

A MULTI-CHANNEL SEISMIC INTERPRETATION OF THE
CANTERBURY BASIN OFFSHORE NEW ZEALAND AND
POTENTIAL HYDROCARBON SOURCES

Senior Thesis

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Approved by

A handwritten signature in blue ink, consisting of a large circular loop followed by several horizontal strokes and a final upward flourish.

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Abstract

The Canterbury Basin off the coast of the South Island of New Zealand is a strong potential source for hydrocarbon exploration. Reflection seismic data from cruise EW0001, collected by the Institute for Geophysics, University of Texas at Austin, have been compiled into seismic images of the basin and interpreted to show potential of hydrocarbons due to rock formations and sequences. Data were collected using Generator Injector air guns shooting sound waves into the ocean and using sources to receive the reflections of the sound waves. Geologic maps of the New Zealand Coast and Canterbury Basin indicate predominantly alternating sandstone and mudstone basin fill sequences. These sequences can be seen in the seismic images due to the change in amplitude of the reflections. A bottom simulator reflector appears in the seismic image suggesting the formation of gas hydrates. The Canterbury Basin remains a strong target for hydrocarbon exploration as it exhibits many signs of what makes a successful reservoir to trap hydrocarbons.

Acknowledgements

I would first like to thank Dr. Derek Sawyer as my research advisor and personal inspiration for my research project. Dr. Sawyer's class on Reflection Seismology quickly drew my interest towards this field of study within the Earth Sciences. His class project on seismic line interpretations allowed me to develop what would become my research thesis. I would also like to thank the various professors within the School of Earth Sciences who have taught me over the years. Their enthusiasm towards their professions has been a great influence for me in continuing to learn. I'd like to thank Dr. Carey for her advice and knowledge on how to properly write a thesis. I want to thank my mother and father for encouraging me all the way through school and helping with financial issues. Thank you to all the fellow Earth Science students whom I've worked with over the years specifically on lab reports.

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Introduction

The objective of this study was to examine the potential of hydrocarbons within the rock sequences of the Canterbury Basin. The Canterbury Basin has not been deeply researched regarding hydrocarbons but has recently become of interest as the basin exhibits many properties of a successful reservoir and may provide a large source of undiscovered hydrocarbons. Interpreting the seismic line data can allow one to predict where and why the hydrocarbons have formed. This thesis is a first-look at the overall geometries and depositional patterns that may be consistent with active petroleum systems but should not be viewed as a comprehensive systems analysis.

Methods

Seismic

2D seismic data were collected from public domain by The University of Texas at Austin Institute for Geophysics to interpret (<http://www-udc.ig.utexas.edu/sdc/>). Cruise EW0001 onboard the R/V Maurice Ewing conducted this seismic survey on the Canterbury Basin using Generator Injector (GI) air guns at 2000 psi. Data were acquired from January 9-29, 2000. The cruise contained two sources for the sound waves with a five second interval allowing a 12.5-meter distance between each shot. The streamer was 1500 meters long and consists of 120 channels with each channel containing 16 hydrophones. Each channel is separated by a length of 12.5 meters. This results in a maximum fold of 60. The seismic data were processed by stacking using a multichannel acquisition. The seismic data were organized into lines showing a cross section of the subsurface geology. Reflection lines occur because of a difference in the acoustic impedance, which is a product of p-wave velocity and bulk density. Changes in acoustic impedance are largely the results of changes in rock type or pore fluid. The reflection lines are usually shown as black, white, or gray, but can be any combination of colors.

