-west crosses the Taranaki Fault, a basement overthrust that forms the eastern boundary of the Taranaki basin, New Zealand's most prolific petroleum province and is in relatively shallow water estimated to be 119.6 ± 2.1 m with water velocity of 1486.3 ± 10.6 m/s. Reflectors on the processed seismic section were clearly visible with strong amplitudes, which revealed the subsurface stratigraphy of the basin. The potential reservoir formation (Miocene sediments) are marked by significant unconformity, over much of the western platform, the unconformity is disconformable. Sediments of Cretaceous and Paleocene age are not present toward the eastern platform, generally due to non-deposition over high-standing basement areas. The Taranaki crustal Fault is clearly visible on the processed seismic section despite lack of surface exposure.

Key words: Seismic, basin, processing, stratigraphy, velocity and petroleum.

INTRODUCTION

Reflection seismology is the most widely used geophysical techniques and has been since the 1930's. Its predominant applications are hydrocarbon exploration and research into crustal structure, with depths of penetration of many kilometers now been achieved. The current state of sophisticated of the techniques is largely as a result of enormous investment in its development made by the hydrocarbon industry, coupled with the development of advanced electronic and computing technology. Part of the spectacular success of the method lies in the fact that the raw data are processed to produce seismic section which is an image of the subsurface structure, although this image is fundamentally different from a depth section, only by understanding how the reflection method is used and seismic sections are created if the geologist make informed interpretation (Yilmaz, 2001).

Seismic data processing requires an orderly approach to converting raw field records into meaningful information about subsurface geology. The final interpretation of the seismic data is only as good as the validity of the processed data. It is imperative that the interpreter be aware of all the problems encountered in the field data acquisition and the data processing stage. A data processing geophysicist must know and understand the regional geology of the Basin and particulars of each processing step. There is no cookbook routine to follow in the processing. Each geologic setting presents its own specific problems to solve. Before routine processing for a prospect, extensive testing on the data should be done to study the problems involved to design the optimum parameters for each

*Corresponding author. E-mail: abubakarmaunde@yahoo.co.uk.

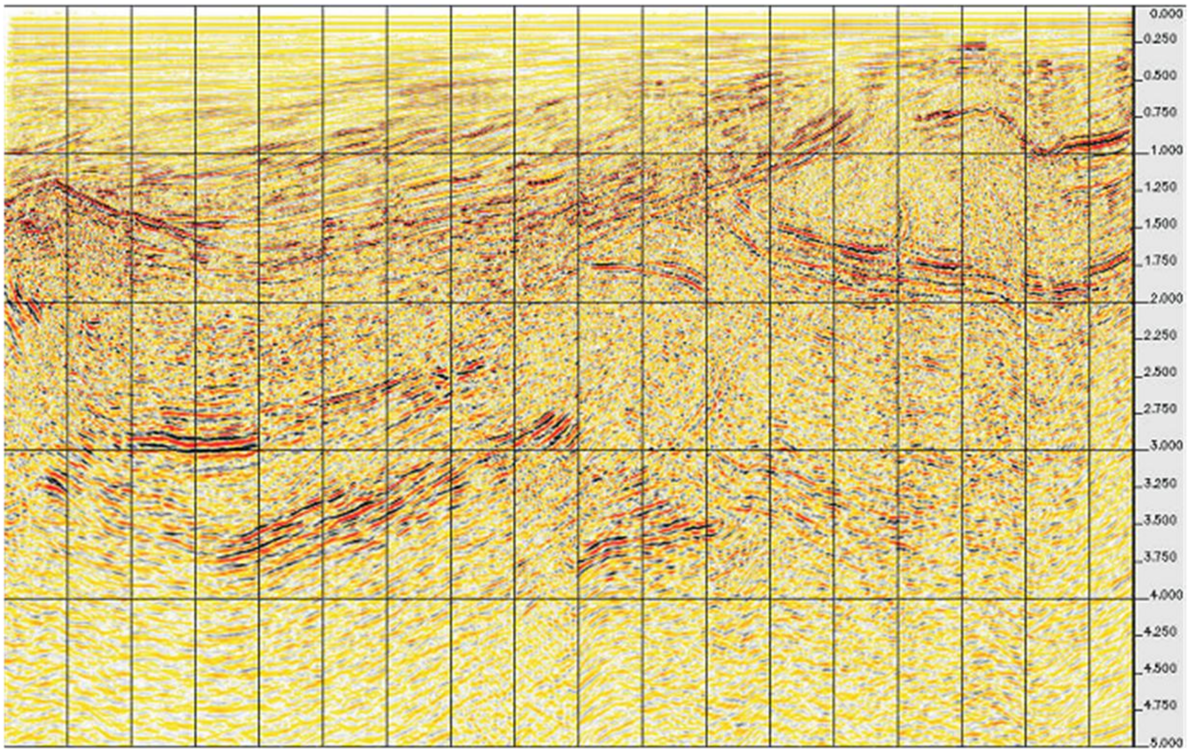

Figure 1. Pre-stack depth migrated section (Nicol et al 2004).

step in the data processing flow (Gadallah and Fisher, 1999). The typical data processing procedures applied for this work are stated and to some degree have been tailored to meet the special requirement of this specific data. However, practical compromises have to be made.

The Norpac international acquired 22.7 km of seismic line TRV-434 off the west coast of New Zealand's North Island in the Taranaki basin in January 1986 for New Zealand oil and gas (NZOG). The seismic line trend east-west crosses the Taranaki Fault, a basement overthrust that forms the eastern boundary of the Taranaki Basin.

The attraction of this seismic line is that paper(s) have been published, with limited frequency band, lack amplitude character and are poorly imaged (especially the shallow events (Figure 1). This present work attempt to improve resolution of the seismic imaging (Figure 1) with the aim of providing a better seismic section that clearly reveal the subsurface stratigraphy in Taranaki basin.

