โครงการการเรียนการสอนเพื่อเสริมประสบการณ์

ธรณีสัณฐานวิทยาทางคลื่นไหวสะเทื่อนของหมวดหินไจแอนท์ฟรอเซต แอ่งทารานากิ ประเทศนิวซีแลนด์

โดย

นายวริศ นวมนิ่ม

เลขประจำตัวนิสิต 5832736723

โครงการนี้เป็นส่วนหนึ่งของการศึกษาระดับปริญญาตรี

ภาควิชาธรณีวิทยา คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ธรณีสัณฐานวิทยาทางคลื่นไหวสะเทือนของหมวดหินไจแอนท์ฟรอเซต

แอ่งทารานากิ ประเทศนิวซีแลนด์

นายวริศ นวมนิ่ม

โครงงานนี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตร์บัณฑิต

ภาควิชาธรณีวิทยา คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2561

SEISMIC GEOMORPHOLOGY OF GIANT FORESETS FORMATION,

TARANAKI BASIN, NEW ZEALAND.

Mister Waris Nuamnim

A project submitted in Partial fulfillment of the Requirements

For the Degree of the Bachelor of Science Program in Geology Department of Geology, Faculty of science, Chulalongkorn University

Academic Year 2018

หัวข้อโครงงาน	ธรณีสัณฐานวิทยาทางคลื่นไหวสะเทือนของหมวดหินไจแอนท์ฟรอเชต แอ่งทารานากิ ประเทศนิวซีแลนด์
โดย	นายวริศ นวมนิ่ม
สาขาวิชา	ธรณีวิทยา
อาจารย์ที่ปรึกษาโครงงานหลัก	ผู้ช่วยศาสตราจารย์ ดร.ปิยพงษ์ เชนร้าย

วันที่ส่ง 13 พ.ค. 2562

วันที่อนุมัติ 13 พ.ค. 2562

ปิยพงษ์ เชนร้าย

(ผู้ช่วยศาสตราจารย์ ดร.ปิยพงษ์ เชนร้าย)

อาจารย์ที่ปรึกษาโครงงานหลัก

Project Title:	SEISMIC GEOMORPHOLOGY OF GIANT FORESETS FORMATION, TARANAKI BASIN, NEW ZEALAND.
By:	Mister Waris Nuamnim
Department:	Geology
ADVISOR:	Assistant Professor Dr. Piyaphong Chenrai

Date of submission 13/5/2019

Date of approval 13/5/2019

Piyaphong Chenrai

(Assistant Professor Dr. Piyaphong Chenrai)

Project Advisor

วริศ นวมนิ่ม : ธรณีสัณฐานวิทยาทางคลื่นไหวสะเทือนของหมวดหินไจแอนท์ฟรอเซต แอ่งทารานากิ ประเทศนิวซีแลนด์ (SEISMIC GEOMORPHOLOGY OF GIANT FORESETS FORMATION, TARANAKI BASIN, NEW ZEALAND) อ.ที่ปรึกษาโครงการหลัก: ผู้ช่วยศาสตราจารย์ ดร.ปิยพงษ์ เชนร้าย, 38 หน้า.

แอ่งสะสมตะกอนทารานากิครอบคลุมพื้นที่ 330,000 ตารางกิโลเมตรในบริเวณทิศตะวันตกของเกาะเหนือ ประเทศนิวซีแลนด์ ในปัจจุบันเป็นแอ่งเดียวเท่านั้นที่ให้ปริมาณปิโตรเลียมที่คุ้มค่าเชิงพาณิชย์ในประเทศ ซึ่งหมวดหินไจแอนท์ฟรอเซตเป็นหมวดหินที่มีความหนาและความเร็วในการสะสมตัวมากจึงมีความสำคัญต่อระบบปิโตรเลียมภายในแอ่ง โดยสภาพแวดล้อมการสะสมตัวของพื้นที่นั้นพบลักษณะของทางน้ำที่มีขนาดเล็กร่วมกับชั้นหินบางซึ่งยากต่อการศึกษาลักษณะธรณีสัณฐานวิทยาทางคลื่นไหวสะเทือนในการจึงใช้การปรับค่าคุณลักษณะทางคลื่นไหวสะเทือนเพื่อให้ได้ข้อมูลที่มากขึ้นเพื่อช่วยในการศึกษาลักษณะธรณีสัณฐานวิทยาในพื้นที่การศึกษานี้ เมื่อทำการปรับค่าคุณลักษณะทางคลื่นไหวสะเทือนด้วยวิธีการต่างๆ พบว่าความสามารถในการปรับค่าคุณลักษณะนั้นสามารถแบ่งได้เป็น 2 กลุ่ม กลุ่มแรกได้แก่ แอมพลิจูดเฉลี่ยรากกำลังสอง สวีทเนส ความถี่ชั่วขณะ และ สเปกตรัล ดีคอมโพสิชั่น ซึ่งเหมาะกับการตรวจสอบความแตกต่างของลักษณะทางศิลาวรรณาของชั้นหิน เช่น ลักษณะการกระจายตัวและรูปร่างของตะกอนทรายที่สะสมตัวบนตะกอนดินเหนียว ซึ่งลักษณะธรณีสัณฐานที่เด่นชัดได้แก่ ขอบเขตและขนาดของทางน้ำ ร่องรอยการถล่ม สันทราย กลุ่มที่สองเหมาะแก่การตรวจสอบลักษณะความไม่ต่อเนื่องทางข้อมูลคลื่นไหวสะเทือนหรือลักษณะทางธรณีวิทยาโครงสร้าง เช่น รอยเลื่อน ขอบเขตของทางน้ำ และ ร่องรอยของการถล่ม เมื่อนำการปรับค่าคุณลักษณะแต่ละวิธีมาประมวลผลร่วมกันทำให้ได้ลักษณะธรณีสัณฐานที่มีทางน้ำเป็นหลักซึ่งมีขนาดที่หลากหลาย โดยทางน้ำขนาดใหญ่มีขนาดตั้งแต่ 150 ถึง 500 เมตรโดยมีลักษณะค่อนข้างตรงและพบการคดโค้งน้อยกว่าทางน้ำขนาดเล็กซึ่งมีขนาดตั้งแต่ 50 ถึง 150 เมตร ซึ่งพบร่วมกับสันทรายจำนวนมาก ด้วยลักษณะของทางน้ำ ตะกอนรูปพัด และสันทรายที่พบนั้นสามารถแปลสภาพแวดล้อมในอดีตได้ว่าอยู่ในระบบการสะสมตัวแบบลาดทวีปที่มีลักษณะตะกอนรูปพัดคล้ายผ้ากันเปื้อน ถึงแม้ว่าหลังจากการศึกษาพบว่าหมวดหินไจแอนท์ฟรอเซตมีศักยภาพในการเป็นหินกักเก็บปิโตรเลียมไม่เพียงพอ แต่ความรู้และความเข้าใจของข้อดีในการปรับค่าคุณลักษณะทางคลื่นไหวสะเทือนนั้นสามารถนำไปใช้ในการศึกษาปิโตรเลียมที่อยู่ลึกได้ต่อไป

ภาควิชา ธรณีวิทยา ลายมือชื่อนิสิต ....

สาขาวิชา ธรณีวิทยา ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

ปีการศึกษา 2561

5832736723 : MAJOR GEOLOGY

KEYWORDS: SEISMIC GEOMORPHOLOGY / TARANAKI BASIN / SEISMIC ATTRIBUTE / SEISMIC CHARACTERISTIC / SEISMIC INTERPRETATION

SEISMIC GEOMORPHOLOGY OF GIANT FORESETS FORMATION, TARANAKI BASIN, NEW ZEALAND. ADVISOR: ASSISTANT PROFESSOR DR. PIYAPHONG CHENRAI, 38 PP.

The Taranaki Basin covers an estimated area of 330,000 km² along the western side of the North Island, New Zealand. There is currently the only producing petroliferous basin in New Zealand. The high thickness and rapid accumulation of The Giant Foresets Formation will have a significant impact on the petroleum systems of Taranaki Basin. 3D seismic data are the main data that used in this study to understand geomorphology in subsurface such as characteristics of channels, slump scars, and sand bars distribution. In this study area, small-scale channels with thin-bed cause a difficult in seismic detection and interpretation, thus seismic attributes used in this study for extracting more information from the seismic data will help to illustrate the geomorphological features of the area. The ability of seismic attributes can be divided into two groups. The first group including RMS amplitude, sweetness, instantaneous frequency and spectral decomposition attribute that is good for detecting the difference of lithology such as sand distribution and sand bodies geometry imaging. The second type is variance attribute which good to detect discontinuity seismic data or geological structure. The dominant of geomorphology features are channels which have 2 sizes including major channels (Width: approximately 150 – 500 meter) and Minor channels (width: approximately 50 – 150 meter). Most of their characteristic of channels is straight to low sinuous channels associated with sandbars and slump scar. So, the deposition environment should be slope aprons environment. Although the Giant Foresets Formation has minor reservoir potentials, but knowledge of using seismic attributes might be beneficial for applying with the deeper petroleum explorations either.

Department:	GEOLOGY	Student's Signature..........
Field of Study:	GEOLOGY	Student's Signature..........
Academic Year:	2018	

ACKNOLEDGMENT

This report has been accomplished with the gratitude and encouragement of many people. Finally, I would like to thank my advisor, Assistant Professor Dr. Piyaphong Chenrai, for effort and time that he spent with me. He always provides me with support and beneficial advice when I needed them the most; this report would not have been succeeded without him.

I would like to thanks to all lectures in Department of Geology, Faculty of Science, Chulalongkorn University for giving me background knowledge, suggestion and experiences in the past three years and many thanks to everyone in Department of Geology, Faculty of Science, Chulalongkorn University for their great advice and support.

To my Family, I would like to thank for their support, encouragement, and believing on me. Finally, I appreciate all support from others that I have not mentioned here too.

(Mister Waris Nuamnim)

Project Author

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 Background and Signification of the Research

Nowadays, petroleum consumption is essential in our daily lives, such as transportation, energy and polymer product causing an increasing demand for petroleum production (EPPO, 2018). One of important tools for petroleum exploration is using the seismic survey data to estimate the properties of the earth's subsurface. However, using seismic survey data come with some restrictions such as small-scale channels with thin bed causing a difficult in seismic interpretation (Todorovic et al., 2011). Present day, new advance techniques in seismic interpretation such as seismic attributes help us to increase the ability of geological interpretation.

The study area located in Taranaki Basin which covers an estimated area of 330,000 km² along the western side of the North Island, New Zealand. Taranaki basin is currently the only producing petroliferous basin in New Zealand (New Zealand Petroleum and Minerals, 2014). The Giant Foresets Formation is characterized by rapid progradation (Sell BP Todd, 1981). The high thickness and rapid accumulation of The Giant Foresets formation will have a significant impact on the petroleum systems of Taranaki Basin (McAlpine, 2000).

Knowledge and understanding in geomorphology, sequence stratigraphy and structural geology might help us understand evolutional of paleo environment and geomorphology in subsurface such as properties, characteristics of channels and area which could be good potential reservoir. However, the Giant Foresets Formation is considered to have minor reservoir potentials in terms of containing sandstone-dominated (Hansen and Kamp, 2006). Thus, seismic attributes are chosen to use for seismic geomorphology in the study area.

Studying of subsurface geomorphology can be done by several methods. Interpretation using seismic reflection is widely accepted that it is preferential method for investigating subsurface geology. It uses benefit of rocks properties such as velocity of seismic wave and density, travel time and different seismic reflections to interpret depth, geomorphology, structures and sequence stratigraphy (Satarugsa, 2007). By using this method, the study covers wider areas than other method and efficiently in deep strata. Consequently, interpretation using seismic reflection might be an appropriate method for this study.

1.2 Objectives

1.2.1 To image seismic geomorphology within Giant Foresets Formation

1.2.2 To compare the ability of seismic attributes used in this study

1.3 Study area

Study area located in Taranaki Basin covers along the western side of the North Island in New Zealand. It covers about 480 km². The study area covers 3D volume seismic reflection dataset of 3D-NIMITZ and contains two exploration wells, namely Well Korimako-1 and Tarapunga-1. (Figure 1.1)

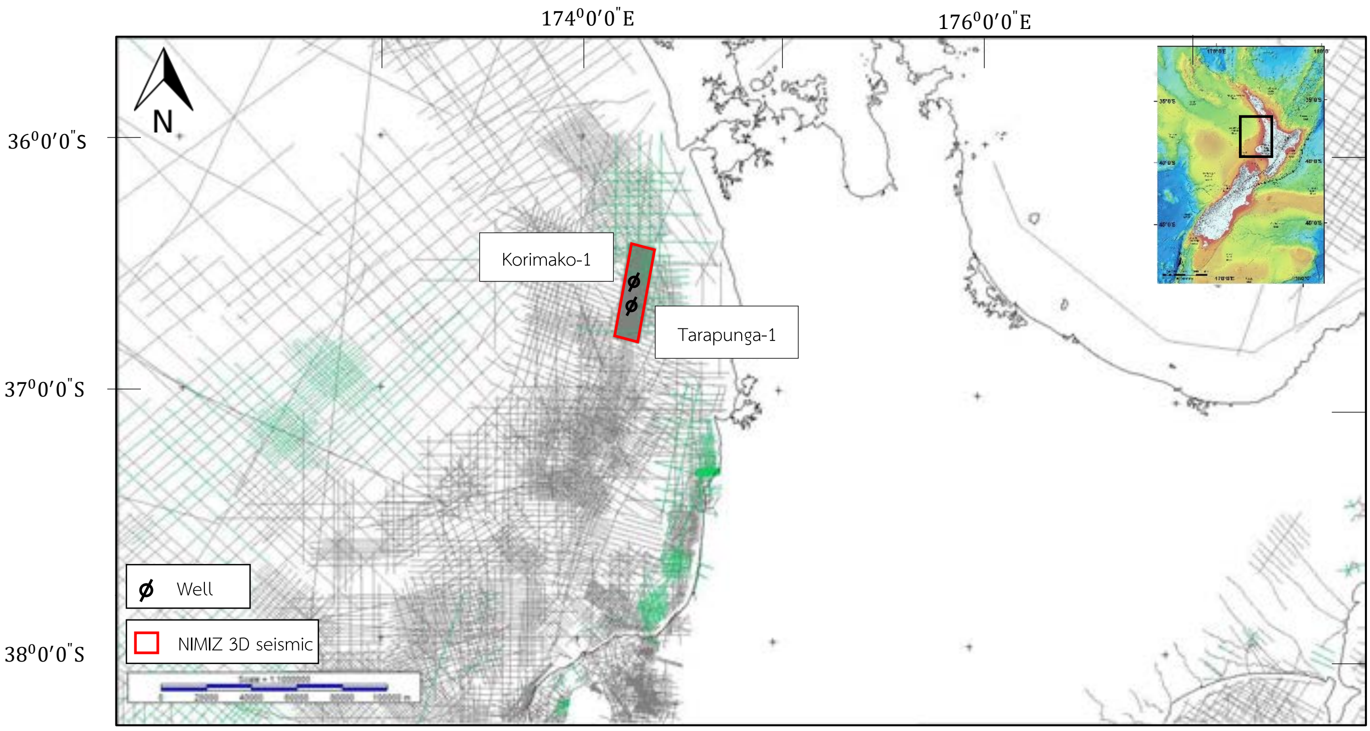


Figure 1.1 Study area, Taranaki Basin, New Zealand with 3D seismic survey and well data.

1.4 Methodology

1.4.1 Literature review

1.4.1.1 Geological setting and paleogeomorphology of the Taranaki basin

1.4.1.2 Seismic interpretation and seismic attributes concerning principles

1.4.1.3 Method of seismic geomorphology and attributes

1.4.1.4 Related researches

1.4.2 Data processing

1.4.2.1 Seismic to well tie: Generating synthesis seismogram for correlate well data and seismic data to determine stratigraphy in seismic data and identify marker key horizon from the well data.

1.4.2.2 Seismic horizons interpretation: Selecting key geological markers from well data and define the seismic horizons that represent key geological markers.

1.4.2.3 Seismic attribute generation: Seismic attribute can help identifying channel or deltaic sand, unconformities and changing in sequence stratigraphy by shape of amplitude and position of a seismic trace over specific time intervals. As a result, this study uses multiple seismic attributes such as RMS Amplitude, Sweetness, Variance and Spectral decomposition.