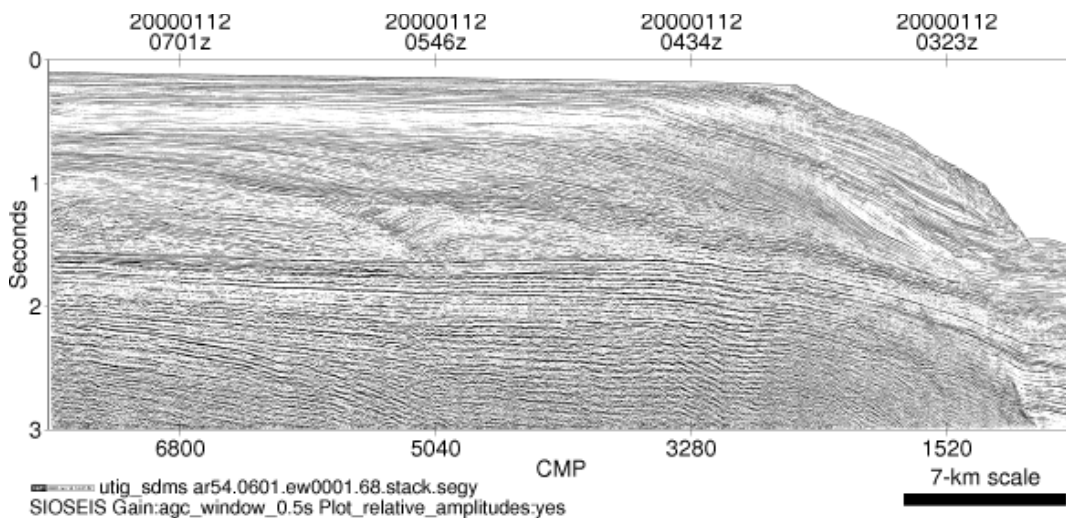


Figure 1. Stacked seismic data of line 68 acquired from Cruise EW0001 of the Canterbury Basin, New Zealand. Vertical scale is measured in two-way travel time of sound waves.

IHS KingdomSuite

The seismic data from Cruise EW0001 are stored as a SEG-Y file. SEG-Y is an open standard data developed by the Society of Exploration Geophysicists (SEG). Uploading SEG-Y files in IHS KingdomSuite geophysical software allows one to see and manipulate the seismic data that has been collected. In KingdomSuite, the seismic data is interpreted in many ways. The data window can be stretched or constricted, depth and two-way time values changed to allow for a better fit, and the reflection lines can be color coded to show previously unseen areas of rock or liquid/gas formations. These modifications allow the user to interpret the data in a more detailed way and fix any vertical or horizontal exaggeration.

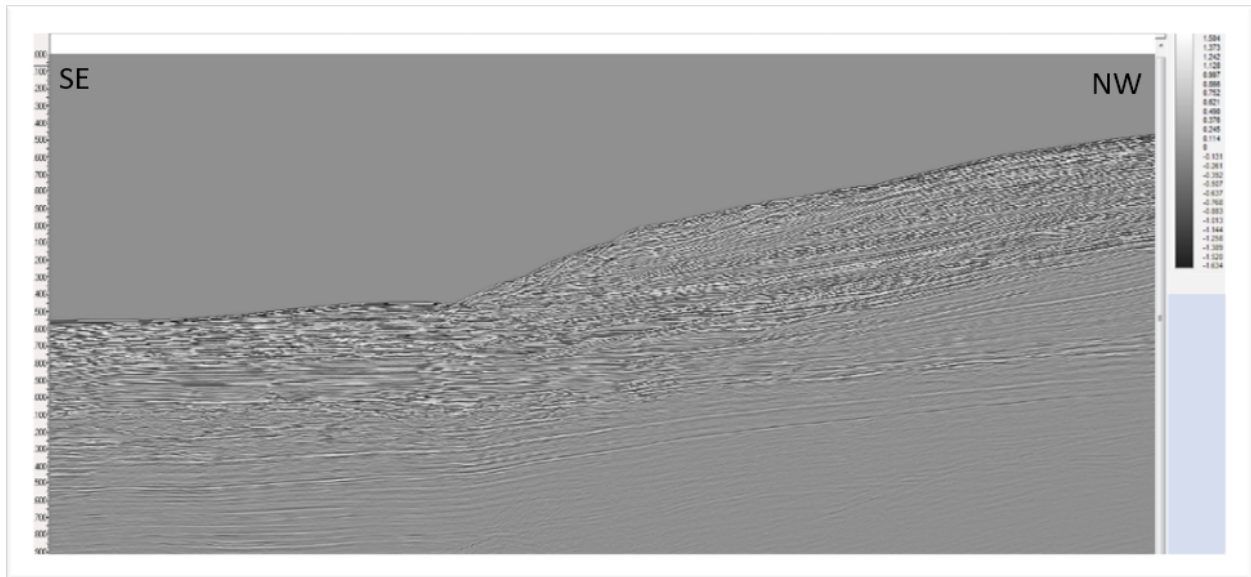


Figure 2. An example of uninterpreted SEG-Y data uploaded in KingdomSuite Software. This is line 68 of cruise EW0001. The grey scale bar indicates white for high amplitude values and black for low amplitude values.