Geology of Taranaki basin

The Taranaki basin (Figure 2) is situated offshore west of New Zealand's North Island and formed in response to subduction of the pacific plate along the Hikurangi margin. This fan-shaped basin widens northwards and is mainly defined by left-stepping segmented normal Faults (King 2000). Most parts of the basin are characterised by sedimentation rates that exceed displacement rates, a condition which permits displacement backstripping of these syn-sedimentary growth Faults (Palmer and Andrews, 1993). Because Taranaki Basin is almost entirely a subsurface feature, the geologic information of the area is short, although rudimentary exploration began 1800's century and hydrocarbon production in the basin has been continuous since 1866 (Katz, 1988). Modern knowledge of the basin begins with the 1955 discovery of the Kapuni Field, on the southern side of the Taranaki Peninsula. This discovery proved the basin to contain sediments as old as Eocene, and as thick as 3.5 km. The basin was formally named in 1967, in an article by Cope and Reed (1967) which stated: "West of the Taranaki Fault, Eocene (or older) sediments rest on basement and they are overlain by an almost complete succession of Cenozoic deposits up to the recent Egmont volcanics''. The term Taranaki Basin is proposed for this sedimentation area covering the pennisular part of the Province.

The acquisition of considerable seismic reflection data since that 1967 article has allowed subsurface mapping of the basin (Shell Oil Company, 1987; Thrasher, 1990). Taranaki Basin is now known to be a predominantly north-south subsurface feature. The present basin is bounded to the east by the Taranaki Fault, a major late-Palaeogene to Neogene reverse Fault which vertically

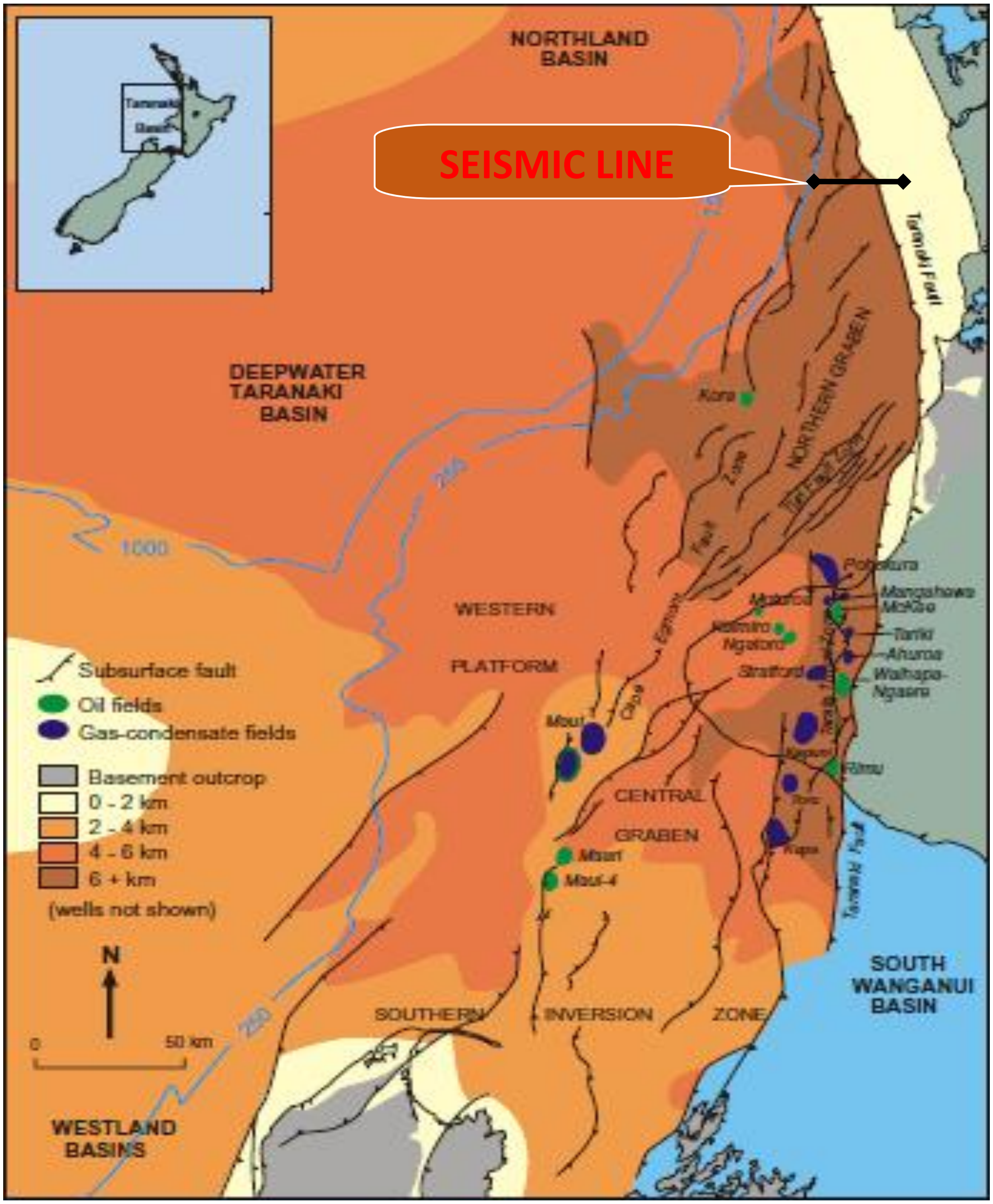

Figure 2. Map of Taranaki basin showing acquisition seismic line. Source: New Zealand Ministry of Economics (2004).

offsets basement by more than 5 km. To the west, the basement gradually shallows onto the Challenger Plateau, an oceanic bathymetric high. The northern and southern limits of the basin are not clearly defined. To the south, the basin merges with the numerous small basins of the northwestern South Island, while to the northwest it merges with the bathyal New Caledonia Basin. Studies show that the basin first formed as a late cretaceous transcurrent rift along the Gondwanaland margin. This eastern edge of Gondwanaland was a belt of terranes accreted during Mesozoic convergent tectonics (Sporli, 1987). Following this initial rifting, subsidence continued throughout the cretaceous and into the early Tertiary. Since the rift phase, the basin has undergone a complex history of subsidence, compression and additional extension. This post-rifting period has been documented by King and Thrasher (1996).

Post-rift tectonic activity in the basin began in the

Table 1. Acquisition parameter and design, (Source: Norpac International Crew #503).