1.4.3 Geomorphology interpretation

1.4.3.1 Determination of seismic facies type within a deposition sequence and association with geological data (e.g. via well data)

1.4.3.2 Highlighting and characterization of identified seismic facies from seismic data (e.g. via seismic attributes)

1.4.3.3 Display of spatial distribution of these facies on a surface that represents a specific point in or phase in geologic time (e.g. via mapped horizons)

1.4.4 Discussion and Conclusion

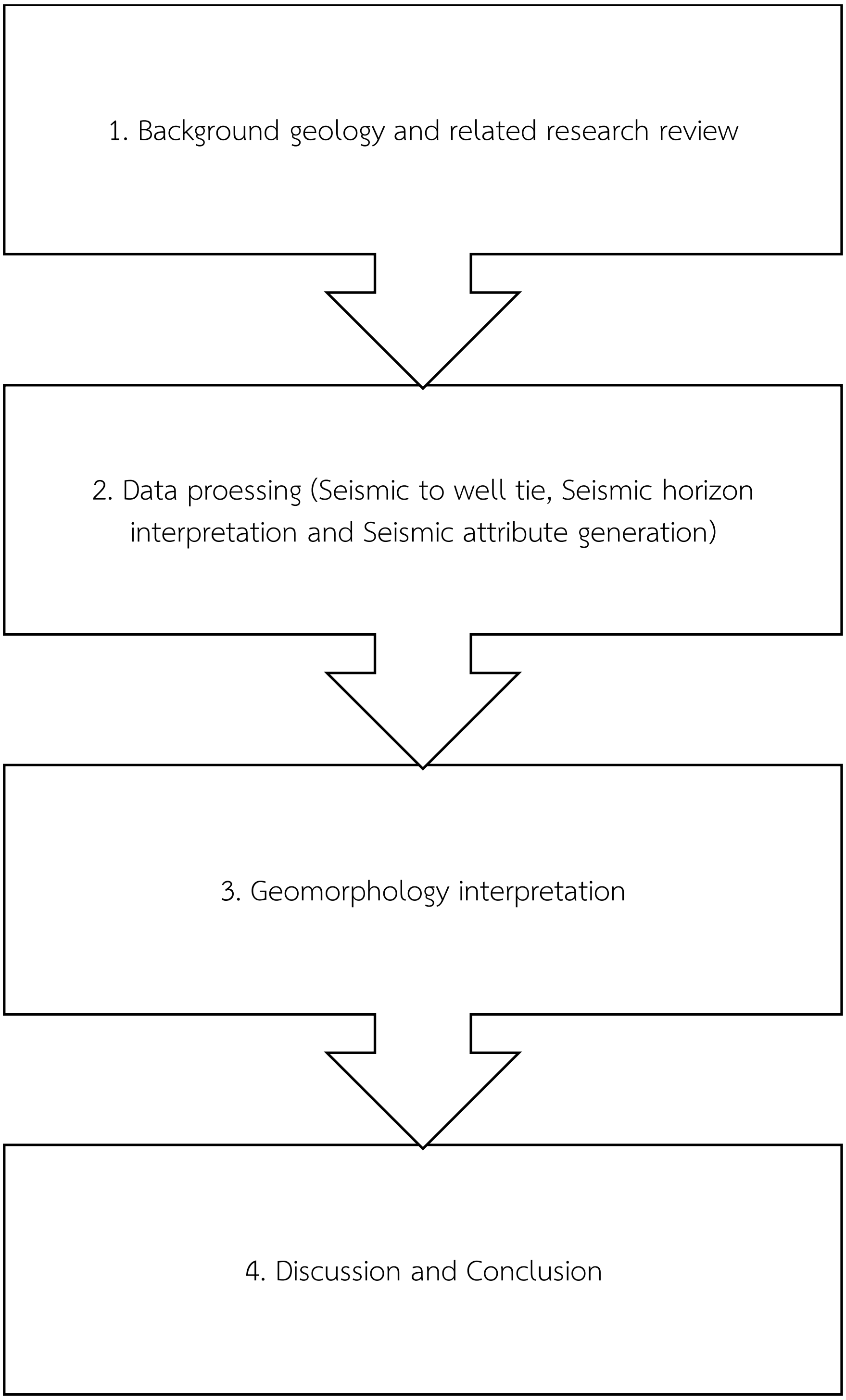


Figure 1.2 Project workflow

CHAPTER 2

THE GEOLOGY OF THE STUDY AREA

The Taranaki basin is adjacent to the Reinga basin in the north and the West Coast basin to the South. More than 400 petroleum exploration and production wells have been drilled and high-quality seismic reflection data sets cover the Taranaki basin. (New Zealand Petroleum and Mineral, 2014). The basin was originated approximately 80 million years ago related to the breakup of Gondwana, compressional and extensional of subduction along the Pacific – Australian plate boundary (King and Thrasher, 1996)

2.1 Tectonic Evolution

The Taranaki basin has been a complicated history form Cretaceous to the present day. There are abundant of geological structures such as normal fault, reverse fault and uplift area (King and Thrasher, 1996). Tectonic evolution of the Taranaki basin can be divided into 4 main phases: subduction of East Gondwana, the failure of the Tasman Spreading ridge, The Tasman sea extension, and the new plate boundary (Figure. 2.1).

The New Zealand region was a marginal part of the Gondwana Supercontinent at least the Triassic to the Late Cretaceous (Bache et al., 2014). Basement dominated by volcanic, plutonic, and metasedimentary rocks from magmatic and metamorphic processes (Uruski, 2007). At least 160 Ma, the New Caledonia basin had been formed as a back-arc rifting by subduction (Uruski and Baillie, 2004) and ceased about 105 Ma. The initial basin formed as a rift margin on the landward side of the Gondwana margin during the separation of the Australian and New Zealand continental land masses (King, 2000)

Late Cretaceous failed rifting caused the recent shelf because of differential spreading directions in the Tasman Sea and Southern Oceans. From 100 Ma to 75 Ma, the Taranaki delta was deposited within the failed rift of the New Caledonia Basin, while the spreading of Tasman Sea had been begun around 80 Ma (Sutherland et al, 2001). This divergence plate boundary as a result unconformity which recorded in transgressive Cretaceous sediments. In addition, thermal subsidence and sediment supply affected the spreading continued in the Tasman Sea until The Paleocene (~55 Ma).

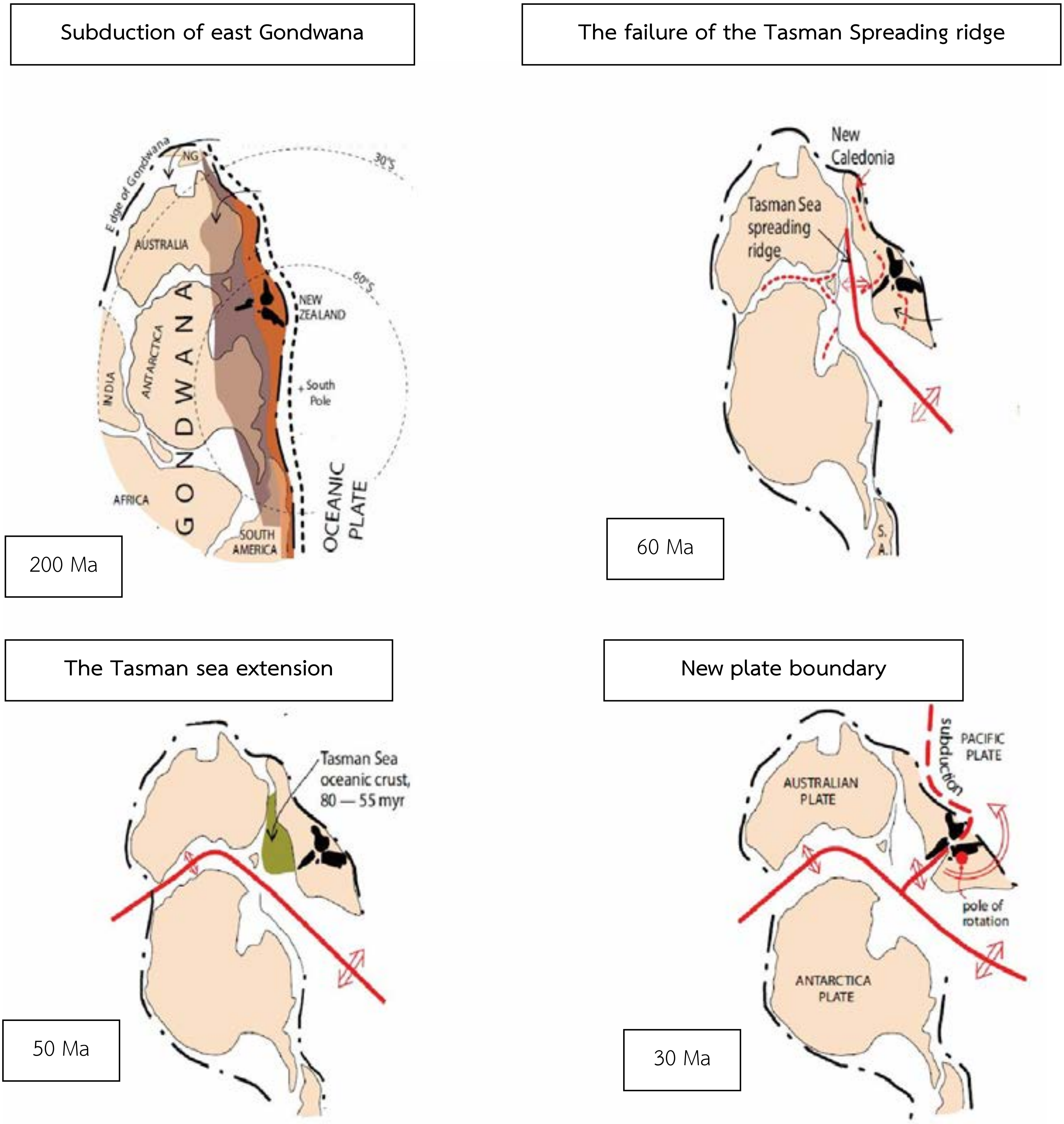


Figure 2.1 Geological tectonic setting of New Zealand (modified after Balance, 2009.)

About 50 Ma, the Tasman arm of the spreading ridge failed and the old rift between Australia, Antarctica, and south of Tasmania was reactivated as the continuation of the mid-Pacific spreading ridge which linked to spreading ridge in the Indian Ocean (Ballance, 2009). The opening of the Southern Ocean developed with the seafloor spreading in the Tasman Sea. As a result, the anti-clockwise rotation affected the extension to the southern part (Turnbull et al., 1993), while the northern part developed the compression (Uruskiet al, 2002). Major, open folds and minor faults were formed in deepwater Taranaki (King and Thrasher, 1996).

Since 25 Ma, the current plate boundary was initiated. Some of the first events developed with this initiation include the obduction of sedimentary and igneous rocks on the Northern Island. The plate boundary rotated to the current position with the NNE trend. As a result, the volcanoes gradually southward younger. This rotation caused the older extensional faults to the South of the Taranaki peninsula. While, the deepwater Taranaki or the western platform was still unaffected by direct tectonism whereas the slighted uplifted and erosion (Sarma et al., 2014)

2.2 Stratigraphy

The knowledge of geological tectonics setting can explain that the Taranaki basin had been initially formed, it had been through many geological events. As a result, the stratigraphy of this basin was very complicated (The Institute of Geological and Nuclear Sciences, 1997). The stratigraphy of the basin can be divided into 5 phases (Figure 2.2-2.3); basement phase, syn-rift phase, Taranaki delta phase, Transgression phase and Regression phase (Uruski, 2007).

Basement of the Taranaki basin includes volcanic, plutonic rocks and metasedimentary units. Igneous units include the Brook Street terrane mafic volcanic rocks and granite of Separation Point and Karamea. Metasedimentary comprises the Buller and Takaka terrains as well as Torlesse supergroup which was deposited as a large submarine fan in the subduction trench (Bradshaw et al., 1981)

Syn-rift phase developed from Jurassic to Early Cretaceous. Sediments deposited in Jurassic are dominated by coarse-grained sedimentary. On the other hand, sediment deposited in Early Cretaceous is commonly fined- grained sediment. Jurassic to Early Cretaceous rocks are determined to deposit in an actively faulting or basin or basins related to subduction at the Gondwana margin. The deepwater pre-delta is dominated by coarse clastic rocks that originated from fault scarps or deposited by fluvial system transportation from elsewhere in the Gondwana hinterland. Low-lying had possibly been accumulated swamp, marsh, and lacustrine sediments. The boundary between this syn-rift phase and delta system deposition is determined by a hiatus at around 105 Ma which was followed by large deltaic deposition.

Around Late Cretaceous, The Taranaki delta phase had developed delta by sea levels change. Delta sequences initiated with highstand systems tracts, followed by the increase of relative sea level sequence, lowstand systems tract and transgressive sequence respectively (Uruski, 2007). Sediment deposition is dominated by mudstone with sandstone limited in a specific environment such as channels shorefaces, mouth bar, and transgressive sequences. The deposition of turbidities by lowstand could have provided a large of organic material which was possibly leaf matter dominated to the basin floor (Uruski, 2007).

About 75 to 25 million years ago, deposition of the transgressive phase has occurred. The transgressive period because of thermal subsidence of the whole mini-continent which began after the separation from Australia. At this time, the extensional faulting and the eustatic sea level change caused complicated deposition of North Cape Formation which is marine sediment was deposited within the basin. This formation deposited on top of the Rakopi Formation and had a thickness about 1000 meters. Moreover, some units of coals have been founded in outcrop and wells. Those coaly units appear to be Puponga and Wainui members. A large widespread Taranaki shelf area that occurred by Taranaki delta ubiquitously influenced the topography of the basin through Paleogene. The continuing subsidence of the New Zealand landmass caused sediment supply was reduced. Accumulation area was commonly restricted to approximately 200 meters for the Paleocene to Eocene. Sediment deposition in this period dominated by fine-grained siliciclastic. During Eocene, carbonate deposition was formed until the end around Early Miocene in the distant offshore of the northwest, New Zealand. The depositional of carbonate was more common as the clastic supply continued to dissolve due to the New Zealand landmass subsidence and dominated by the Oligocene. During these transgressive phases, the margin of Northland and the Taranaki shelf were generally flooded by sea water as proved by the domination of transgressive coarse-grain sediment in the Paleocene overlying on Jurassic rocks.

The last phase, regression phase during 25 Ma to the present day. The New Zealand uplifting caused clastic sediment supply deposited in this period. A large of clastic sediment supply had been created the present-day shelf associate very large channels and turbidities systems which appear to continue at least along the ancient New Caledonia Basin located on the northwest side of Deepwater Taranaki basin (Uruski and Wood, 1991). During Pliocene, in Deepwater Taranaki basin is characterized by deposition of turbidite associated with extremely large mass transportation which can be observed by chaotic or disrupted internal reflectors. In addition, mud volcanoes and the field of pockmark can be founded in many areas on the sea floor (Uruski, 2007).