The seismic data of line 68 were altered in KingdomSuite to fix vertical exaggeration and gamma was increased to allow for more visual clarity of the reflection lines. Notice how in figure 1 the steepness of the slope is more extreme than in figure 2. The image has also been reversed to show the coast of New Zealand emerging on the right side and the basin forming towards the left. Color coordination has been left to a similar scale as the original image because black and white are good indicators for extreme changes in amplitude.

Results

Figure 3 shows a map of southern New Zealand continental shelf along with the study area of the Canterbury basin done by cruise EW0001. Each blue line represents a line of data acquired by 2D acquisition. Lines are mainly divided into NE-SW and NW-SE trips along with few intercepting lines.

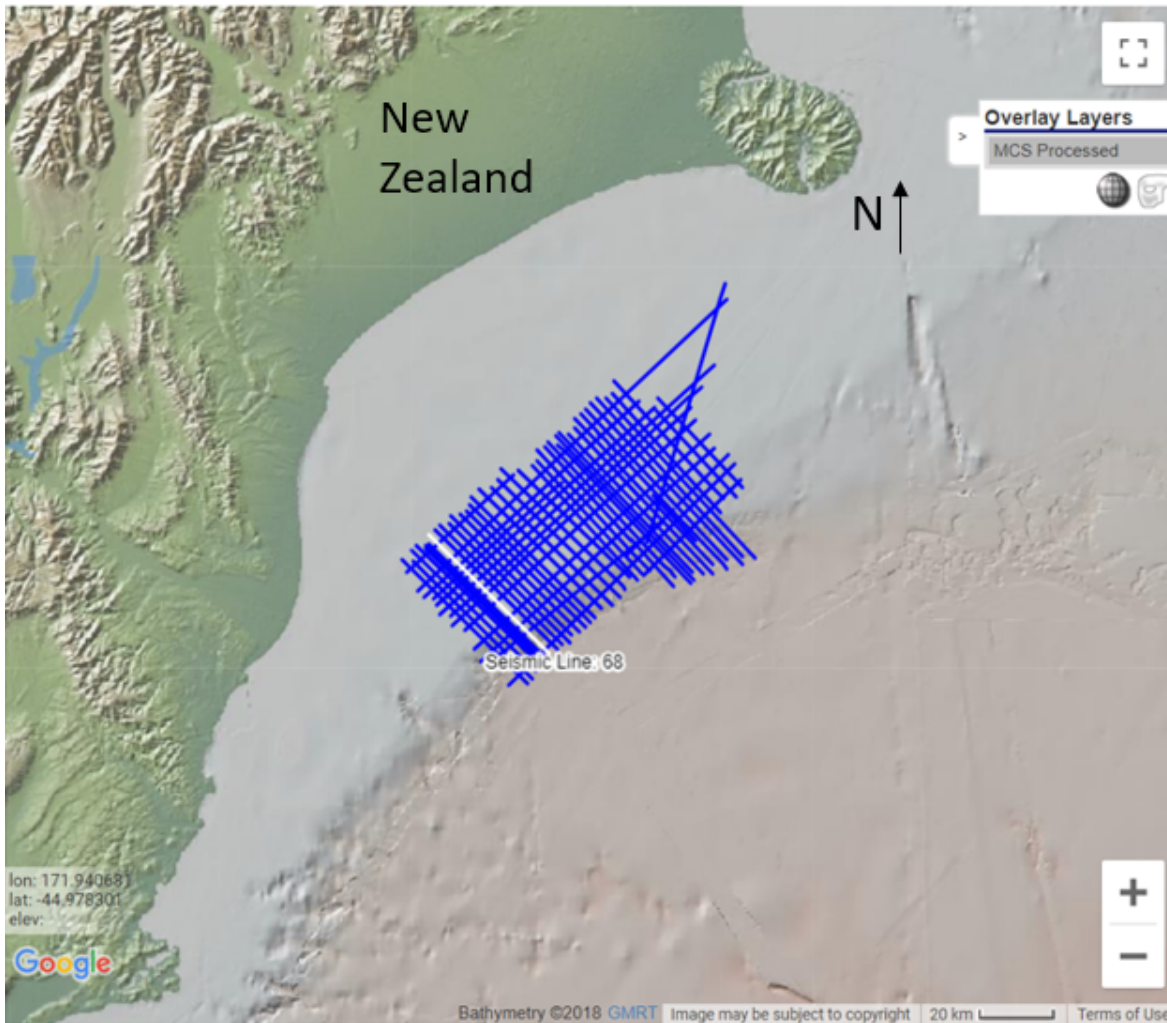


Figure 3. Map of the study area of the Canterbury Basin done by cruise EW0001. Each line contains 2D data of the basin. Water depth increases towards the Southeast. Image adapted from <http://www-udc.ig.utexas.edu/sds/>.