S/N	Acquisition parameter	Acquisition design
1	Source type	Air gun array
2	Source tow depth	10 m
3	Shotpoint interval	25 m
4	Receiver type	Streamer cable
5	Group interval	25 m
6	Number of groups	120
7	Receivers tow depth	8 m
8	Near offset	258 m
9	Far offset	3233 m
10	Recoding system	DFR-V
11	Data format	SEG-D Cartrige
12	Sample interval	2ms

late-Oligocene, when a dramatic increase in subsidence in the eastern portions of the basin is documented. This subsidence is believed to have been foreland basin development associated with transgression along the Taranaki Fault Zone (King and Thrasher, 1996). Basement on the eastern side of the Fault overthrust basin sediments during the Miocene, to form the eastern margin of the basin. The amount of shortening associated with this thrust is unknown, and is one of the more interesting problems of Taranaki Basin geology. Associated with west directed thrusting of basement across the Taranaki Fault are thin-skinned overthrust soling within the Palaeogene section (Hoolihan and Yang, 1991, King and Thrasher 1996). These "sled-runner" structures have been a major exploration target of the last decade. About 10 Ma, the region of major compression shifted south, and the "Southern -zone" became a region of major structural inversion of older normal Faults. Many of the most spectacular anticlinal features in the basin were formed by this compression during the last 10 million years. The compression led to considerable uplift and erosion in the south, and a subsequent increase in sedimentation in the northern and western portions of the basin. The same period has hence been one of very high sedimentation rates, which have caused the progradation of the continental shelf to the northwest as a series of giant, clinoform-bounded, sediment wedges. Complicating this pattern of uplift, erosion and progradation has been the subsidence of the North and South Taranaki grabens due to back-arc rifting (with associated volcanism) and flexure. The present configuration of the basin, which is dominated by the stable western platform, the subsiding Taranaki Grabens, and the Taranaki Fault Zone, is a combined result of the tectonic processes of the last 100 million years. However the architecture of the basin is in large part controlled by the tectonic trends of the late cretaceous rift phase.

Seismic data acquisition

The seismic line TRV-434 was collected by Norpac International crew #503 in January 1986, and is available from the New Zealand Ministry of Economic Development under the New Zealand open file system. The seismic line trend east-west crosses the Taranaki Fault, a basement overthrust that forms the eastern boundary of the Taranaki basin, New Zealand’s most prolific petroleum province, and is in relatively shallow water estimated to be 119.6 ± 2m with water velocity of 1486 ± 10.6 m/s along the seismic line. A total of 976 shots were collected. Detailed summary of the acquisition parameter and design were presented in Table 1.

SEISMIC DATA ANALYSIS

The seismic data was originally acquired in SEG-D format using 2 illisecond sample interval and was later reformatted from the original SEG-D to SEG-Y format as specified by the processing system being used (that is, ProMax^{TM} Landmark Software). The collected 976 shots raw gathers (Figure 3) were loaded into processing software ProMax^{TM} and visually inspected after applying an optimum gain function (AGC) of 85 ms (Figure 4), in order to observe the general trends of the datasets at different locations and for differing environmental conditions as well as to make deeper reflections visible for analysis. The arrivals (that is, events) identified on the collected shots gather were shown in Figure 5. The characteristics of the identified noises present on shots gather were tabulated in Table 2. Interactive spectral analysis was carried out to examine the frequency contents of the dataset, the prominent arrivals in the spectrum (Figure 6) are the required signals (that is, reflections), bubbles pulse, source and receiver first

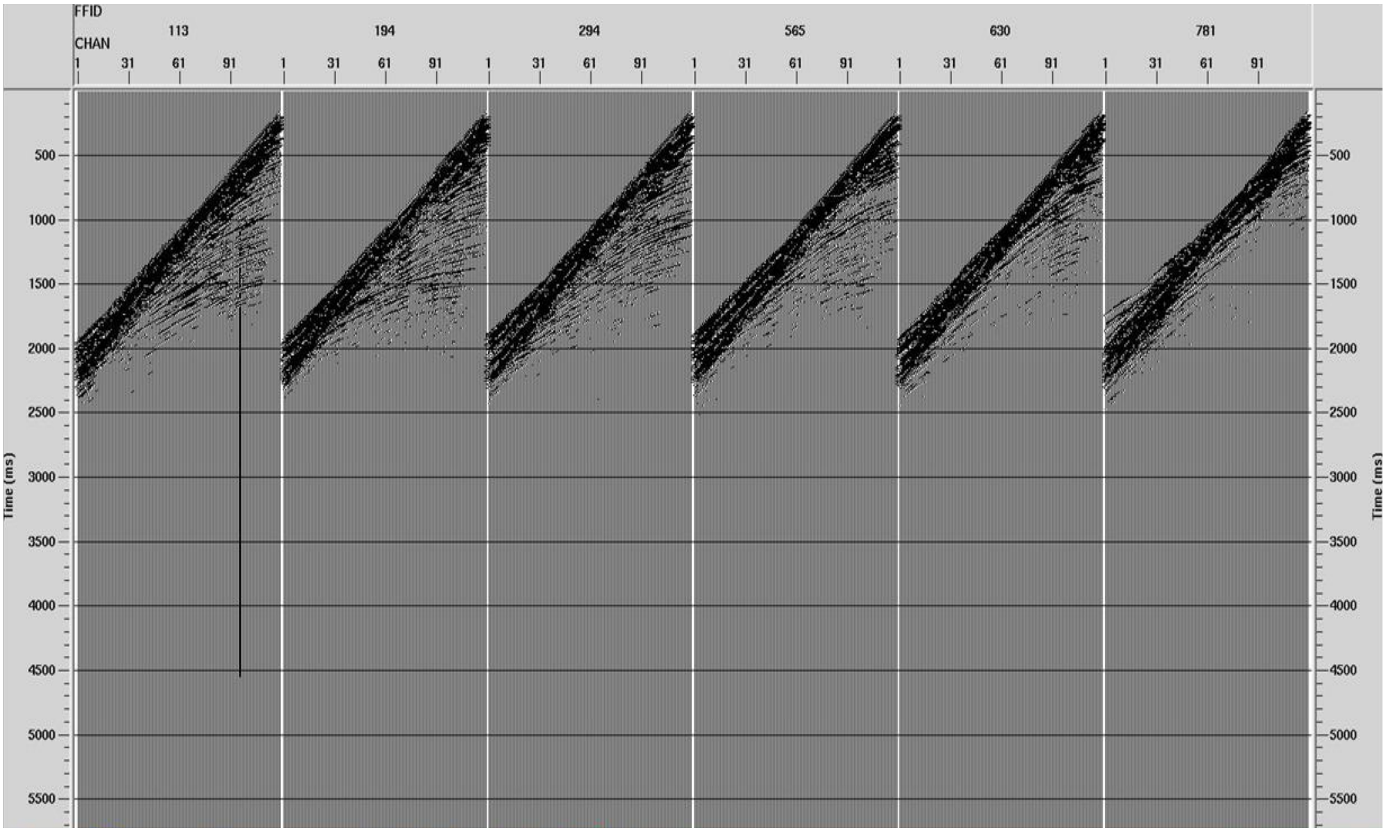

Figure 3. Raw shot gathers recorded in field. Black vertical line represent death trace.