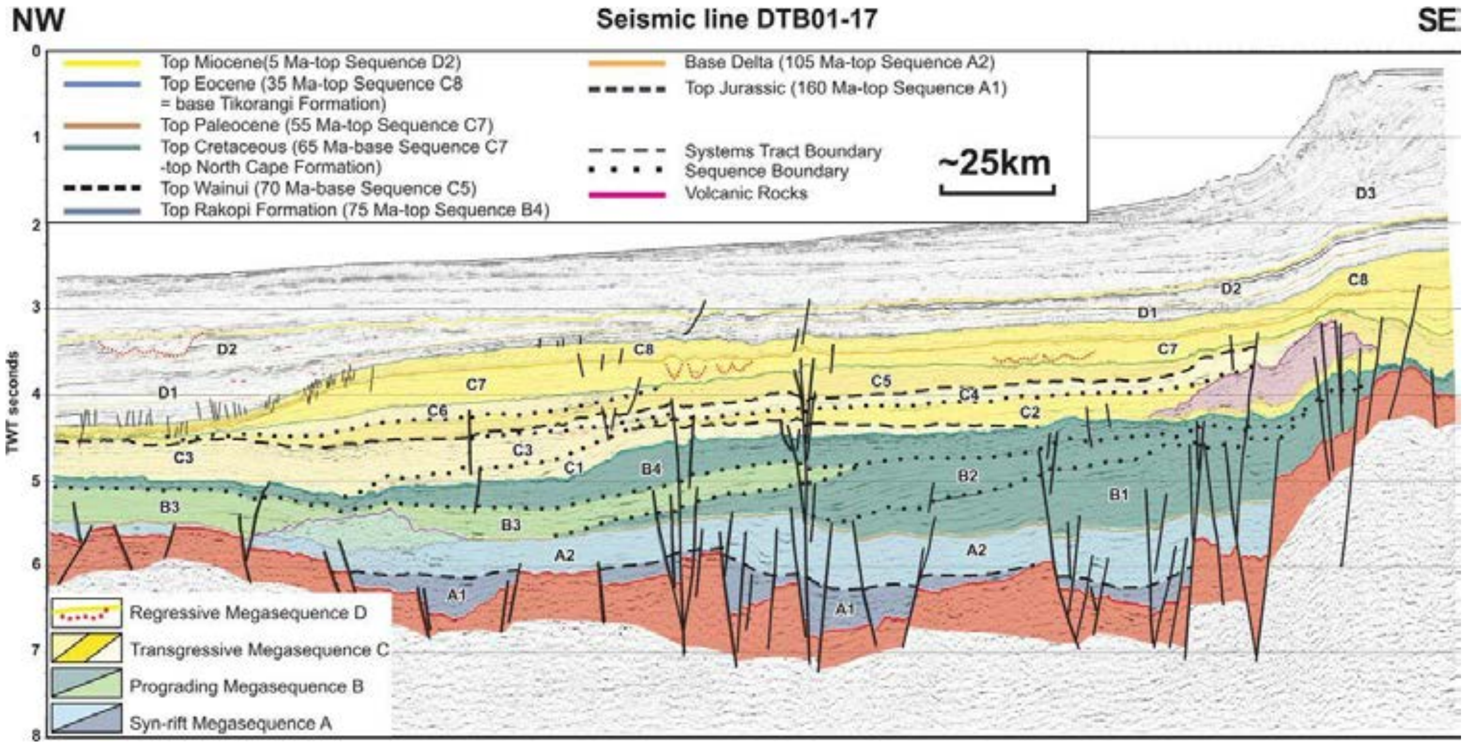


Figure 2.2 Sequence stratigraphy of Taranaki basin (Uruski, 2014).

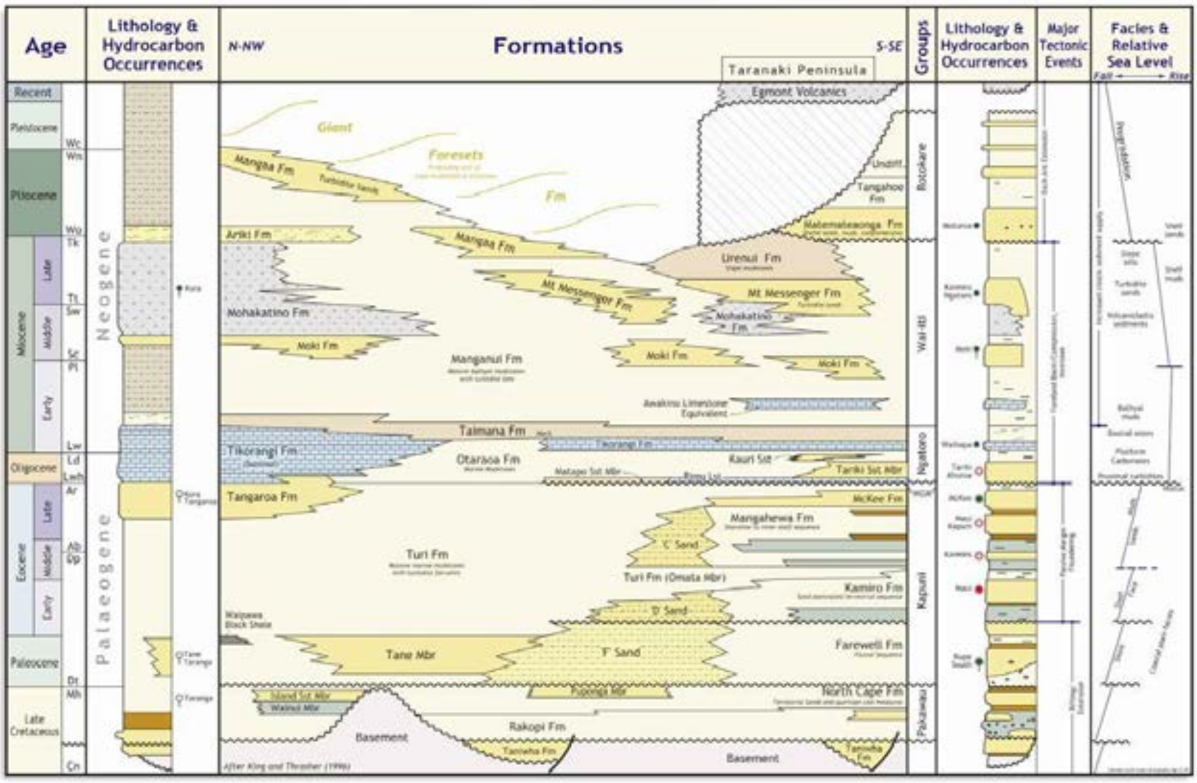


Figure 2.3 stratigraphy of Taranaki basin (King and Thrasher, 1996)

2.3 Giant Foresets Formation

The Giant Foresets Formation deposited overlying on the sedimentary section throughout the North Taranaki Graben and across a large portion of the central basin and NW Western stable platform. In some areas, this formation deposited at the top of the Mohakatino/Manganui Formations divided by the paraconformity, while in some areas this formation overlies the Ariki or Mangaa Formations separated by paraconformity (Figure. 2.3). The absolute basal age of this formation is diachronous because of the extremely progradation of the formation, however, it is commonly no older than 4 Ma (Hansen & Kamp, 2004). The age of top boundary surface is the seafloor and therefore present day.

The Giant Foresets Formation was formed by rapid uplift of New Zealand landmass along the Alpine Fault and Hikurangi subduction zone during the Miocene (Kamp et al., 2004). Sources of sediment supply were Patea-Tongaporutu in the south and Herangi Highs in the east. Deposition of sediment in the basin was rapid with some wells in the central and northern areas that water depths decreasing from mid-lower bathyal (600-1500 m) to mid-shelf (50-100 m) in under 2 Ma, even as the graben underwent extensional faulting (e.g. Arawa-1, Taranga-1, Awatea-1) (ARCO Petroleum, 1992; Murray & de Bock, 1996; Morgans, 2006).

CHAPTER 3
METHODOLOGY

3.1 Data and software used in the project

The data used in this project are available 3D seismic survey which covers about 480 km² along the western side of Northern New Zealand Island. The data acquired by New Zealand Petroleum and Minerals 2007. The 3D seismic volume (NIMITZ3D block) has an available recording length of approximately 5.0 s (Two Way Time) and a bin spacing of 12.5 m. × 25 m. In inline and crossline directions, respectively. The 3D seismic volume is post-stack where acoustic impedance increases are indicated by positive amplitudes and zero phase display. Moreover, in this study contains two exploration wells include Korimako-1 well and Tarapunga-1 well which plays an important role in determine stratigraphy such as lithology and top formation in the study area. Seismic interpretation, seismic to well tie and attributes analysis were performed by using Petrel 2014 and Kingdom version 8.8.

3.2 Seismic to well tie

Before seismic interpretation, this project correlates well data and seismic data to determine stratigraphy in seismic data and identify marker key horizon from the well data.

Synthesis seismograms were generated from available check shot data, sonic and density logs. Acoustic impedance and reflection coefficients were calculated from sonic and density log to do convolution with a wavelet of seismic data. The synesthetic seismogram will be calibration to seismic data by shifting synthetic seismogram to correlate with seismic data. Finally, the true depth in meters of each rock formation is derived in the well (Figure 3.1).

After deriving know top of formations correlated to the seismic line, the seismic reflection lines of each top formations will be tracked to correlated to 3D seismic volume. The horizon of each top of rock formation will be created by tracking and used to correlate to the emplacement timing of sedimentary deposit.

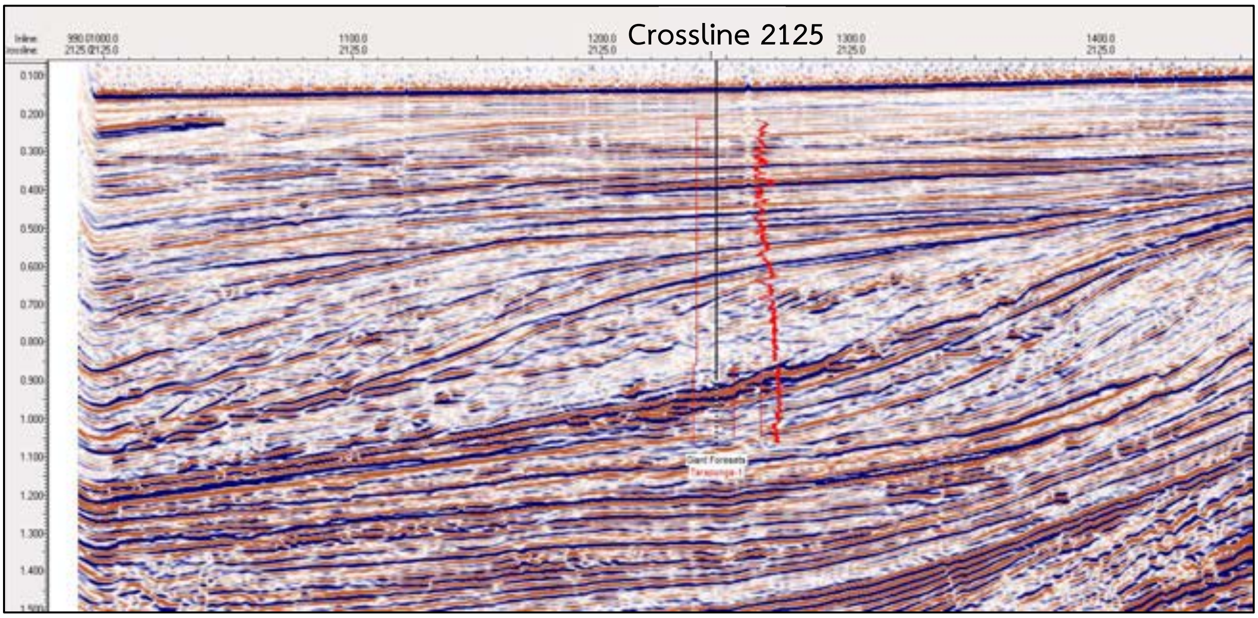


Figure 3.1 Example correlation between well data and seismic data in Kingdom version 8.8.

3.3 Seismic horizons interpretation

The interpretation of seismic horizons was to determine significant seismic reflection, seismic facies changes or sequence boundaries. The seismic horizons were correlated with lithostratigraphic formation tops. (Figure 3.2)

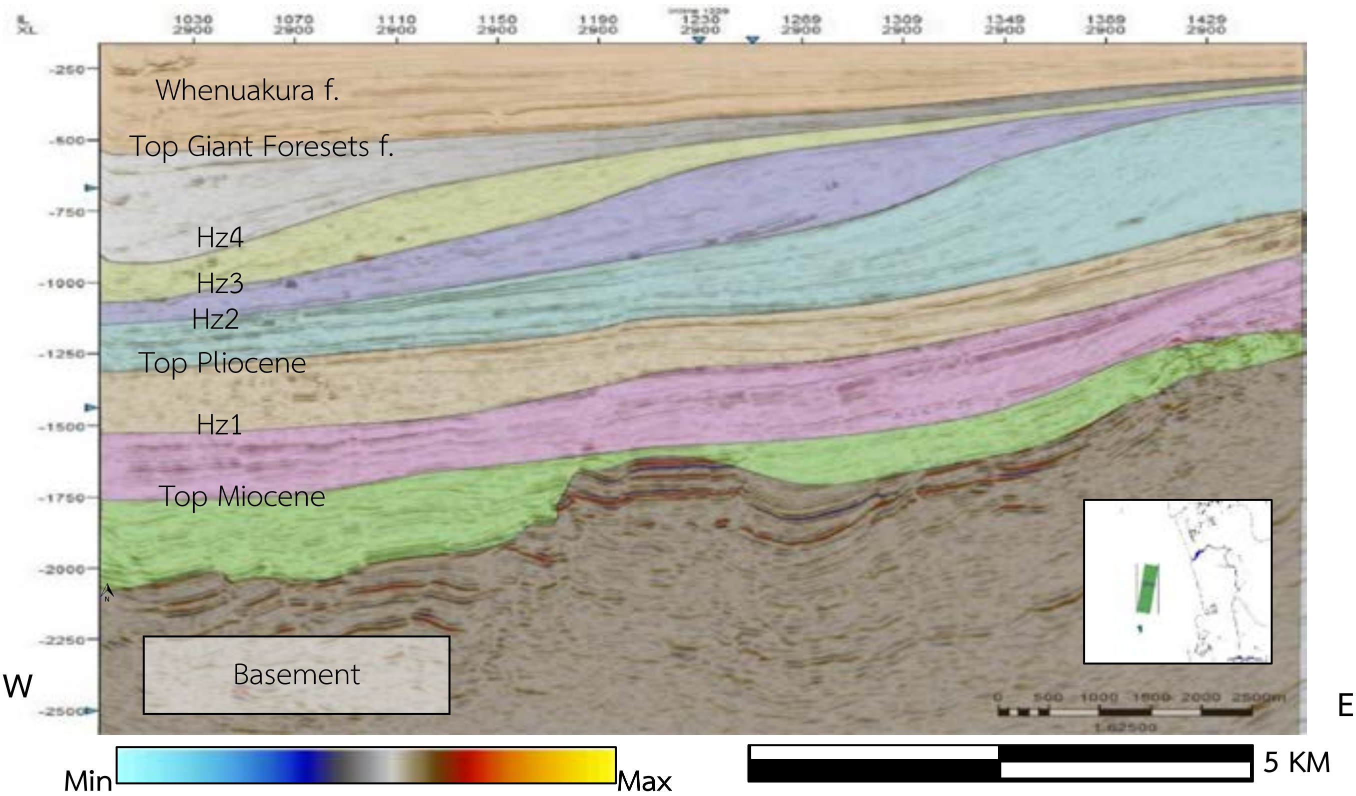


Figure 3.2 Example of seismic horizons interpretation in Cross-Line 2900.

3.4 Seismic Stratigraphy Characteristic Interpretation.

Seismic stratigraphy can be interpreted from seismic facies and seismic reflection data. Variation of sedimentary architecture, lithofacies, and associated impedance character are showed in seismic data by changing the reflection character such as geometry, amplitude, and reflection pattern. According to Sangree and Widmier (1979), significant seismic characteristics that were used in this study are seismic reflection amplitude, seismic reflection termination (Figure 3.3A) and seismic configuration (Figure 3.3B). Each of these seismic characteristics represents different meanings and implies specific knowledge or geological information. Moreover, these characteristic plays an important role to predict the depositional environment of them.