Figure 4 shows the SEG-Y data processed through KingdomSuite software to display a 2D seismic image. These data are two-way travel time in seconds to study the depth and composition of the marine rock. Amplitudes of reflections are colored on a grayscale. White is a positive reflection coefficient and black is a negative coefficient. Colored lines are horizons mapped by KingdomSuite and reveal sequences and depositional geometries, including clinoforms.

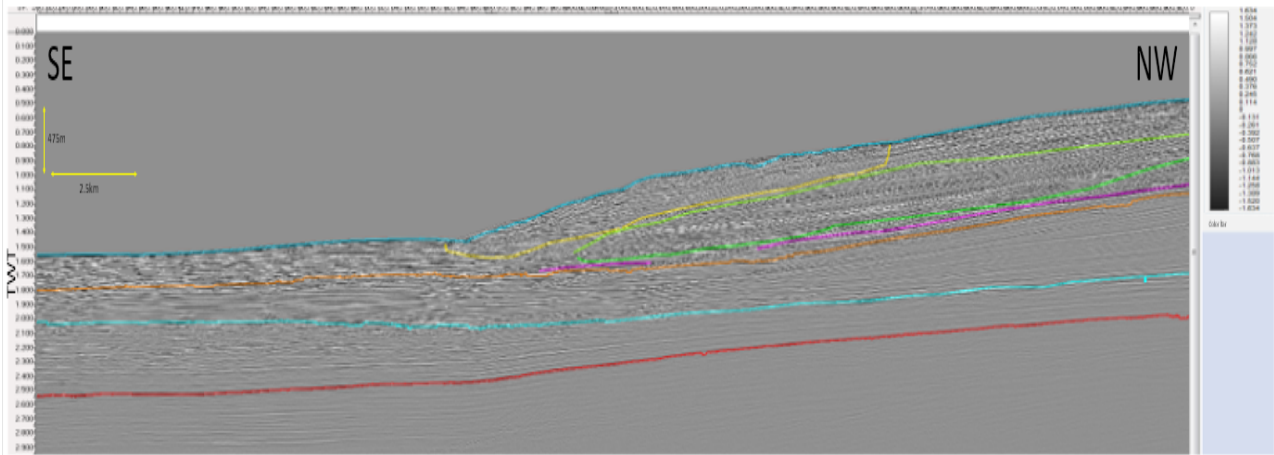


Figure 4. 2D seismic reflection image of Line 68 projected in KingdomSuite software. Amplitudes are shown in white and black. Colored lines show sequences and seafloor. Two Way Travel Time is used for depth.

Figure 5 is a geologic map of Southern New Zealand with two images labeled A and B. In image A, site expeditions are marked with red squares and stars. The geology of the study area is color coded with respect to the legend. Rivers are shown in black lines along with their drainage areas. Coastal current directions are shown with arrows. In image B, the continental shelf of the Canterbury Basin is detailed according to sedimentary make-up. The three drill sites are marked with red dots which contain the seismic data. The basin is divided into gravel, mud, sand, and biogenic sand.