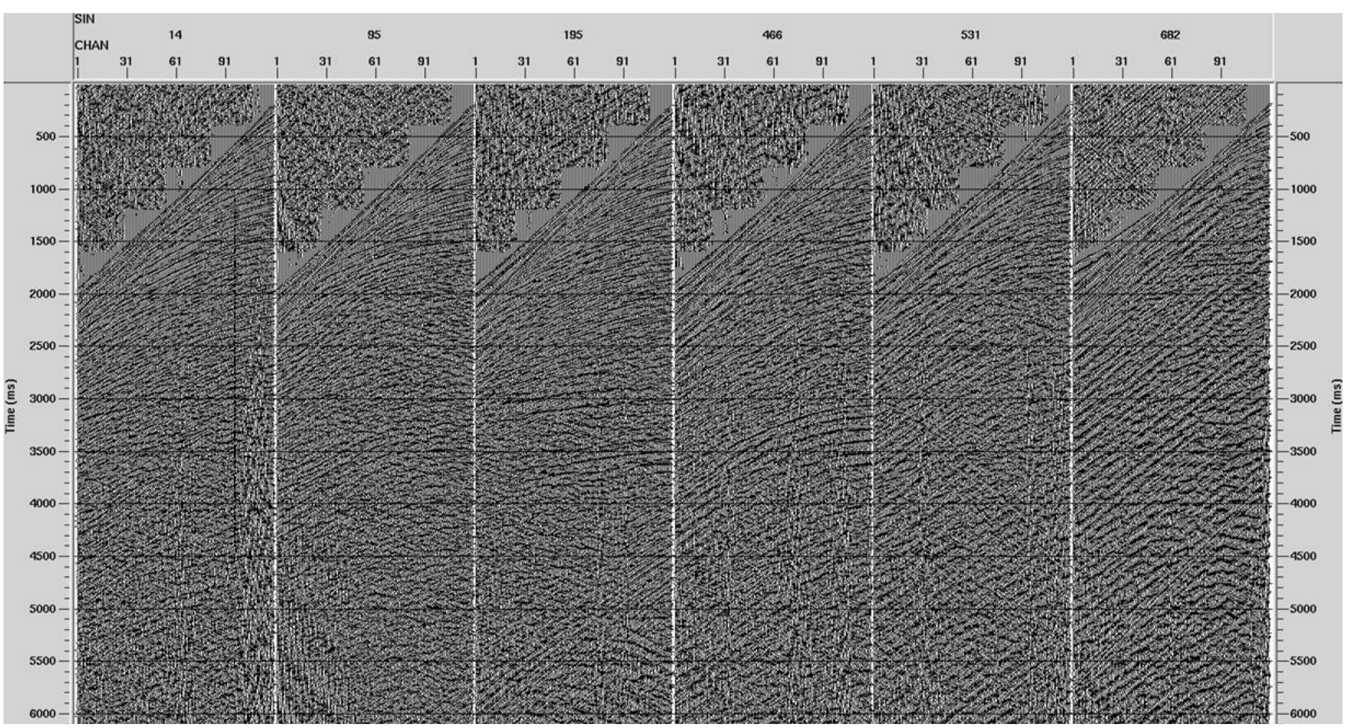

Figure 4. Raw shot gathers with 85 ms automatic gain control window length applied.

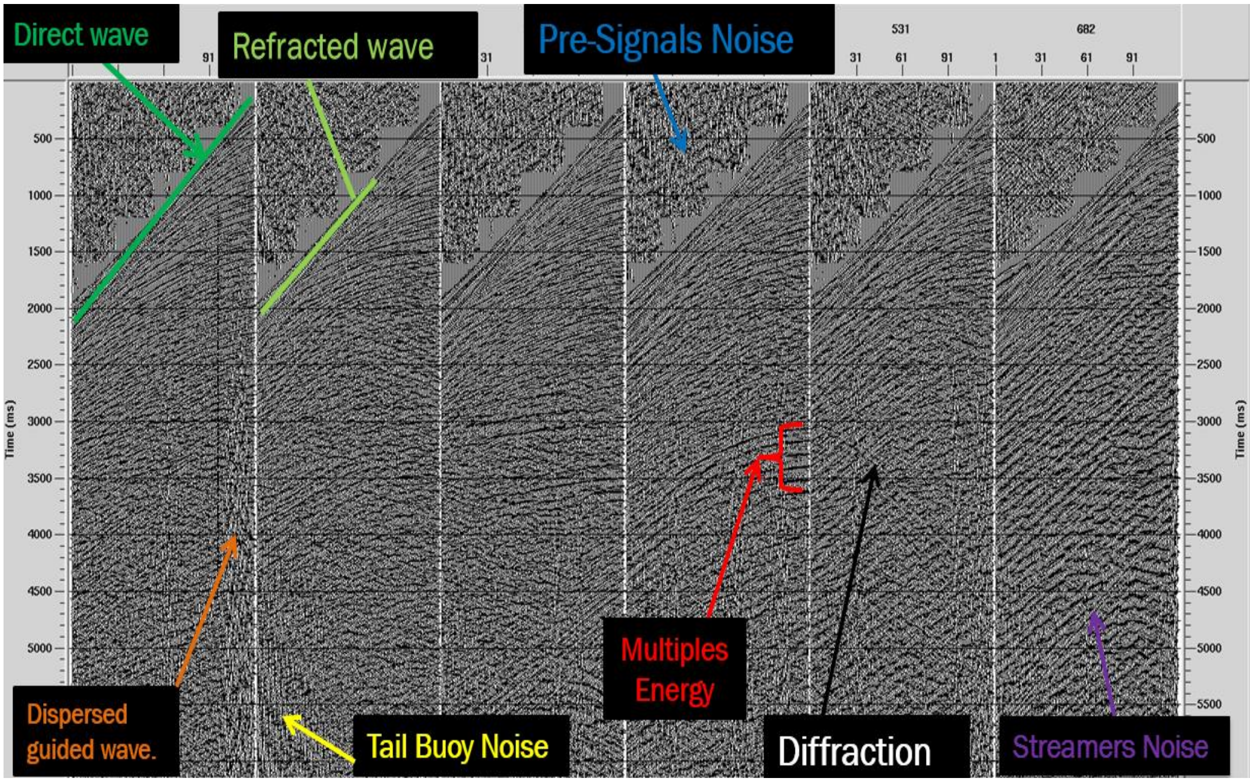

Figure 5. Identified arrivals on raw shots gather after agc window of 85 ms applied.