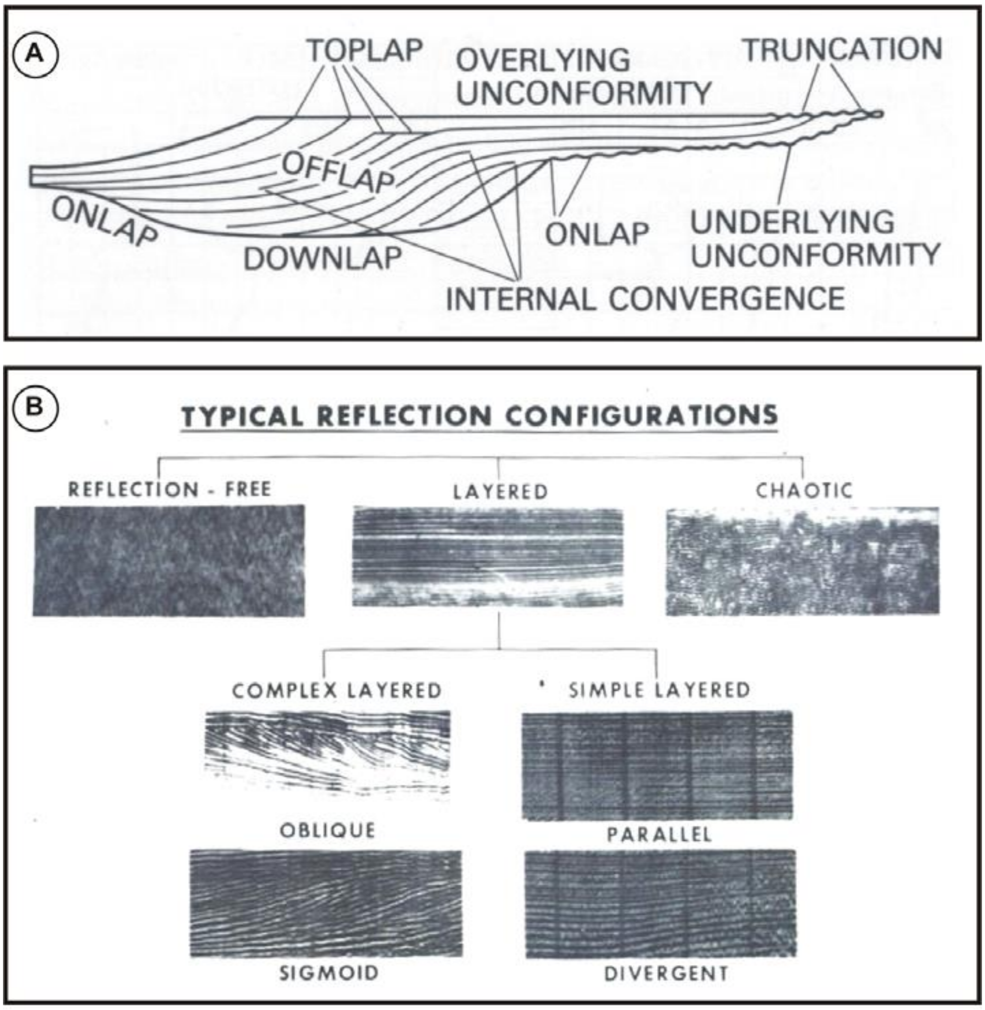


Figure 3.3 A) Schematic nature of seismic reflector terminations and geometry of seismic facies units (modified after Mitchum et al., 1977). B) Typical reflection configurations on seismic reflection (data from Sangree and Widmier, 1979).

3.5 Seismic attribute generation

This study uses seismic attributes including sweetness, instantaneous frequency, RMS amplitude, variance and spectral decomposition for determining geomorphology features. After the interpretation of seismic horizon, seismic attributes were applied at the location of the interpreted seismic horizons and then created seismic attribute maps (Figure 3.4).

Seismic attributes are mathematical descriptions of the shape amplitude and position of a seismic trace over a specific time interval that help to visually enhance or quantitative measure of a seismic characteristic of interest (Chopra and Marfurt, 2005). In this study, seismic attributes analysis is used to enhance and highlight channel distribution related to stratigraphy and geomorphology. The ability of each seismic attributes is described in this part.

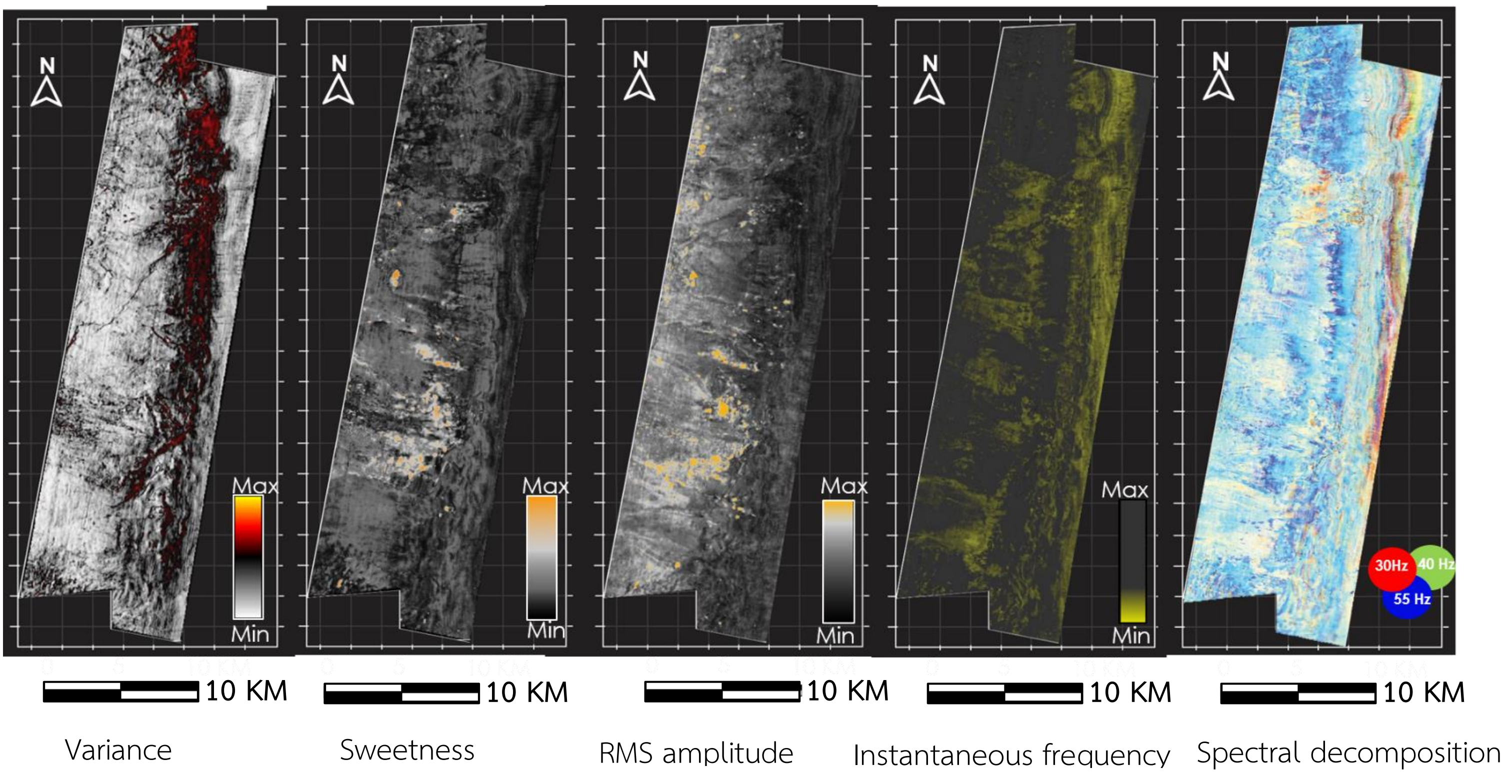


Figure 3.4 Example of seismic attributes include sweetness, RMS amplitude, variance, and instantaneous frequency in horizon 2

3.5.1. RMS (Root Mean Square) amplitude attribute

A post-stack attribute that computes the square root of the sum of squared amplitudes divided by the number of samples within the specified window used. It is a calculated window of N samples as the square root of the sum of all the trace values x squared where w and n are the window values as shown in Equation 1.

$$x_{rms} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} w_n x_n^2}$$

Equation 1

This attribute is used to map hydrocarbon indicators within a zone by providing a statistical measure of the magnitude of variation in amplitude throughout a dataset. Generally, higher acoustic impedance variations (associated with variations within stacked lithology) will result in higher RMS values. In addition, Higher RMS amplitude in the extraction window indicates higher proportions of channel sands or better reservoir facies, especially when coupled with higher attenuation levels. However, RMS amplitude attribute is sensitive to noise as it squares every value within the window.

3.5.2 Instantaneous frequency

Instantaneous frequency is defined as the rate of change of phase over time derivative as presented in Equation 2.

$$F(t)=d(f(t))/dt$$

Equation 2

Instantaneous frequency represents the frequency of the sinusoid that best matches to the seismic trace. The use of Instantaneous frequency is to enhance vertical and lateral variations of lithology, as well as a Direct Hydrocarbon Indicator (DHI) since lower frequency usually is associated with hydrocarbons occurrence. Seismic waves travel more slowly in hydrocarbon zones. This signal time delay is a major factor causing low frequency anomalies

.

3.5.3 Sweetness attribute

Sweetness attribute is calculated by dividing the instantaneous amplitude or amplitude envelope a(t) by the square root of the instantaneous frequency f(t) as shown in Equation 3.

$$s(t) = \frac{a(t)}{\sqrt{f_a(t)}}$$

Equation 3

The value in the sweetness attribute will reduce the high-frequency events on your result image. Areas including higher anomalies amplitude and lower frequencies (sand layers) will present the highest values for sweetness attribute, while the lower amplitude and higher frequency sediments (thinly shale layers) will show lower values for sweetness attribute. This combination image is useful for identifying gas zones, hydrates, and the top, flank, and base of Salt bodies. All of these features will show high sweetness values due to their higher amplitude values.

3.5.4 Variance attribute

Variance (edge method measures the similarity of waveforms including shape and amplitude or traces adjacent over given lateral and/or vertical windows. Generally, it reveals discontinuities in seismic data either related to stratigraphic terminations or structural lineaments.

High amplitude values on this attribute corresponds to discontinuities in the data, while low amplitude values correspond to continuous features. Discontinuity varies between zero and one, where zero is continuous and one is discontinuous.

3.5.5 Spectral decomposition attribute

The spectral decomposition attribute (RGB blending) is created by illuminating the structures with three different frequency bands. However, when three frequency magnitude responses are combined using a three-dimensional RGB (Red-Green-Blue) color bar, the interplay between different frequency responses becomes apparent. This provides a more sensitive method of analyzing the amplitude variation within the data. Specifically, the color balance within the RGB blend relates to geometrical (thickness) variations, via the sensitivity of each frequency band to tuning effects, and to frequency dispersion caused by fluids (McArdle & Ackers, 2012). RGB blends often starkly highlight geological features and can be used both to focus interpretation and to image geological elements including those at or just below the limit of seismic resolution.

3.6 Geomorphology Interpretation

One of **the** main objectives in this study is to image seismic geomorphology. Fundamental to the study of seismic geomorphology is the characterization of seismic facies via seismic attributes. The study of seismic geomorphology usually uses a combination of multiple seismic attributes to highlight and characterize of identified seismic geomorphology form shape, amplitude and depth in surface attributes by correlating with surface geomorphology conceptual model (Figure 3.5).

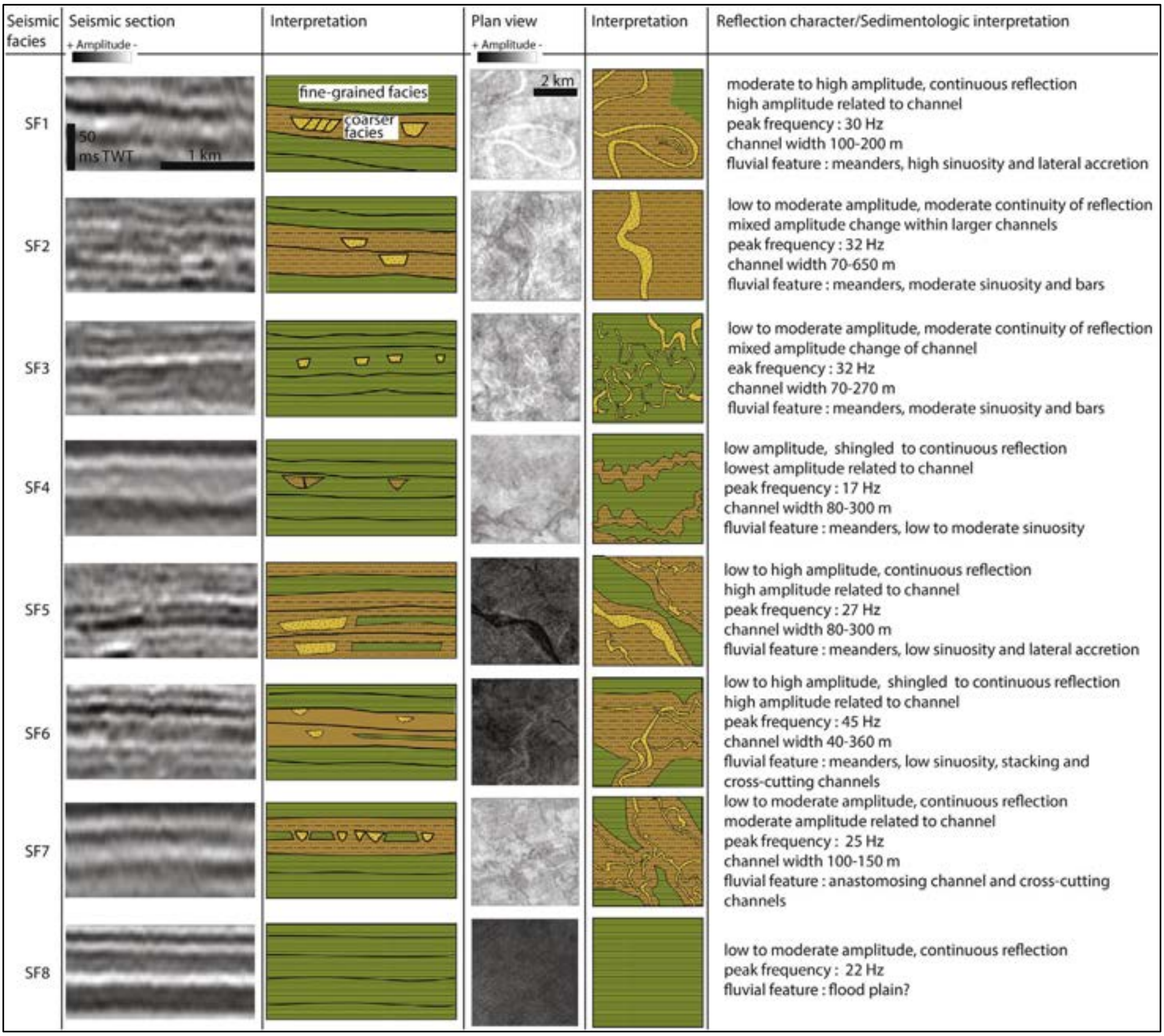


Figure 3.5 Example of imaging seismic geomorphology from seismic data (Calvès et al., 2018)

CHAPTER 4

Result

4.1 Seismic stratigraphy in the study area

According to seismic data and well data within study area including Tarapunga-1 and Korimako-1, the seismic stratigraphy in this study area can be divided into 4 main Units: 1) Basement, 2) Miocene Marl, 3) Giant Foresets formation and 4) Whenuakura formation. The horizons in Giant Foresets formation can be separated into 6 horizons (Figure 4.1). The description of each unit is shown in this part.

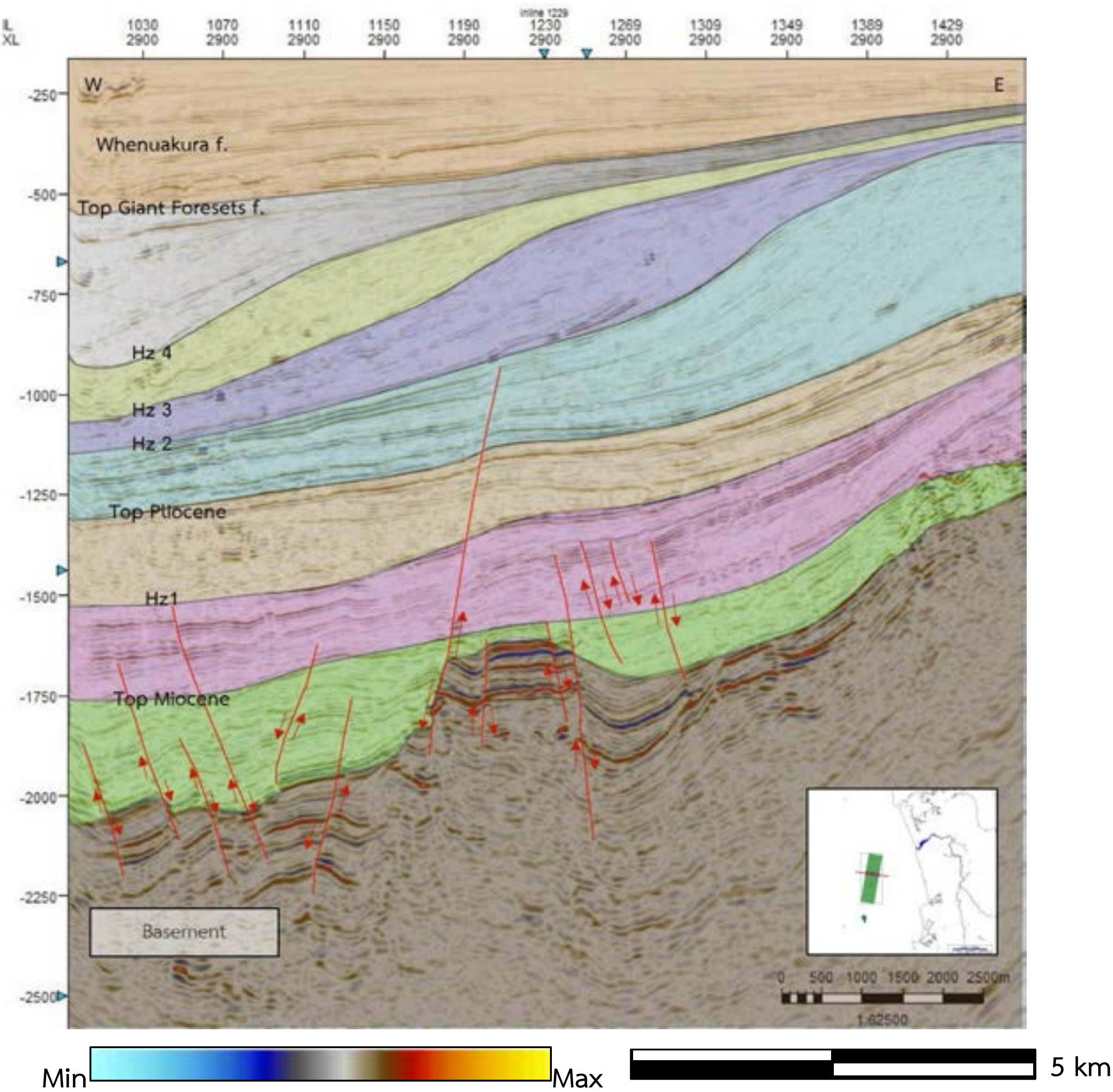


Figure 4.1 Crossline 2900 show seismic stratigraphy in this study area.