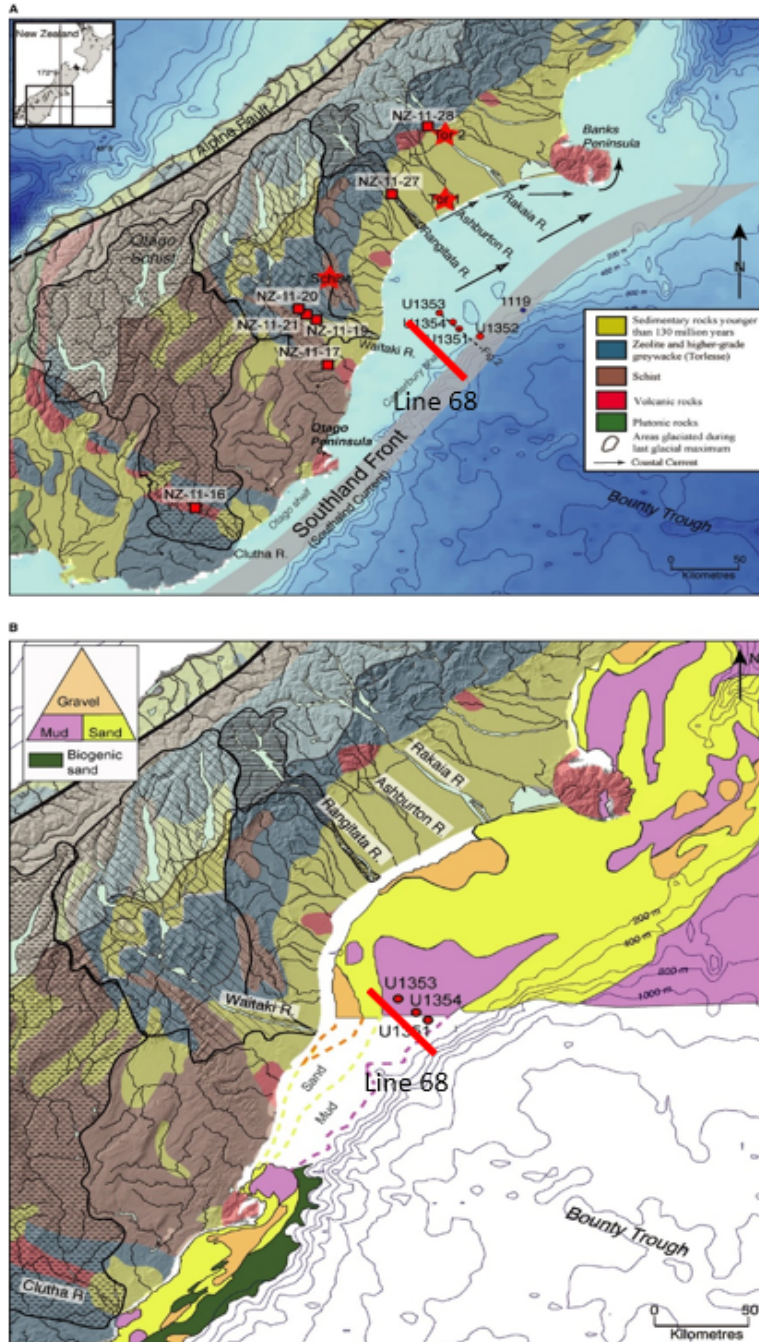


Figure 5. Geological map of Southern New Zealand and coast. Image A shows rock facies and expedition sites of Southern New Zealand. Image B shows sedimentary make-up of the continental shelf to the Canterbury Basin. Figure adapted from Villaseñor et al., (2014).

Figure 6 contains a 2D seismic image from the Canterbury Basin with an illustration of the image interpreting sequences in the rock facies. These sequences help determine potential of hydrocarbons within the basin. Drill sites are marked with red lines representing their depth in two-way travel time. Onlap, truncation, and downlap are marked by arrows. Circles represent clinoforms.