Table 2. Characteristics of noise present on raw CMP's shot gather.

S/N	Noise	Amplitude	Frequencies (Hz)	Velocities
1	Tail buoy noise	High	3 – 15	46 – 1200 m/s
2	Dispersed guided waves	High	3 – 14	0.5 – 1.3 m/ms
3	Streamers noise	Intermediate	14 – 25	0.7-1.35 m/ms
4	Direct and refracted wave	Low	45 – 58	1.45–2.5 m/ms
5	Multiples energy	Low	25 – 45	1.3 – 1.5 m/ms

ghost notch respectively.

SEISMIC DATA PROCESSING

ProMax™ Landmark Software (Figure 1) was utilise for the processing of the 976 collected shots gather acquired in field, the processing steps applied to the dataset have been divided into three main stages in order to meet the special requirements of the dataset. The stages are:

1) Pre-processing
2) Main processing stage and
3) Post-stack processing stage.

Pre-processing stage

This stage was carried out to improve the signal-to-noise (S/N) ratio of the shots gather recorded in the field, the stage was carried out as follows. Unwanted traces, pre-signal noises, direct and refracted waves were edited and muted out. An optimum Band-pass filter of (15-30-70-125) Hz was designed to discriminate between signals and noises on the basis of their frequency contents and to suppress noises on the dataset, minimum phase pre-stack predictive deconvolution was applied to the dataset to suppress short part predictable multiples energy, reverberations and to improve lateral resolution of the dataset. Window length of 19 ms, lag time of 21 ms and percentage white noise of 0.1% were determined by

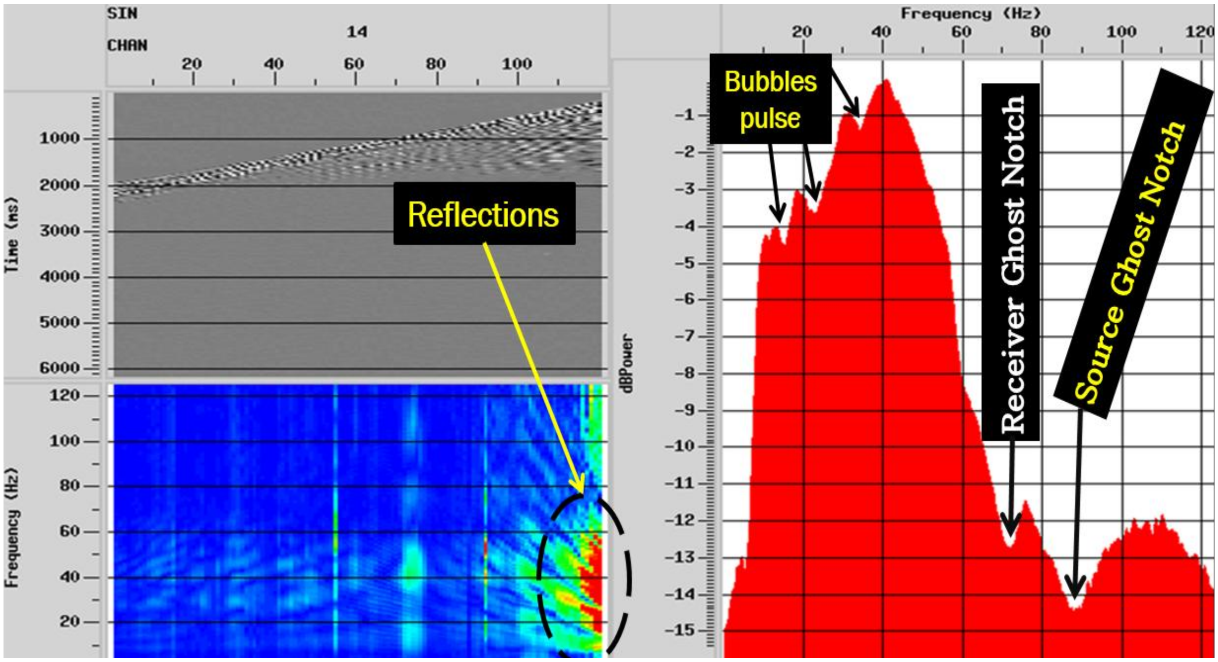

Figure 6. Spectral analysis showing frequency content and prominent arrivals.

autocorrelation of the seismic traces to aid deconvolution processes on the dataset.

Main processing stage

The processes that were carried out at this stage are: Velocity Analysis, F-K multiples attenuation and Dip Moveout (DMO) correction. Velocity analysis was the main and important part of reflection processing, because once optimum primary velocity is computed, Normal Moveout (NMO) corrections can be applied to CMP's gathers, which is concurrently stacked making signal stack in phase and noise out of phase thus increasing the signal-to-noise ratio. Semblance velocity analysis method was carried out to determine the velocity fields of the dataset for normal moveout correction. Eleven CMP's Supergathers were created at regular CMP's intervals along the seismic line from the best pre-processed data, in order to improve picking the correct velocity. Subsequent F-K multiples attenuation technique was applied to suppress the long path multiples energy on the datasets, followed by application of DMO correction for the nonzero offset seismic data to exhibits the same zero-offset for all offsets. This transformation from nonzero offset to zero offset yields improved velocity estimates and higher lateral resolution, as well as a few other desirable side effects, such as the attenuation of coherent noise. Semblance velocity analysis was repeated twice after DMO correction in order to obtain the optimum velocity fields. The seismic stacked section (Figure 8) was generated using the optimum velocity fields (Figure 7) obtained from semblance velocity analysis method.