4.1.1 Basement

The oldest unit in this study has a highly chaotic, high amplitude seismic reflection character but becomes highly complicated, opaque amplitude and poorly resolved seismic reflection. Chaotic seismic character generated by faults and depth. Structure dominated by planar normal faults generated in the extensional phase. High amplitude seismic character represents the igneous body and unconformity (Figure 4.2).

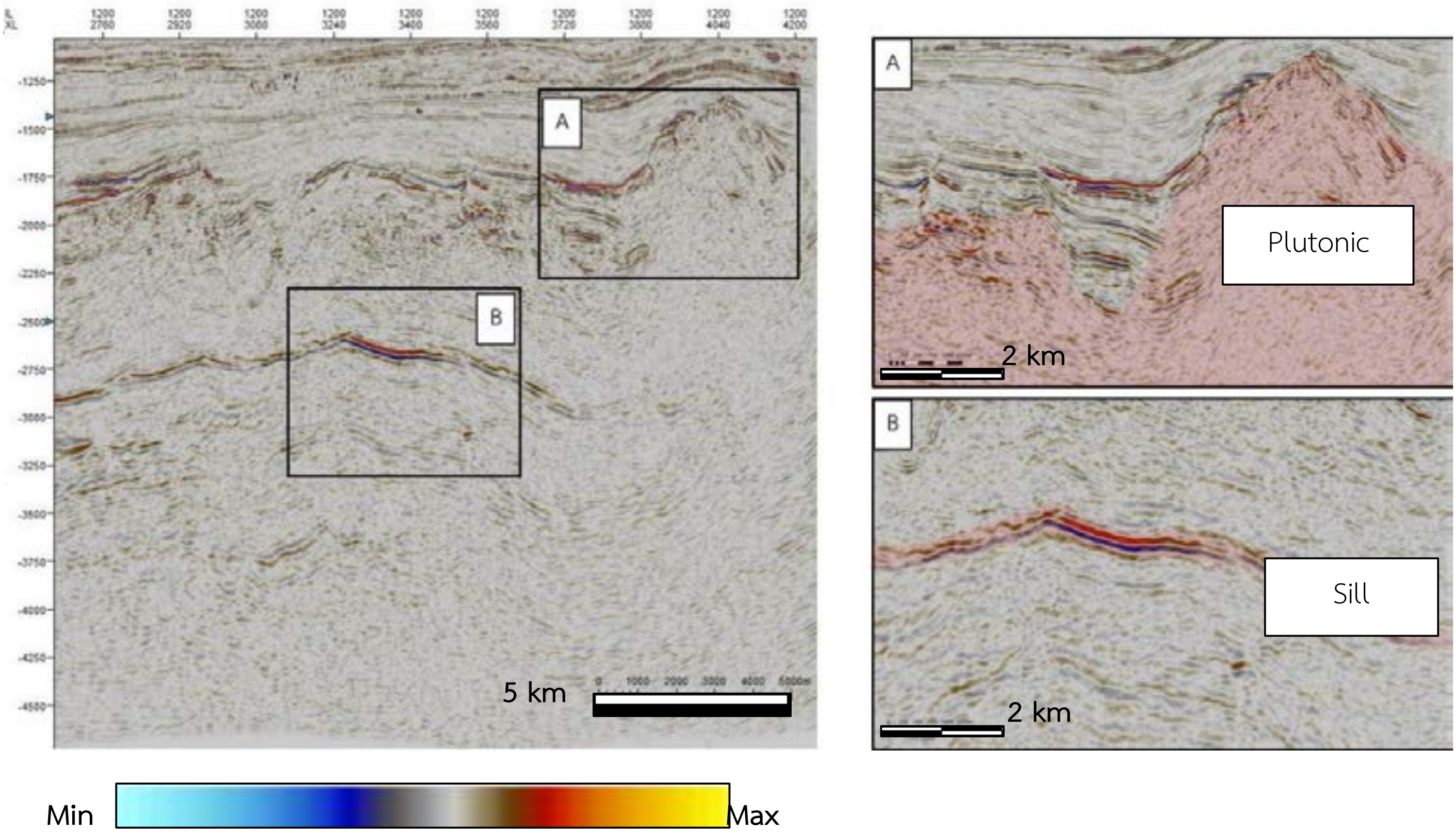


Figure 4.2 Inline 1200 shows high amplitude in basement; (A) the igneous body that has concave upward and downward shape or dike like intrusion. (B) sill or igneous tabular sheet intrusion that has intruded between older layers of sedimentary rock.

4.1.2 Miocene Marl

This unit dominates by subparallel seismic reflection character due to the depositional environment and divergence seismic reflection character caused by igneous intrusion put up sedimentary rock layers.

4.1.3 Giant Foresets Formation

Giant Foresets Formation dominates by sigmoid and clinoform seismic reflection character by progradation and degradation process. It can be divided into 6 horizons including horizon 1, top Pliocene, horizon 2, horizon 3, horizon 4 and top Giant Foresets formation (Figure 4.1). Due to highly thickness, this unit has variation of seismic reflection characteristics that show in table 4.1

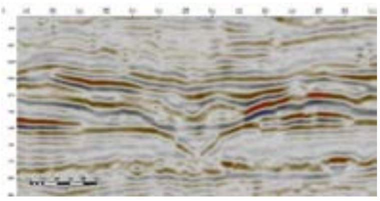
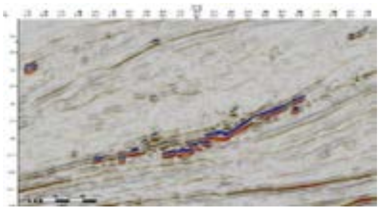
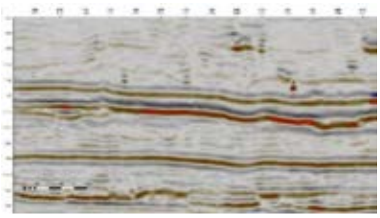
Seismic section	Seismic reflection characteristic	Sedimentological interpretation
	- high amplitude - concave upper surface - sub- chaotic within concave - parallel and continuous reflection	- channel
	- high amplitude - chaotic and discontinuous reflection - reflection parallel horizon - topset and foreset reflection	- slump scar
	- high amplitude - continuous and parallel reflection - topset reflection.	- sand sheet - delta
	- low to moderate amplitude - shingled to continuous reflection - sigmoid and foreset reflection - dipping	- slope

Table 4.1 Seismic reflection characteristics of Giant Foresets Formation

4.1.4 Whenuakura formation

The youngest unit in this study has a chaotic, low to moderate amplitude, topset, parallel and continuous seismic reflection character (Figure 4.3).

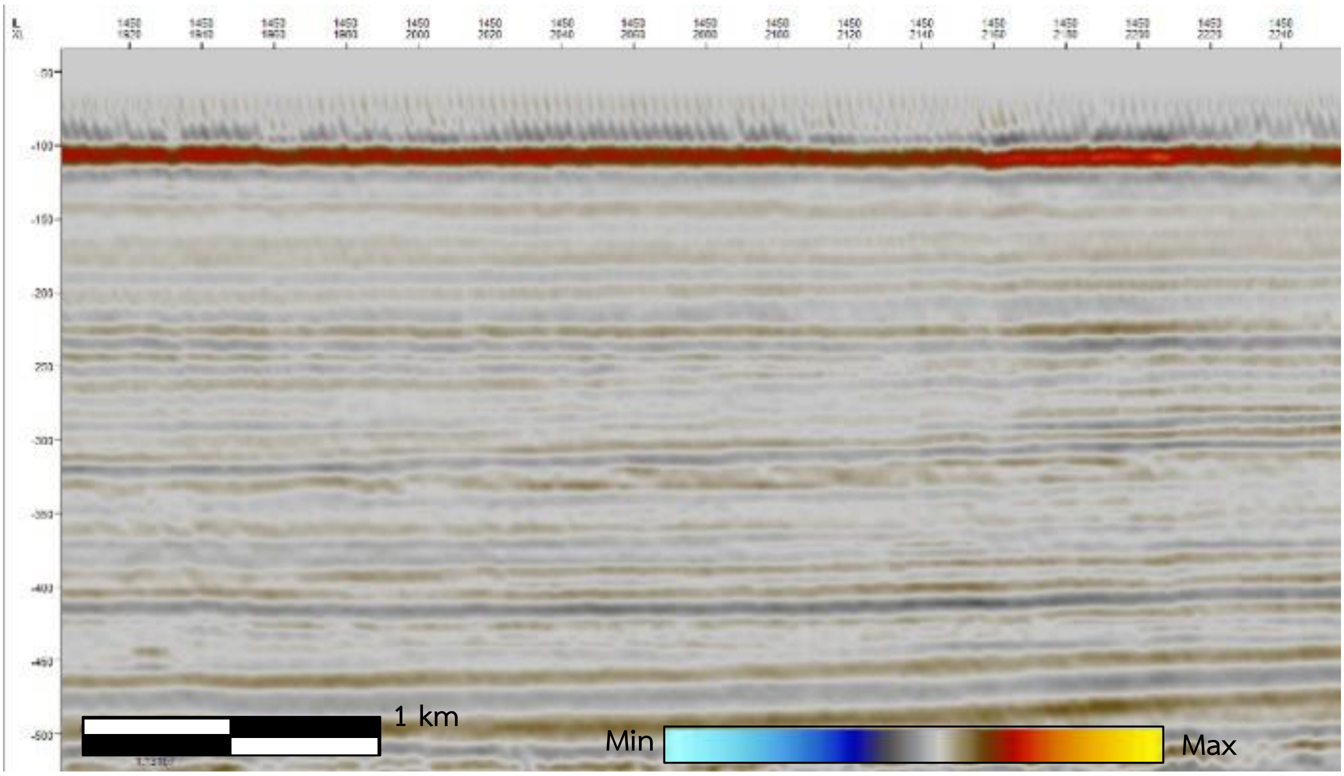


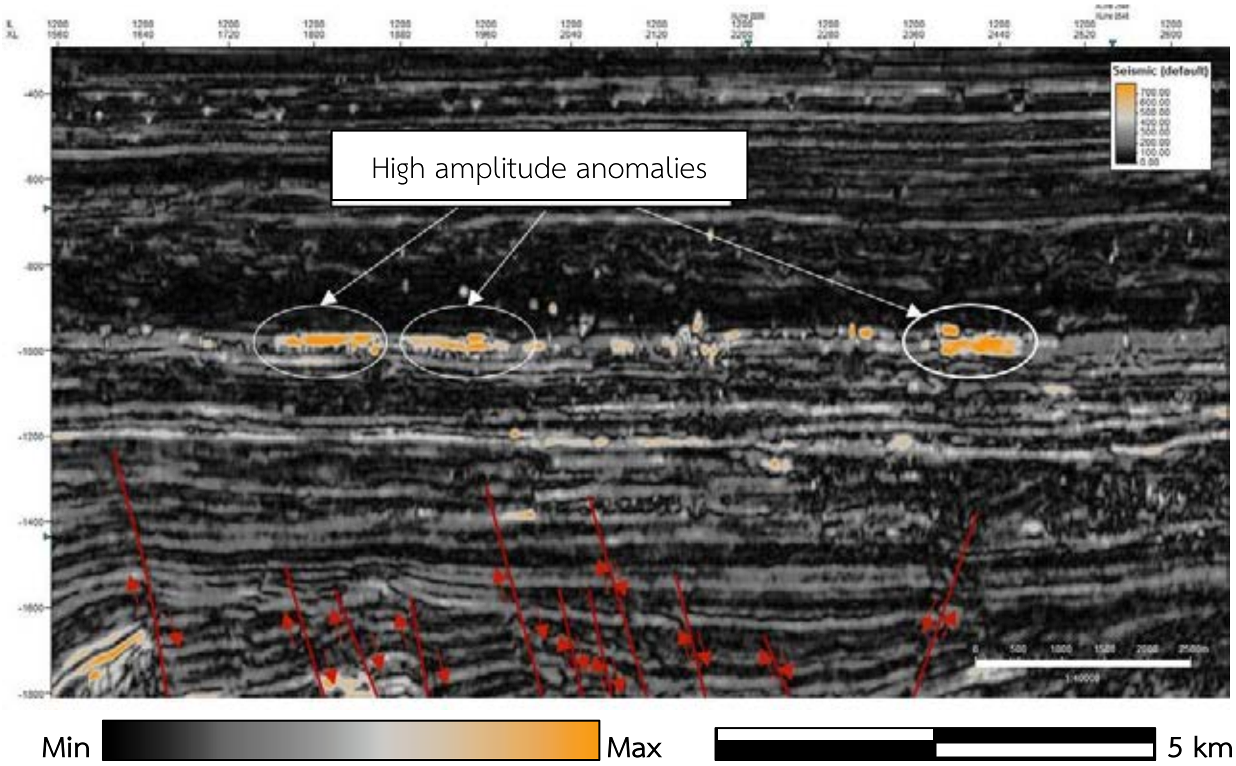
Figure 4.3 Inline 1450 show parallel and continuous reflection of Whenuakura formation.

4.2 Seismic attributes

In this study seismic attributes are used to determine geomorphological features. All of these are post-stack attributes including sweetness, RMS amplitude, variance, instantaneous frequency, and spectral decomposition. The ability of seismic attributes is described in this part.

- **Sweetness attribute**

Sweetness attribute shows seismic data tend to have high amplitudes and low frequencies. In this study, the sweetness attribute is useful to highlight coarse-grained (sand) interval or bodies. This attribute enhances the imaging of channel characteristics. The high amplitude anomalies caused by the contrast of lithology between coarse-grained (channels, slump area) and fine-grained (delta plain, coastal plain) (Figure 4.4). However, some of the high amplitude anomalies are not necessary that must be sand bodies, it probably be unconformity between two rock layers that highly different acoustic impedance (Figure 4.5)



. Figure 4.4 Seismic profile of inline 1200 from sweetness attribute volume showing high amplitude anomalies that represent sand bodies.