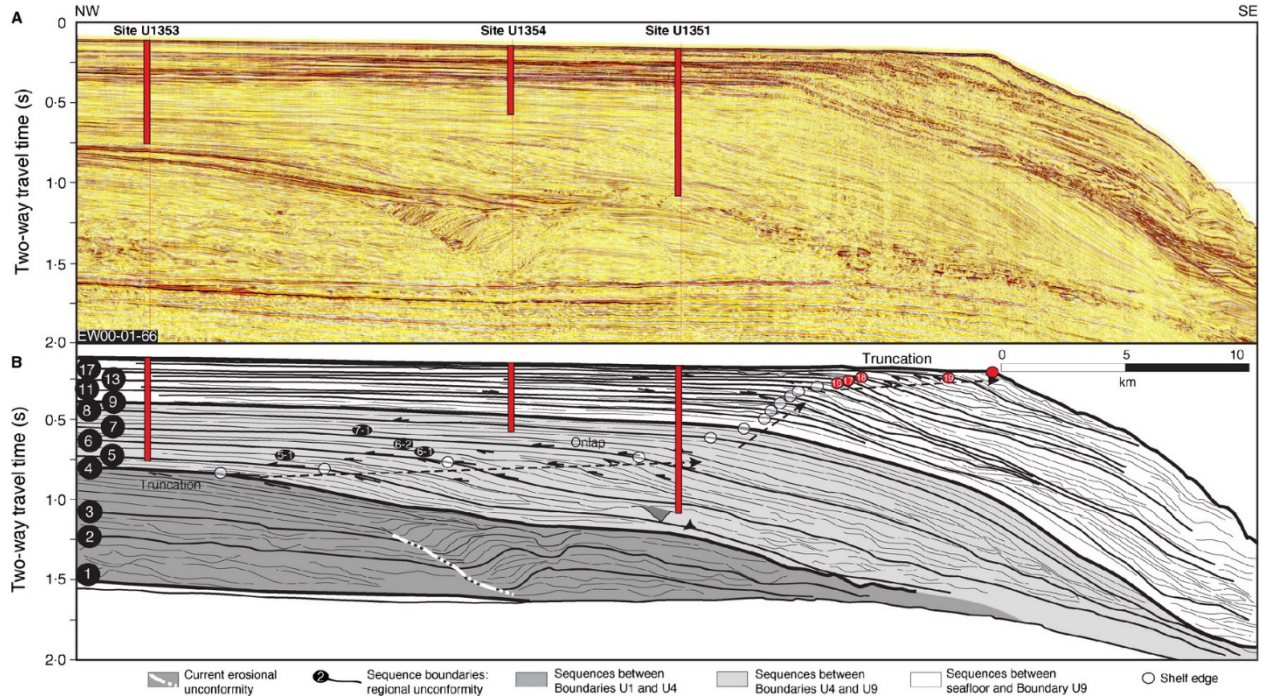


Figure 6. 2D seismic reflection image of drilling sites in the Canterbury Basin and illustration of the data showing an interpretation. Figure from Villaseñor et al. (2015)

Figure 7 displays interpreted seismic reflection images from the study area of the Canterbury Basin shown in the lower right. Data lines are labeled a, b, c, and d. Sequences are marked by P10, K90, K80, and K50. Rock facies are shown consisting of mudstones, siltstones, and sandstones. Bright reflections of red and black reveal large changes in amplitudes throughout the rock.