Post-stack processing stage

The main process that was carried out at this stage is the post-stack migration, which involves in moving the reflections to their proper places with their correct amount of dips. This results in a section that more accurately represents a cross-section of the earth, delineating subsurface details such as Fault planes. The optimally processed stacked section (Figure 8) was migrated using Kirchhoff post-stack time migration algorithm with optimum migration aperture of 800 m and maximum dip of 30°. The post-stack Kirchhoff time migrated stacked section was shown in Figure 9. Depth conversion was also carried out using the stacking velocity Fields in Figure 7 which was adjusted from normal moveout (NMO) to the final datum via velocity manipulation, 80% velocity scale factor was used to preserve the true velocities and maximum frequency of 125 Hz. Figure 10 shows the result of this depth migrated section.

DISCUSSION AND CONCLUSIONS

High resolution seismic imaging of complex tectonic environment, Taranaki basin would play vital roles to unlock the secret behinds the complex tectonic

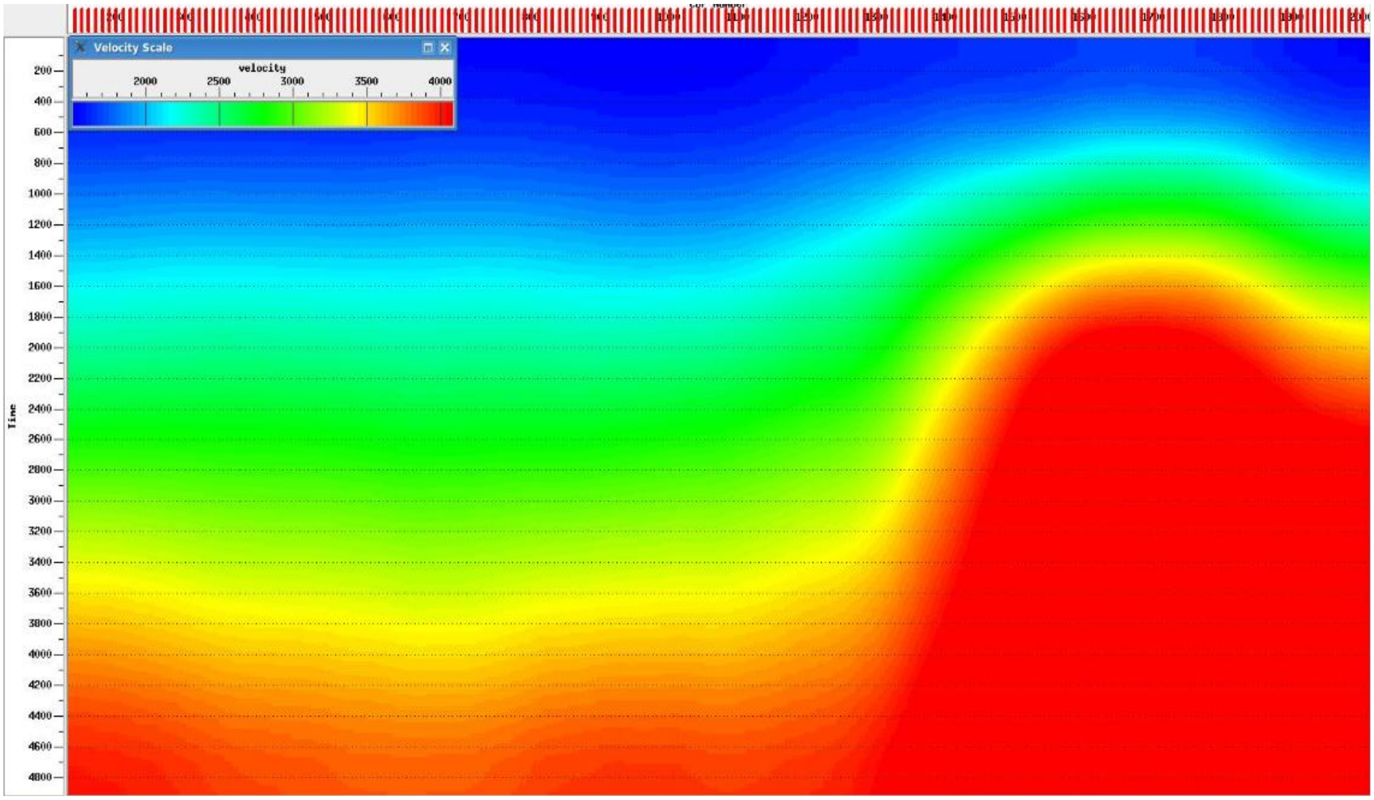

Figure 7. An Optimum stacking velocity fields derived from semblance velocity analysis.