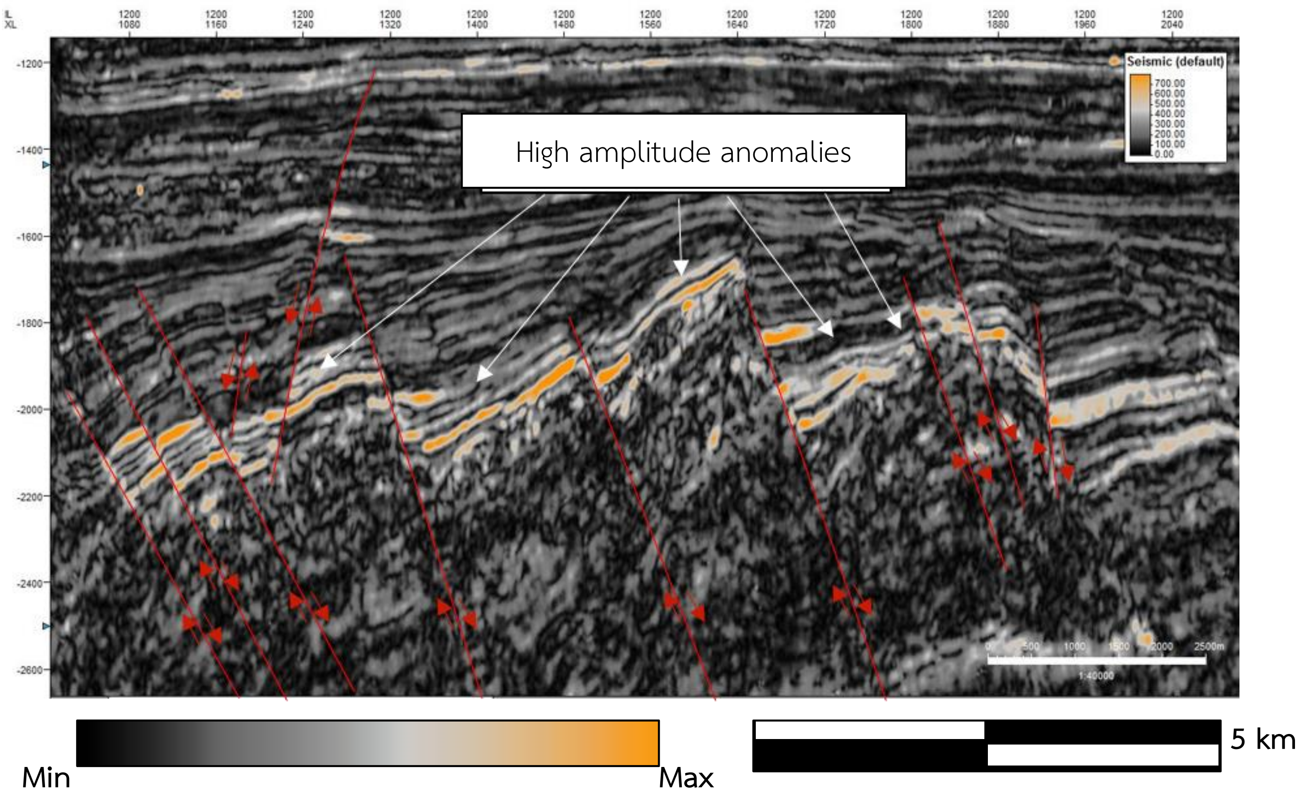


Figure 4.5 Seismic profile of inline 1200 from sweetness attribute volume showing high amplitude anomalies that represent unconformity.

The plan view image of the sweetness attribute shows detail on geomorphological features such as sand body from slump deposit, channels, and delta. Channels edges and slump areas are clearly highlighted in comparison to the surrounding area (Figure 4.6).

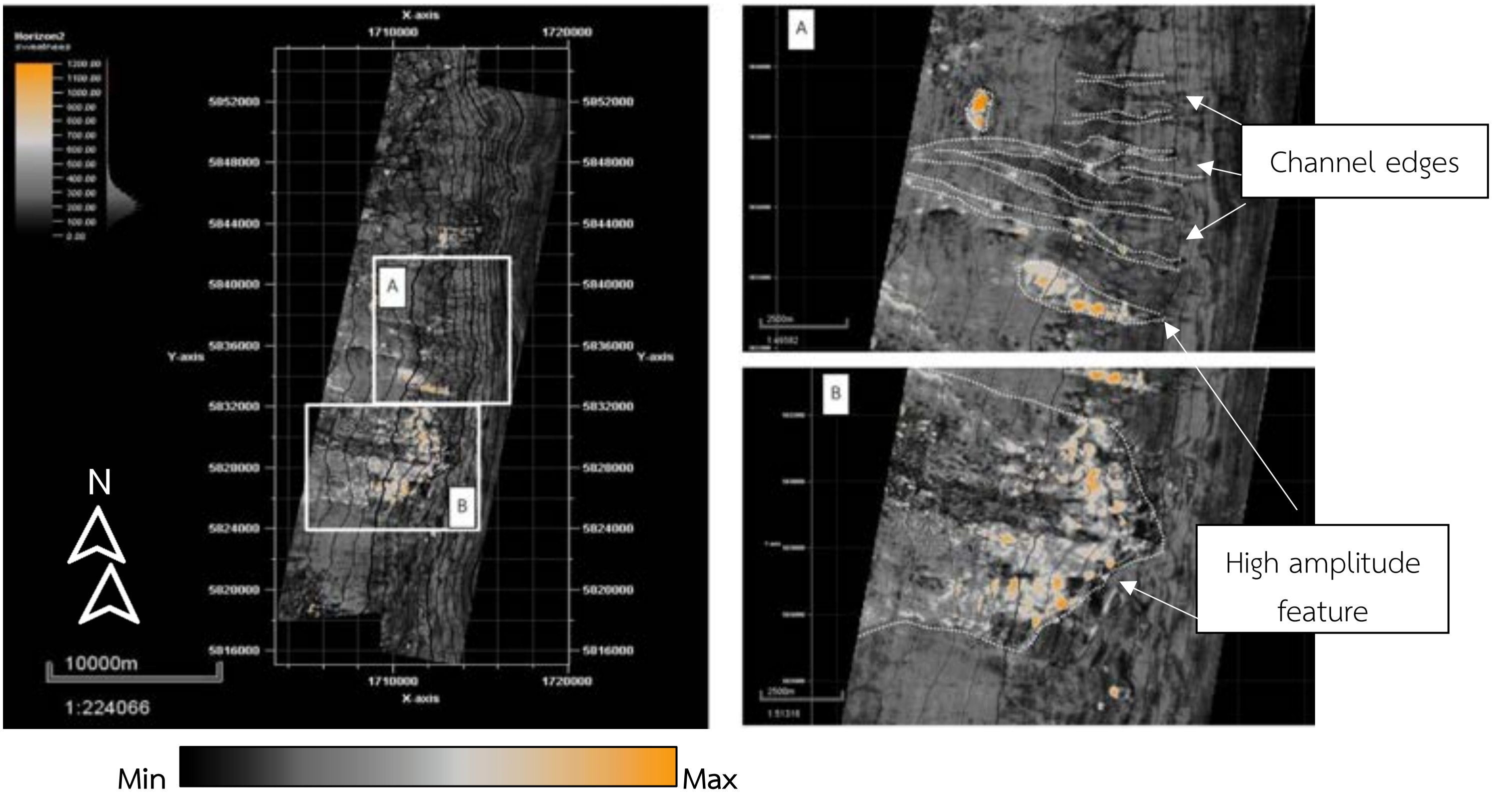


Figure 4.6 Sweetness attribute map on horizon2 shows channels edge (A) and slump area (B)

- **RMS amplitude attribute**

RMS amplitude applied to reveal amplitude anomalies that used for detecting coarse-grained facies and unconformities (fig 4.7). In this study, this attribute improved the imaging of sand bodies which represent channels distribution and slump area (fig 4.8). The high amplitude anomalies caused by the lithology between sand bodies and delta or coastal plain. This attribute shows high amplitude anomalies in the same area to the sweetness amplitude.

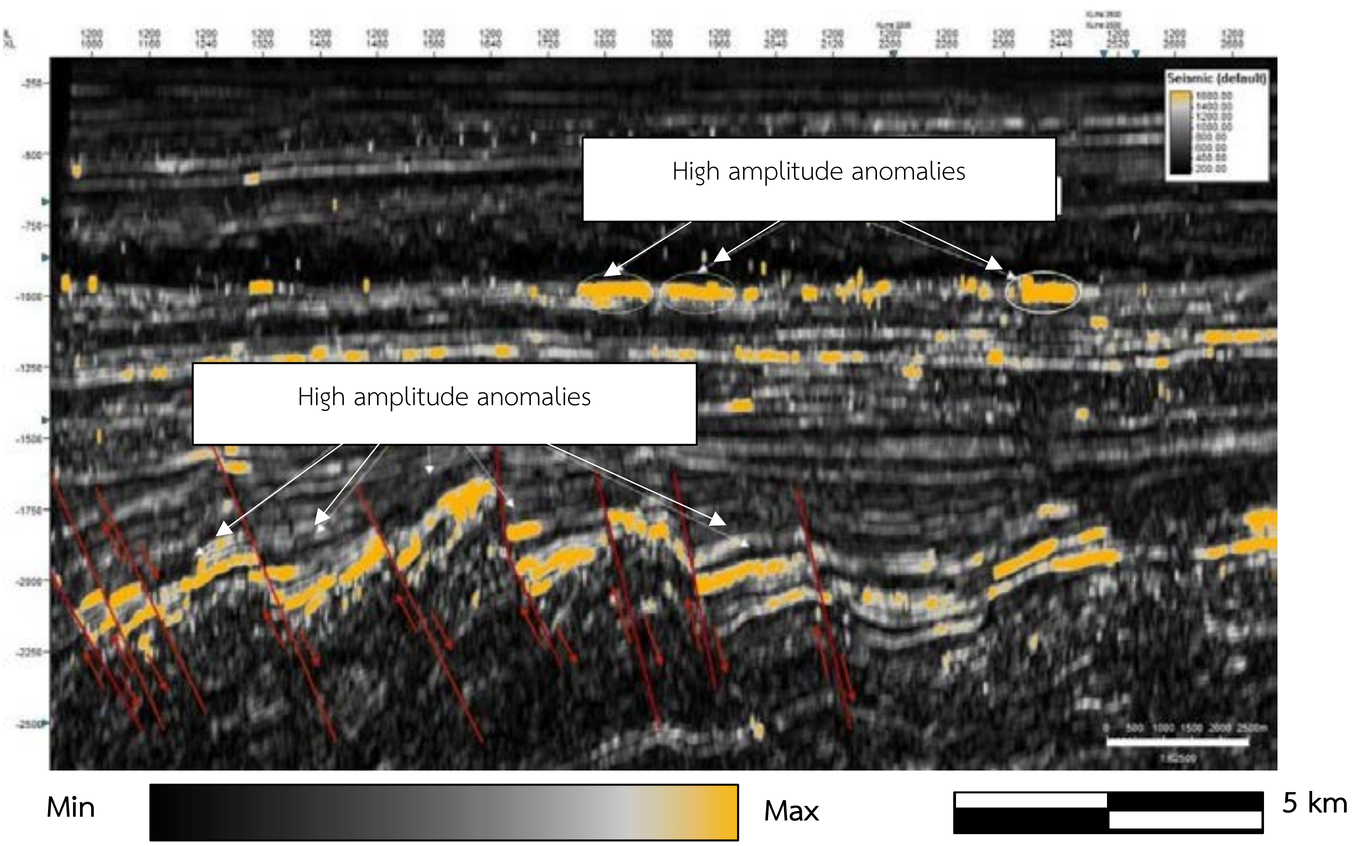


Figure 4.7 Seismic profile of inline 1200 from RMS amplitude attribute volume shows high amplitude anomalies possibly due to lithology contrast.

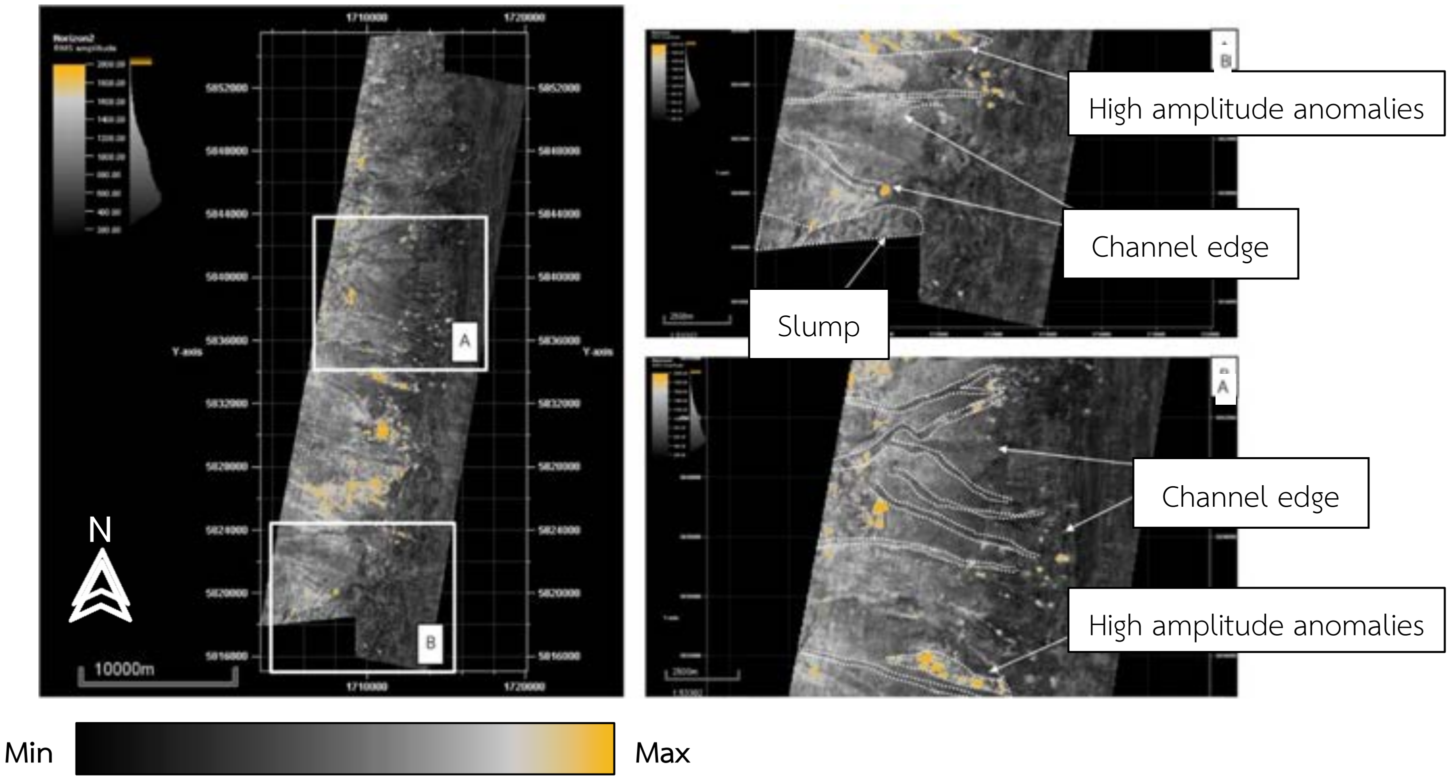


Figure 4.8 RMS amplitude attribute map on horizon2 shows channels distribution and high amplitude anomalies supposed to be sand bodied.

- **Variance attribute**

Variance attribute (edge method) is the measurement similarity of waveforms including shape and amplitude or traces contiguous over given vertical and lateral windows. This attribute was run to image the discontinuity of seismic data related to stratigraphy and fault (Figure 4.9). In this study, variance attribute is an important role for delineation channels edges and faults which show in variance attribute map (fig 4.10). Moreover, in this study area can identify the shelf edge and slump scar from high anomalies area was generated by unconformity seismic data.