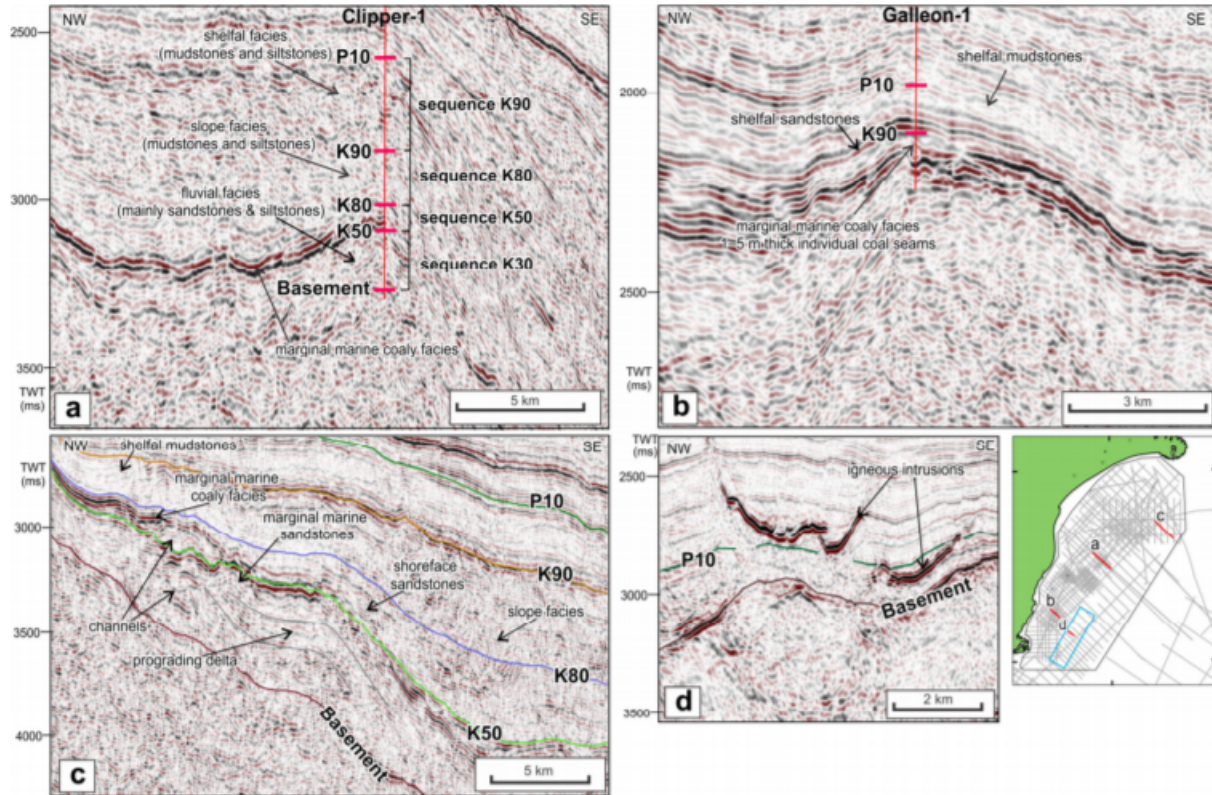


Figure 7. Seismic images from the study area of the Canterbury Basin. Facies and sequences are shown for data lines a, b, c, and d. Study area is included with references to lines. Figure from Sahoo et al. (2014)

Discussion

The seismic data of the Canterbury Basin can be interpreted to predict potential sources of hydrocarbons. Figure 8 shows an interpretation of Figure 2 using horizon mapping in KingdomSuite. The seafloor of the image is shown by the first negative (black) reflection in the image. It is marked by the blue horizon line. As sound waves travel deeper into the ocean and through rock sequences, the strength of their reflections become weaker. This is shown by the decreasing brightness and alternating of amplitudes. These strengths are divided into sections. The first section includes the brightest reflection zone which goes from the seafloor (blue) to the orange line. The next section goes from the orange line to the cyan line where reflections are just bright. The reflections start to dim from the cyan line to the red line. Finally, where the marine rock is the deepest, reflections are ambiguous, and one cannot interpret anything from this zone with confidence from the red line downwards. The area between the seafloor and the yellow horizon line contains sloping sediments and a very steep hill. The cause of this slope may be a marine landslide causing a mixed assortment of sediments and undeveloped rock sequences unlike other areas. The area marked by the green lines shows a clinoform slug model. Clinoforms, an inclined depositional surface, produce distinctive seismic reflection patterns due to the sequential layering of the sediments. Lastly, the purple line is a possible bottom simulating reflector (BSR), which shows up as a reflection that mimics the seafloor horizon. The BSR, if present, may be an indicator of the presence of gas hydrates.