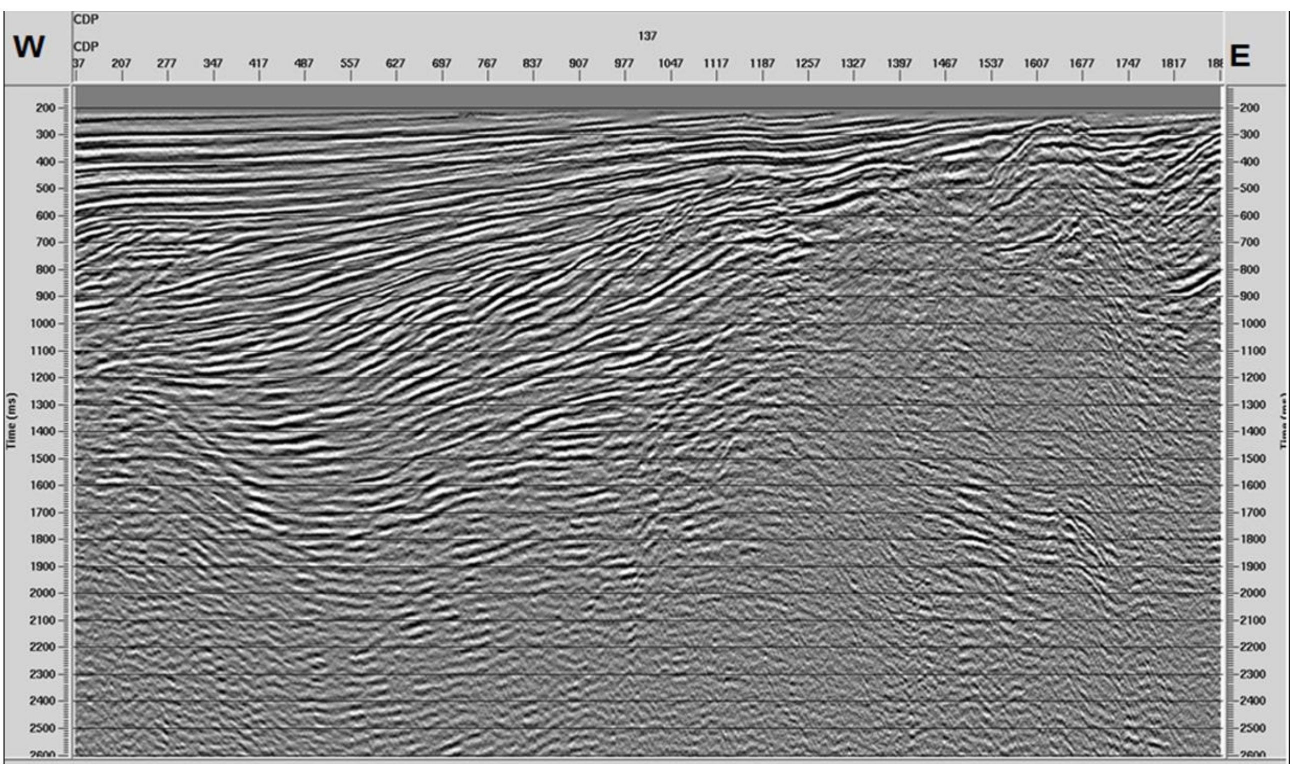

Figure 8. The optimally processed stacked section.

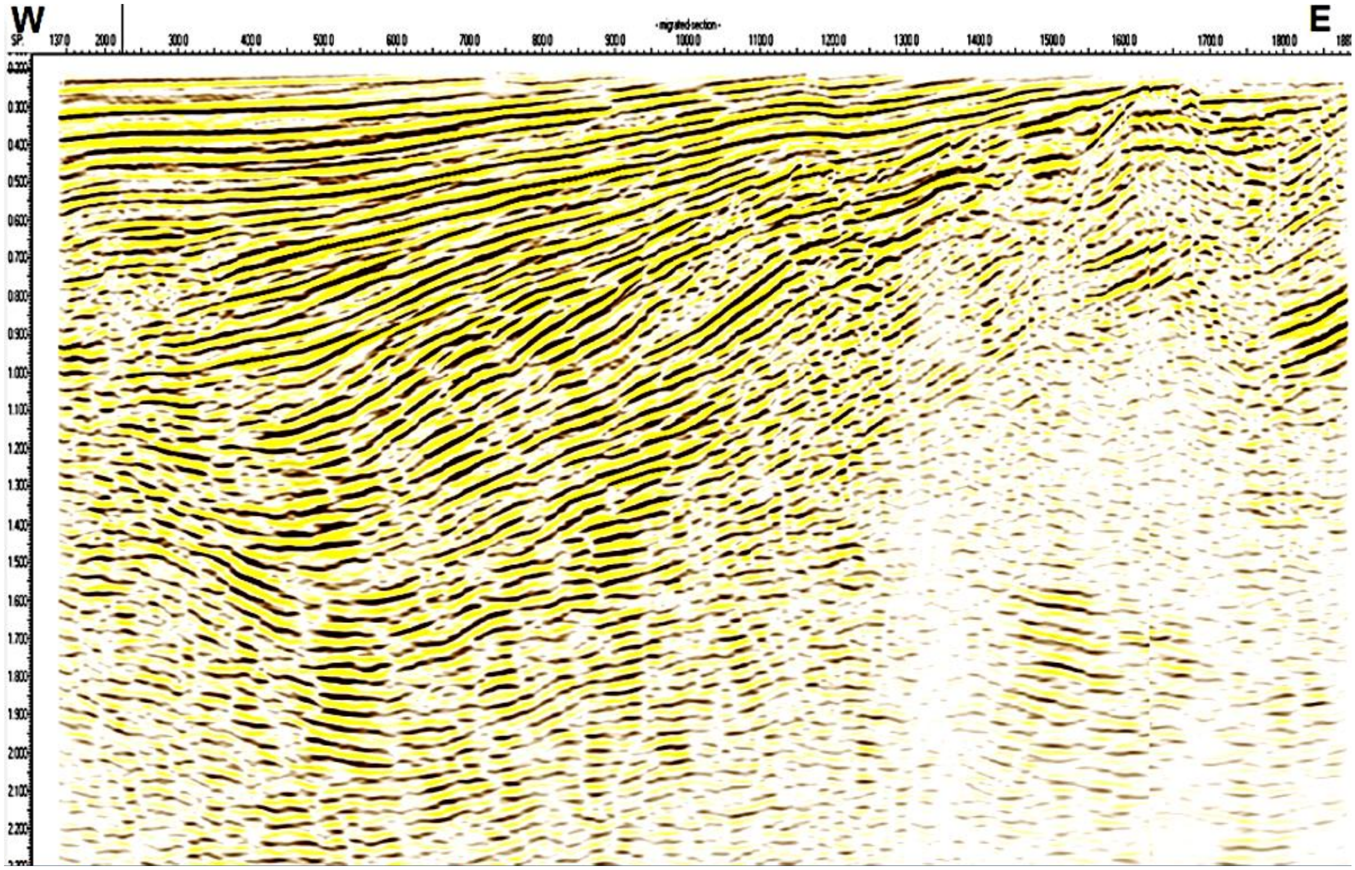

Figure 9. Post stack kirchhoff time migrated section.