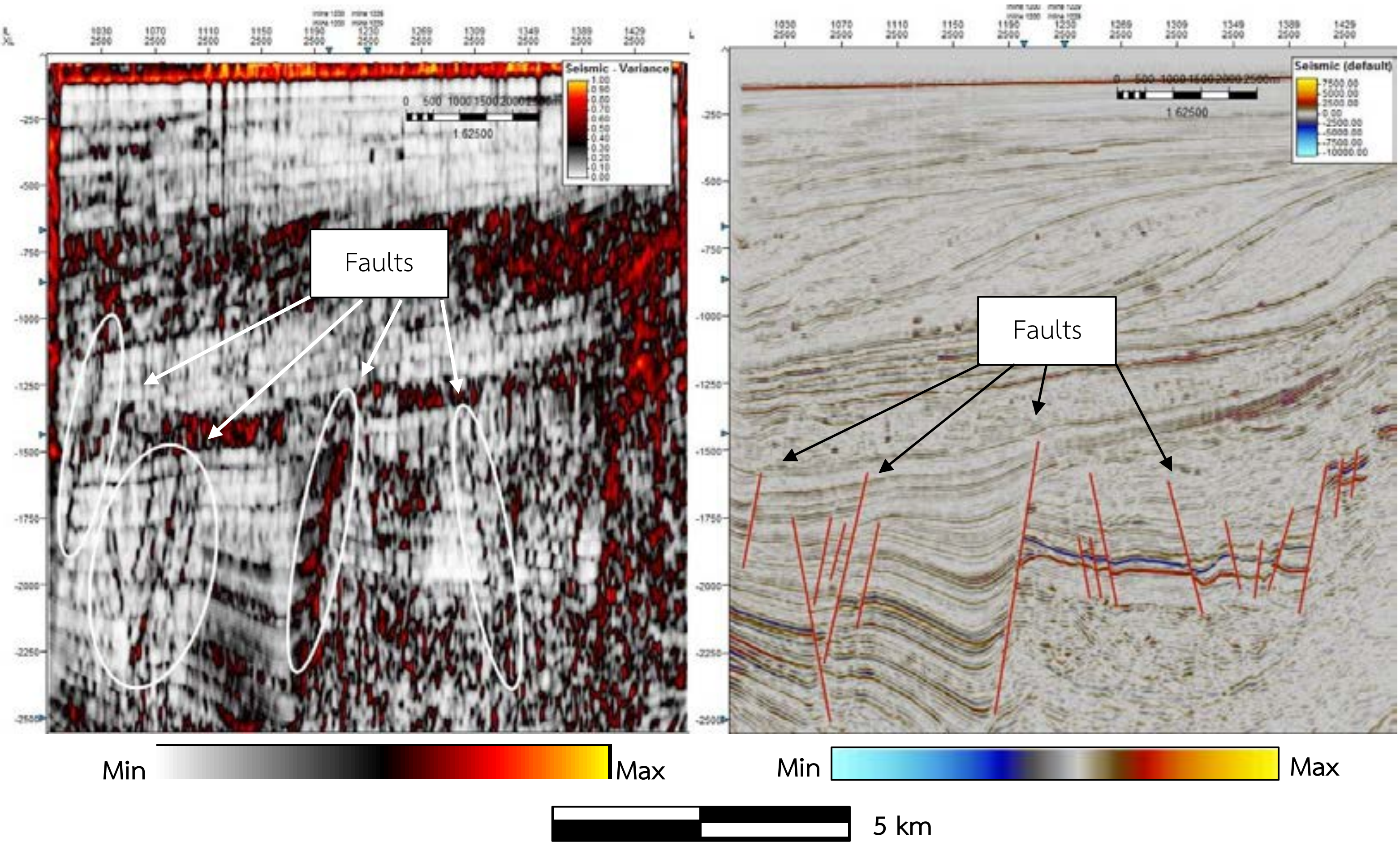


Figure 4.9 (A) Seismic profile of crossline 2500 from variance attribute volume shows high amplitude anomalies and discontinuity feature possibly faults (B) Seismic profile of crossline 2500 shows fault in the same area.

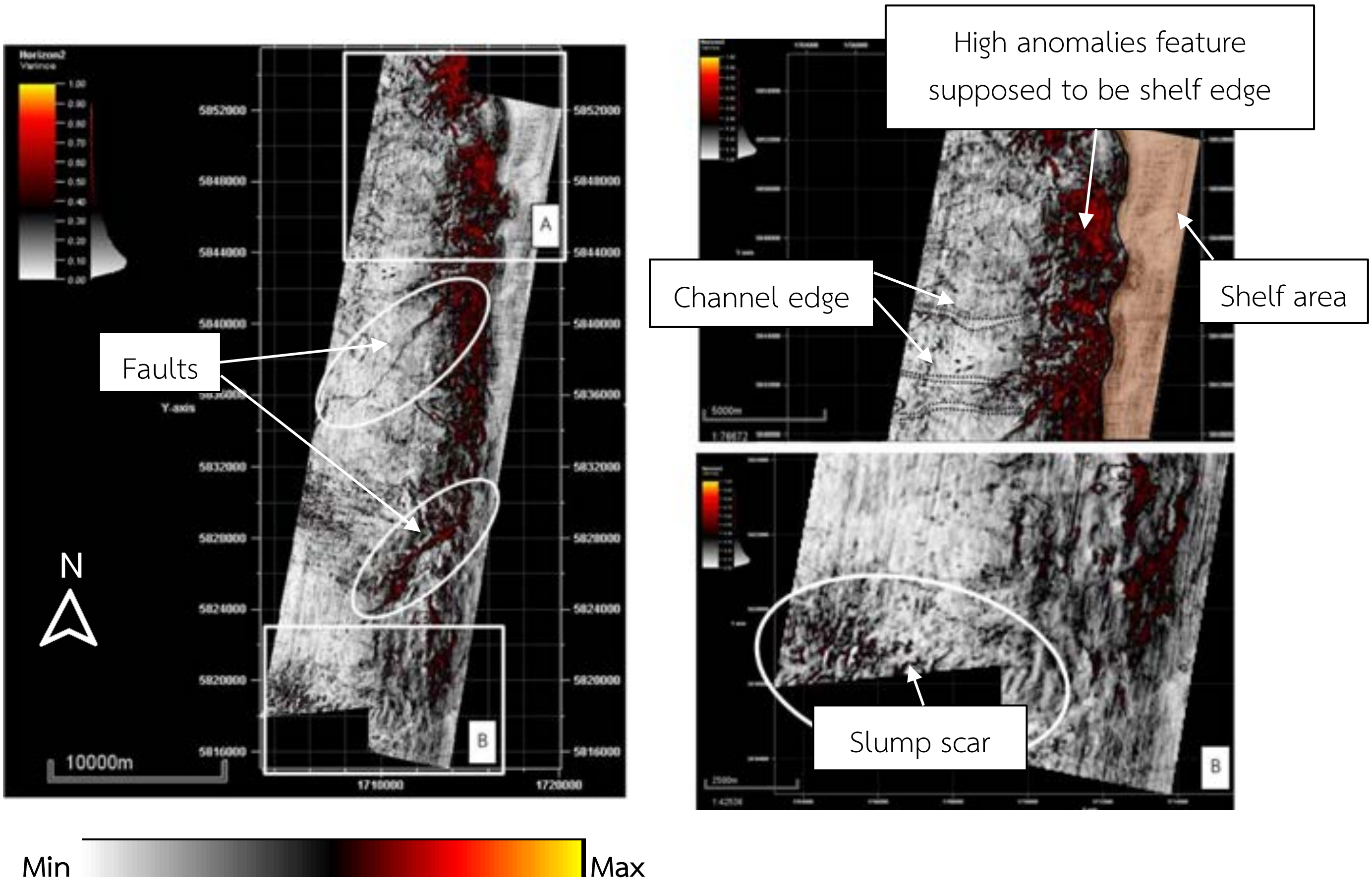


Figure 4.10 Variance attribute map on horizon2 shows discontinuity feature in high amplitude anomalies supposed to be faults, slump scar, and channel edge.

- **Instantaneous frequency attribute**

Instantaneous frequency is defined as the rate of change of phase over time. It represents the sinusoid that best matches the seismic trace in a small window about that time. This attribute usually used to enhance lateral and vertical variation of lithology, as well as a Direction Hydrocarbon Indicators (DHI) since lower frequency usually is associated with hydrocarbon occurrence. The low-frequency anomalies because of seismic waves that travel more slowly in the hydrocarbon zone. In this attribute map, the lower frequency usually is located on outside of the delta area and in vertical 2d seismic profiles, the lower frequency usually shows on low amplitude or chaotic seismic reflection (Figure 4.11). As a result, it can determine edge of the delta and slump scar areas (Figure 4.12).

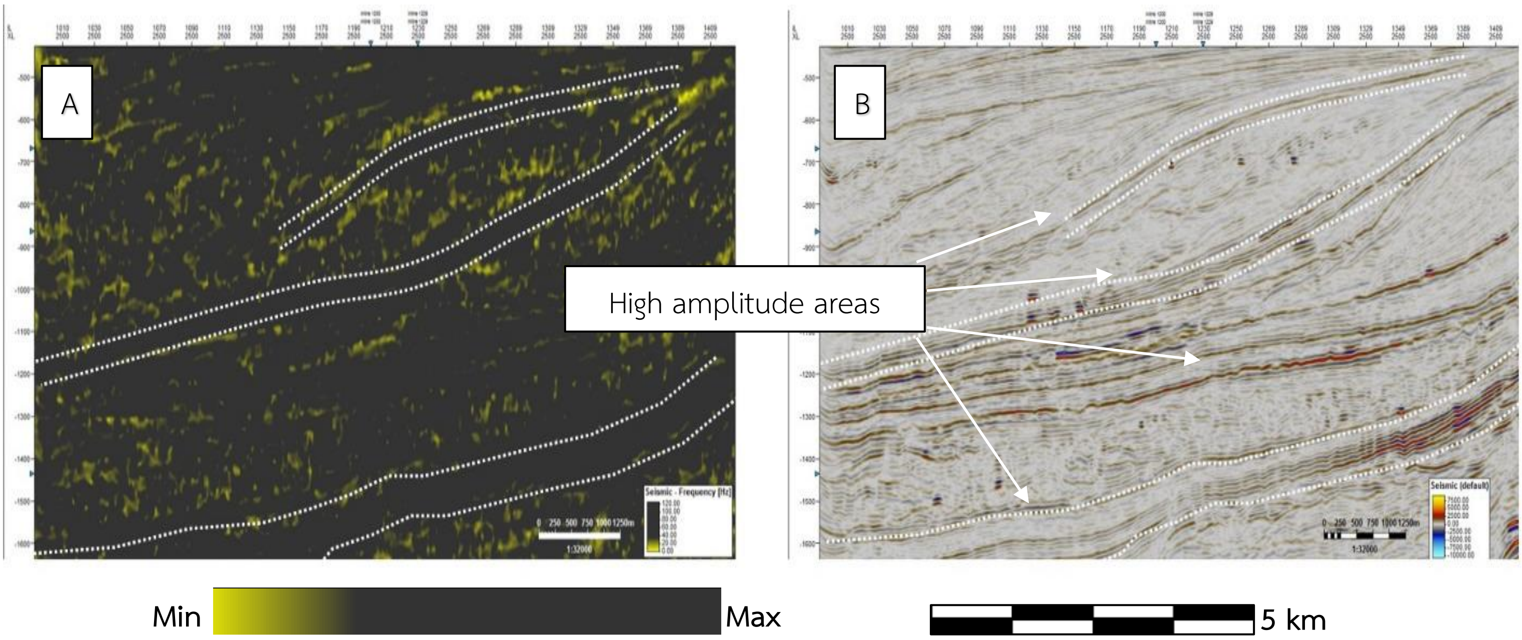
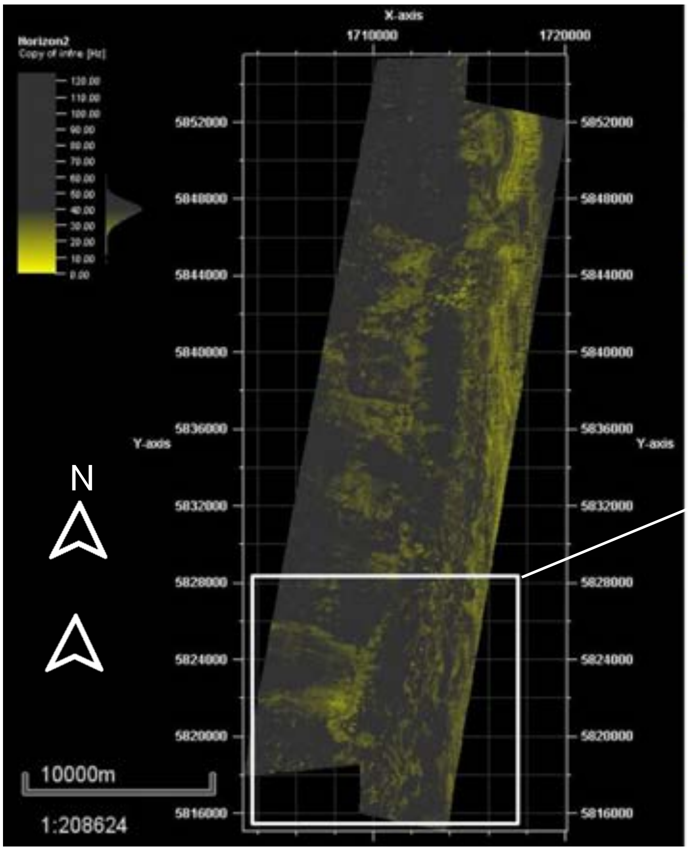


Figure 4.11 (A) Seismic profile of crossline 2500 from Instantaneous frequency attribute volume shows the low-frequency anomalies located on low amplitude areas related to the seismic profile of crossline 2500 (B).



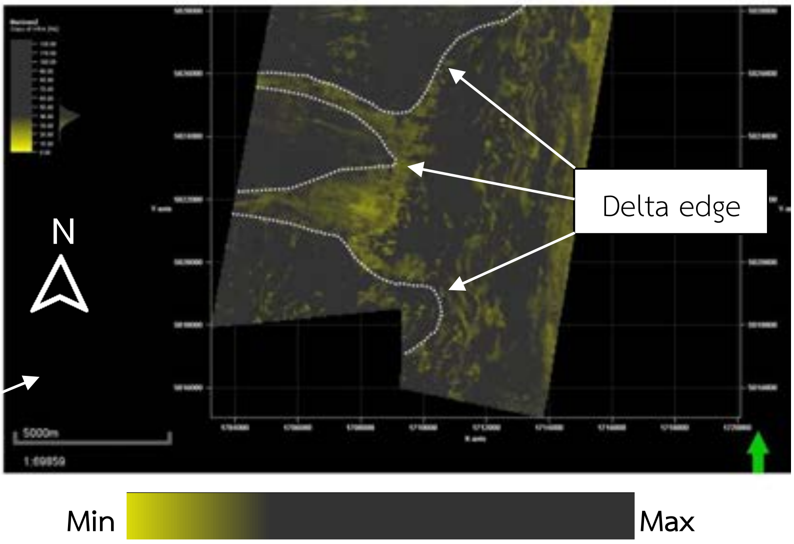


Figure 4.12 Instantaneous frequency attribute map on horizon2 which used determination of delta edge by the low frequency anomalies

- **Instantaneous frequency attribute**

Spectral decomposition was used for mapping the sand body which response each frequency in different ways. In this study, the combination of three different frequencies was blended into one volume to investigating the effect of thickness variation of the sediment layers within this study. After blending, this attribute shows great details on the geomorphology features such as slump scar, channel patterns, channel edge and especially the minor channels (Figure 4.13). The minor channels are significantly appeared in this attribute compared to other attributes. In this study, spectral decomposition attribute is a very effective tool for solving the problem of the thin-bed sediment layers. Furthermore, the smallest channel which this attribute can detect is approximately 50 meters. The colors of this attribute map depend on the blending difference frequency layers and decomposition method. According to the resulting image (Figure 4.13), red color (30 Hz) represents thick bed sediments, while blue color (55 Hz) represents thin bed sediments. The color between red and blue show the thickness between those two colors.