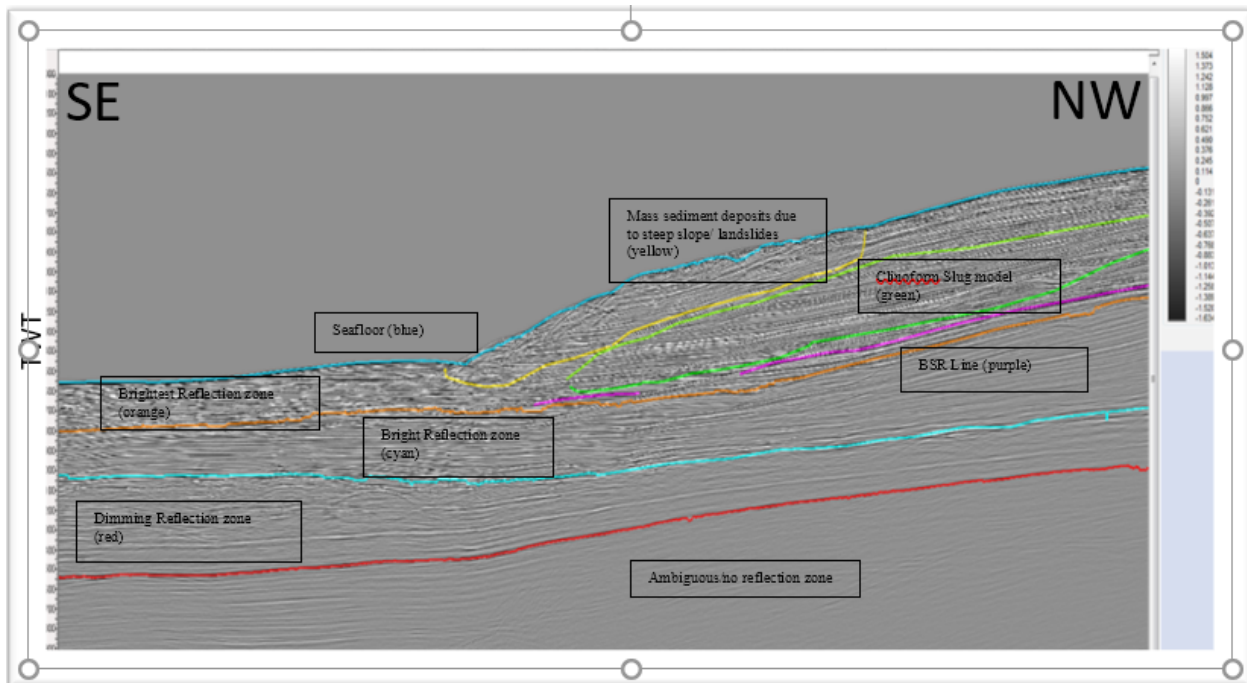


Figure 8. An interpreted image of the original seismic image in KingdomSuite from Figure 2. Colored lines represent zones of reflection brightness and other significant geologic structures.

Observation of the geologic map from Figure 5 shows that the basin contains mainly sand and mud. Layering of these sediments is integral to the trapping of hydrocarbons due to the different density and porosity of the sediments. The repetitive black and white amplitudes are very suggestive of a repeating layering of sandstone and mudstone sequences within the basin. Figure 7 shows how the mudstones and siltstones are layered from the amplitudes color coded by red and black. These layers repeat throughout the depth of the rock and show stronger where geological structures are located. Image A is roughly the same study area as the EW0001 cruise and should be considered when comparing the lithofacies of the interpreted image. The brightest reflections indicate the coaly facies and the best source of hydrocarbons. However, as mentioned before, the brightness of reflections goes down as the sound waves travel further downwards due to decreasing strength. Figure 8 is an image from data acquired in 2000 while Figure 7 includes data from 2006 and 2007. The difference in quality can easily be seen by the more distinct colors and the fact that the seismic reflections continue with the same strength even towards the deepest part of the image. Some parts of the image may have more potential than what is shown. Hydrocarbons are most likely to reside in the Bright and Dimming Reflection Zone which includes the orange line to the red line. Depth of the rocks play an important role in identifying hydrocarbons. Unfortunately, in the Ambiguous Zone, there are no distinct reflections due to the technology and strength of equipment at the time of data retrieval. This area could also contain many trapped hydrocarbons.

A bottom simulating reflector, if present, could be indicative of a hydrocarbon system. Gas hydrates are natural gas (mostly methane) in a solid ice-like form. The BSR can be easily identified as it parallels the seafloor and is different from all other reflections. However, this is not a guarantee of gas hydrate potential as the BSR is only an interpretation and not all reflection lines truly show what is there. The presence of gas hydrates has been argued to be associated with increased slope instability (Senger, 2006).

Conclusions

The objective of this research was to interpret available seismic reflection data within the Canterbury Basin. The Canterbury Basin off the coast of New Zealand is a potential source of trapped hydrocarbons and potential gas hydrates. The sedimentary make-up, age of rock, and sequencing of rock types all are great conditions for hydrocarbons to form and be trapped. Data used for this conclusion comes from the year 2000 which may not reveal all significant changes in rock formations seen within the image. For a more confident conclusion, more data needs to be taken with better technology allowing for clearer, deeper images.

Suggestions for Future Research

This thesis represents a preliminary analysis, but much more thorough analyses can be done with the available seismic data. In addition, oil and gas operators could continue exploring within the Basin to evaluate the hydrocarbon potential of the basin. At this moment, the basin remains a potential spot for hydrocarbons, but no serious oil drilling is being done. The data used in this research were obtained in the year 2000, while it is telling of the rock formations, data acquired in 2018 or beyond can be useful to compare to. New seismic data should be taken within the same area to verify predictions and help create a stronger hypothesis.

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