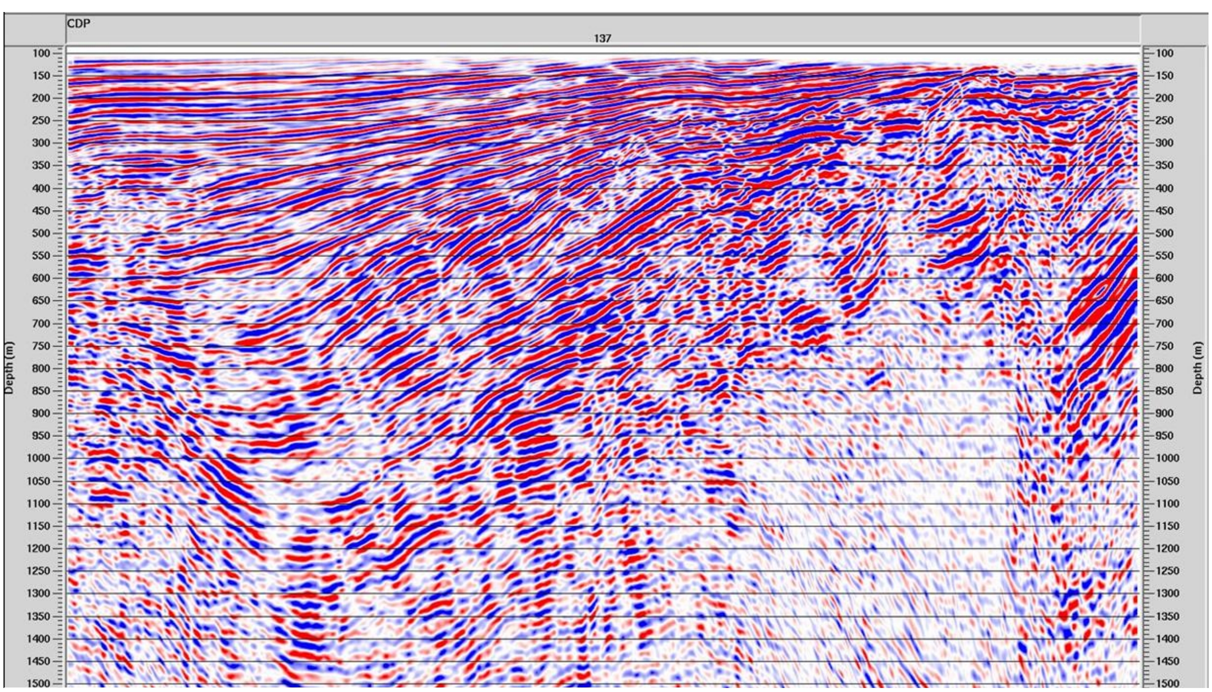

Figure 10. Post-stack depth migrated stacked section.

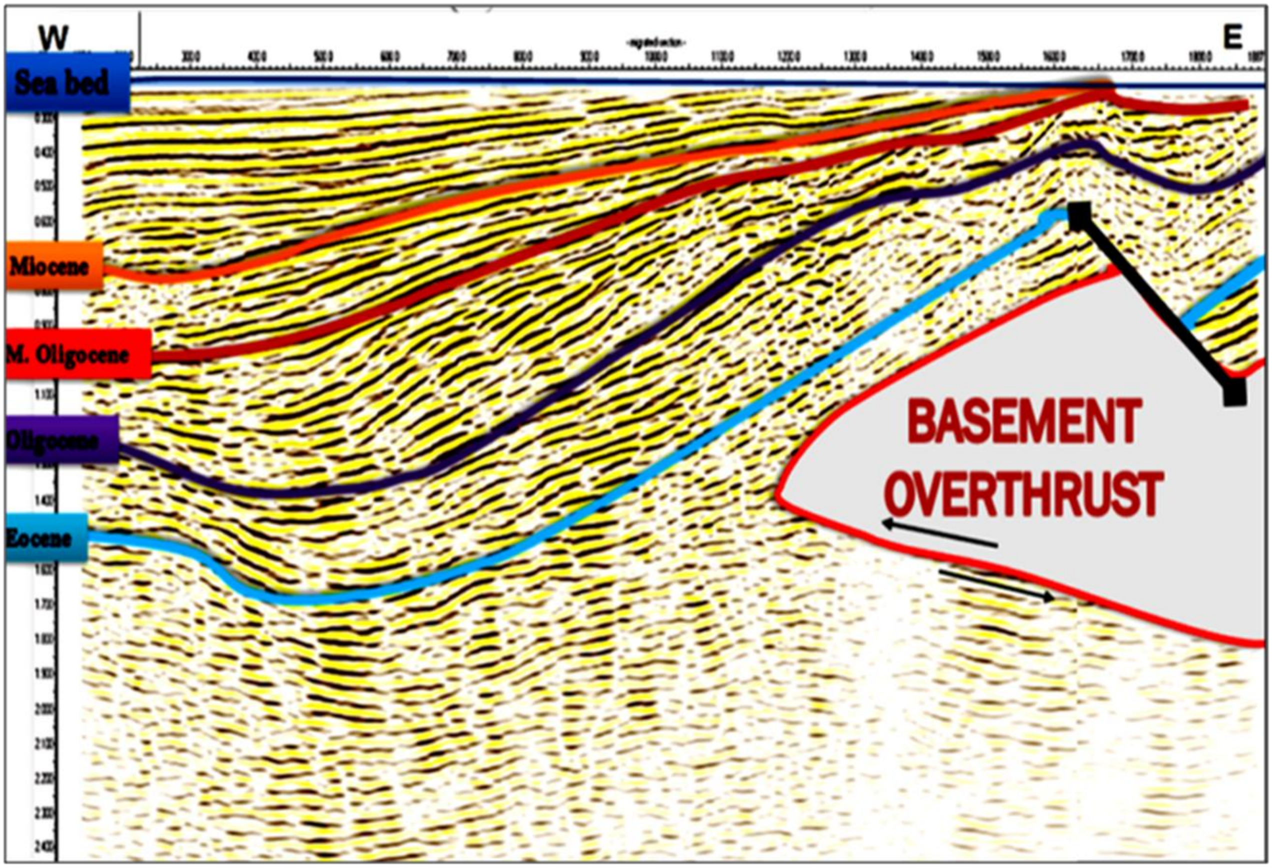

Figure 11: Post Stack Kirchhoff Time Migrated Interpreted Section.

environment. Reflectors on the present processed seismic section are laterally continuous with strong amplitudes and slightly weaken toward the eastern margin due to high stand basement overthrust on younger sediments (Thrasher, 1998), and can be distinguish from one another toward western margin of the seismic section (Figure 9).

Sediments of cretaceous and paleocene age occur in deep grabens associated with the earliest rift history of the basin (Thrasher, 1998) and as a thin transgressive sequence over much of the western Platform. Elsewhere toward the Eastern platform, these sediments are not present generally due to non-deposition over high-standing basement areas (Figure 11).

The Taranaki crustal Fault is clearly visible on the seismic section despite lack of surface exposure. Sediments of Eocene age are generally affected by Fault toward the eastern platform (Figure 11). The potential reservoir formation in the basin (that is, Miocene) is generally marked by a significant unconformity (Thrasher et al., 1995) and are easily recognized on the present seismic section, over much of the western platform the unconformity is disconformable (Figures 9 and 11). The processed seismic section (Figure 9) clearly revealed the subsurface formations and can help for further stratigraphic interpretation of the basin.

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