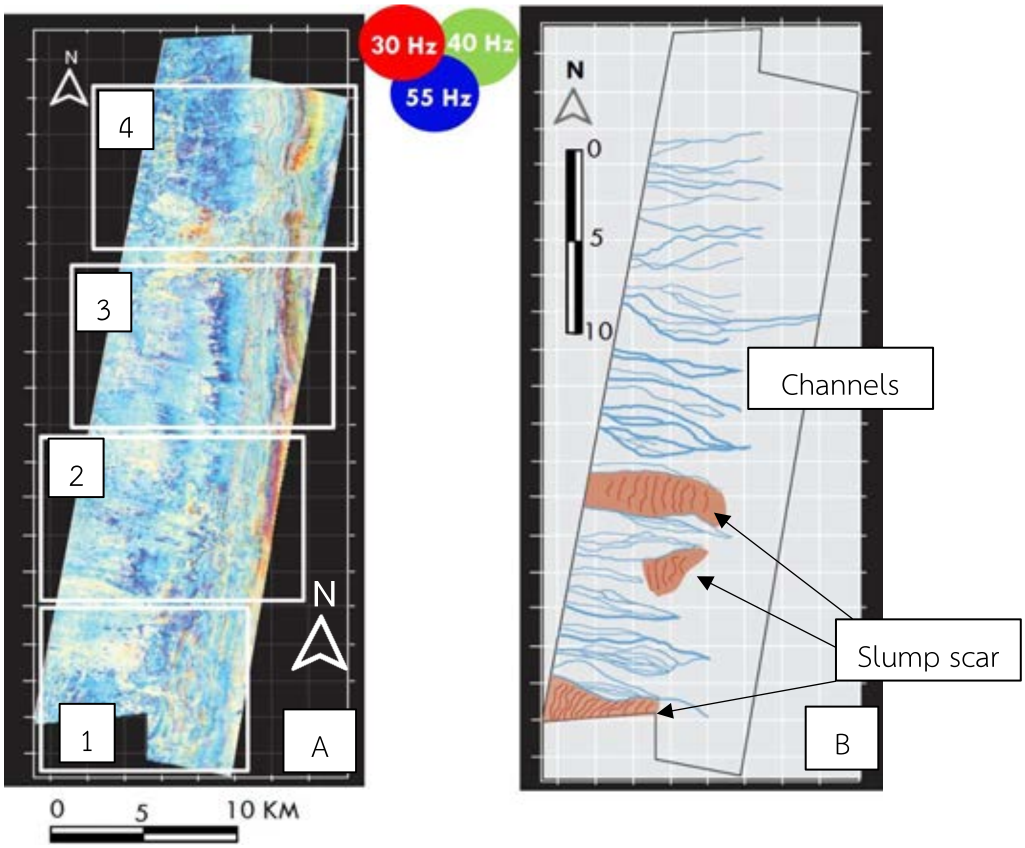


Figure 4.13 Spectral decomposition attribute map displays great details on geomorphology including slump scar and especially minor channels which are difficult to be detected in other attributes due to tuning-effect (A) compare with geomorphology feature map was imaged from this attribute.

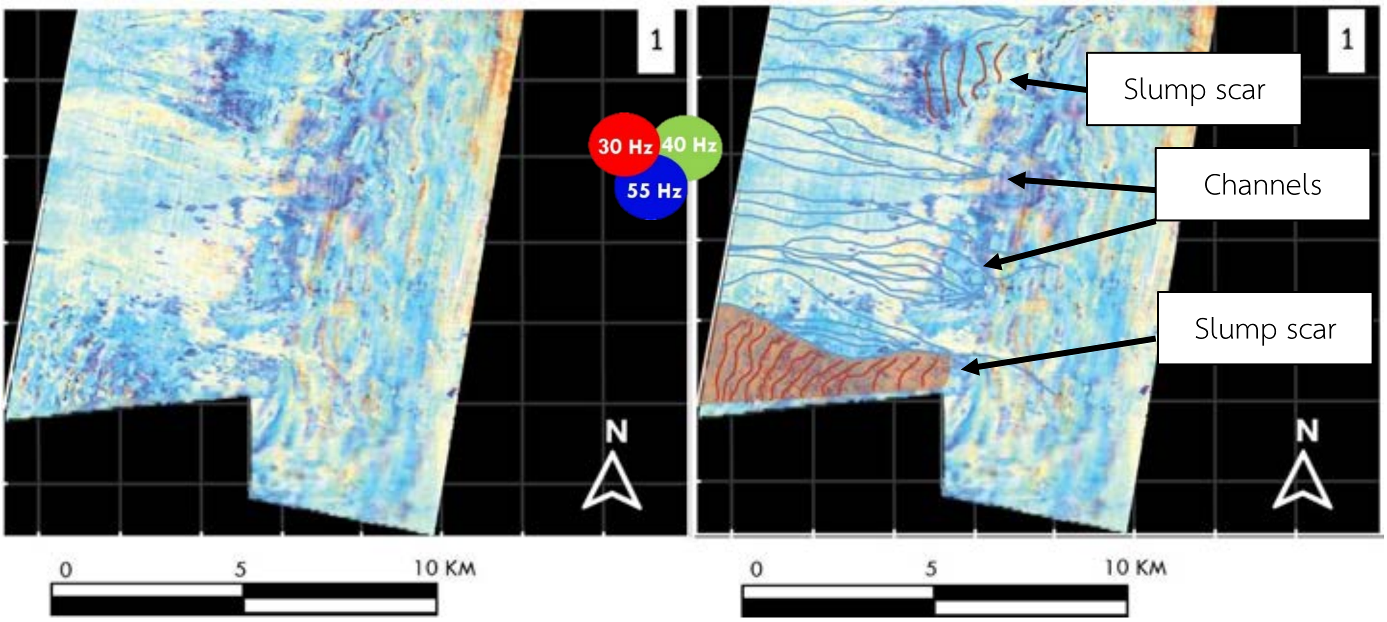


Figure 4.13.1 Spectral decomposition attribute maps on horizon 2 (1) show characteristics of channels and slump scar area.

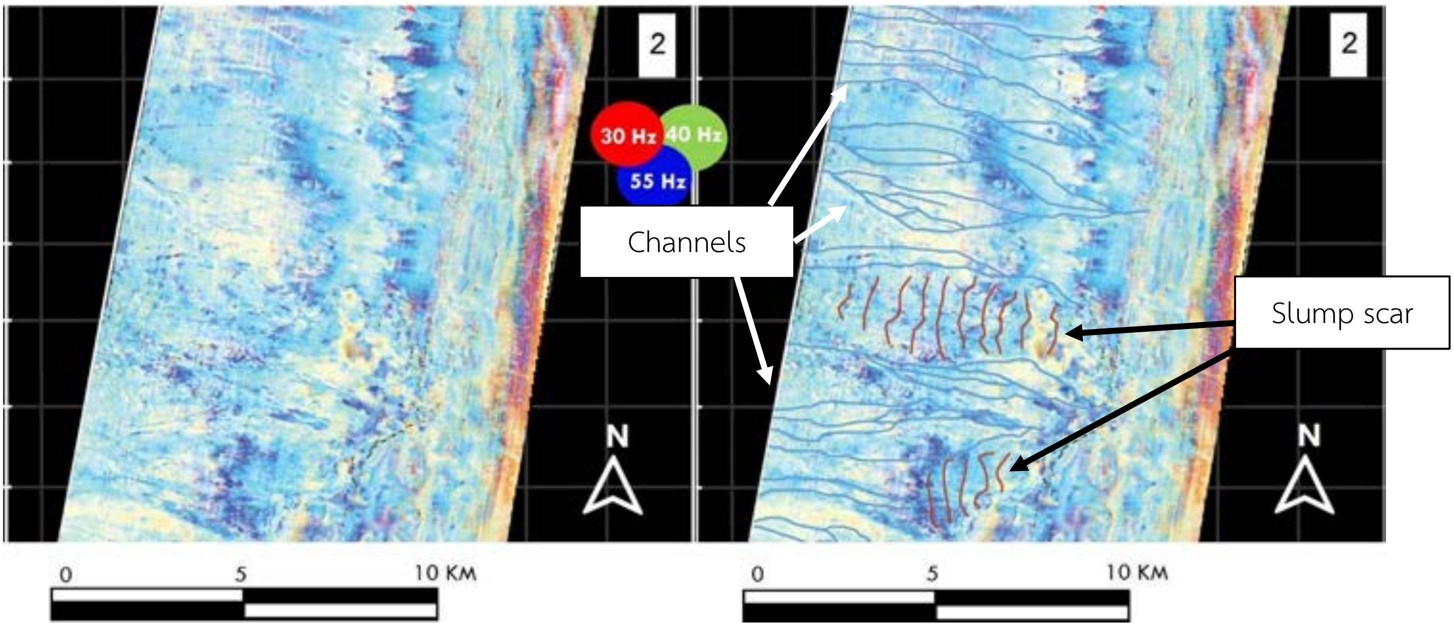


Figure 4.13.2 Spectral decomposition attribute maps on horizon 2 (2) show characteristics of channels and slump scar areas.

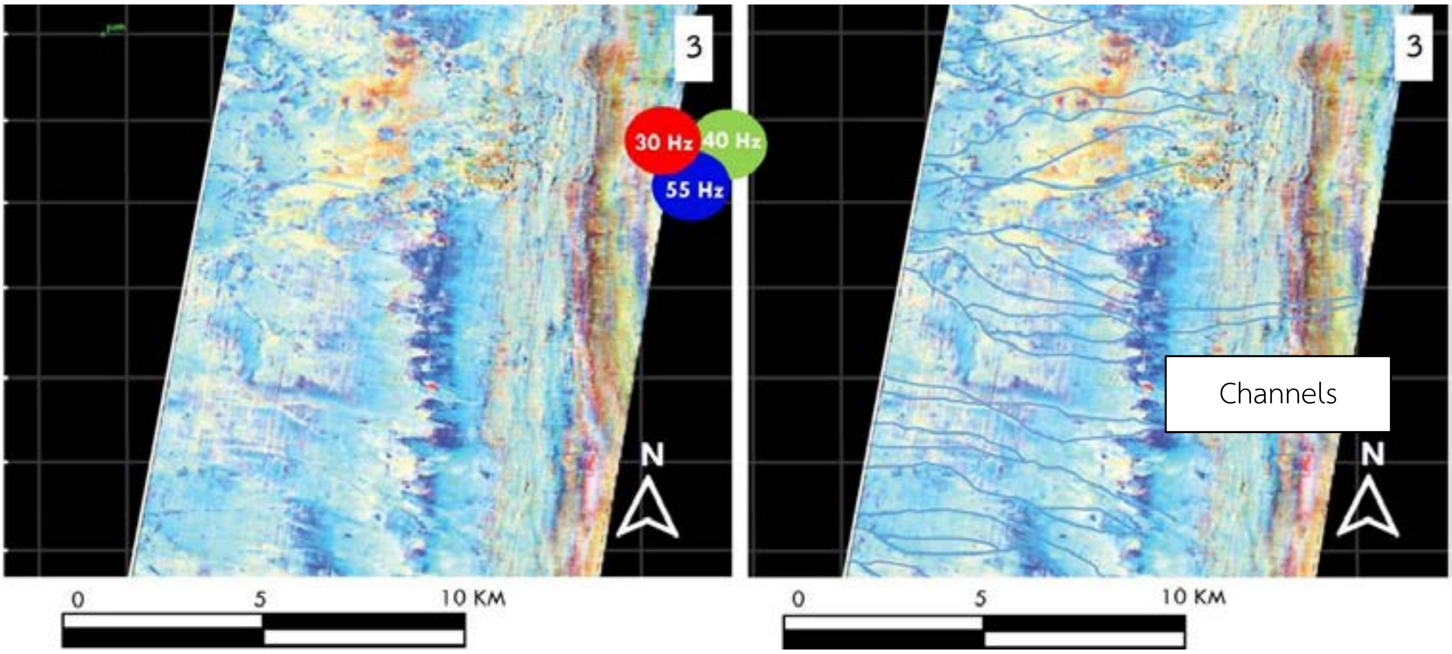


Figure 4.13.3 Spectral decomposition attribute maps on horizon 2 (3) show characteristics of channels.

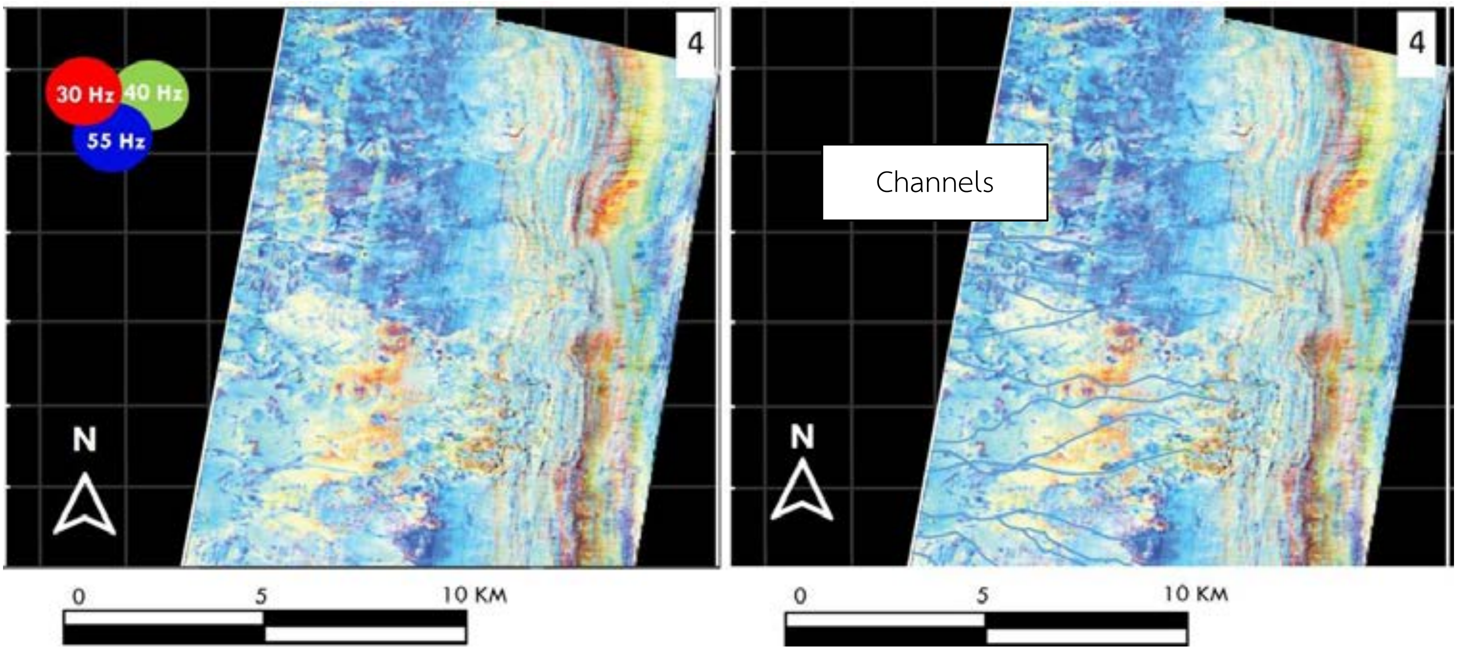


Figure 4.13.4 Spectral decomposition attribute maps on horizon 2 (4) show characteristics of channels

4.3 Seismic geomorphology interpretation

One of the key objectives in this study is image seismic geomorphology from multiple attributes. The seismic attributes show different kinds of geomorphology features. Consequently, the combination of each attribute result can help for interpretation of the paleo-depositional environment and the characteristics of geomorphology features.

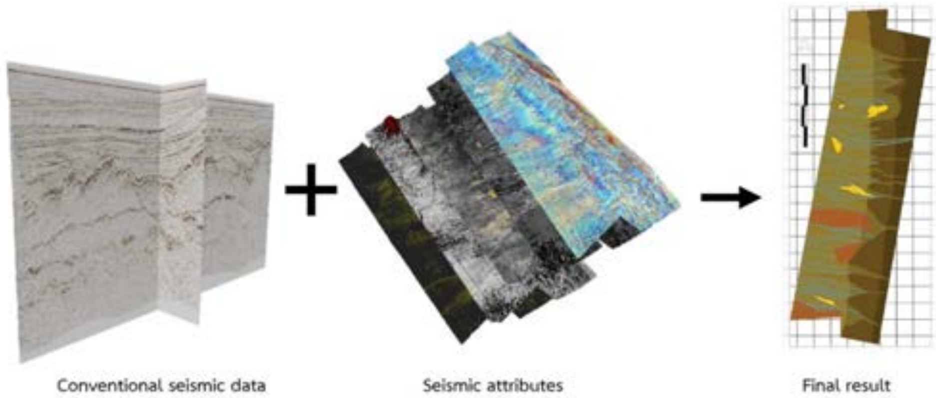


Figure 4.14 Geomorphology interpretation using conventional seismic data and seismic attributes to image seismic geomorphology mapped the surface of the study area.

1. Channels

In this study area, channels are the most dominant geomorphology feature. The main characteristic of channels is straight to low sinuous channels associated sandbars. The variation of channel sizes can be divided into 2 types including major channels and minor channels.

1.1 Major channels (Width: approximately 150 – 500 meter) can be detected by all seismic attributes and clearly observed in RMS amplitude, sweetness and variance attributes. Almost all of them are straight to low sinuosity channels. Some areas can observe linkage and cutting points with minor channels.

1.2 Minor channels (width: approximately 50 – 150 meter) can be detected in some attributes which have high resolution such as RMS amplitude and especially spectral decomposition attribute that can be detected some channels which cannot be detected in other attributes due to tuning-effect. Most of them have the sinuosity and connectivity channels more than the major channels.

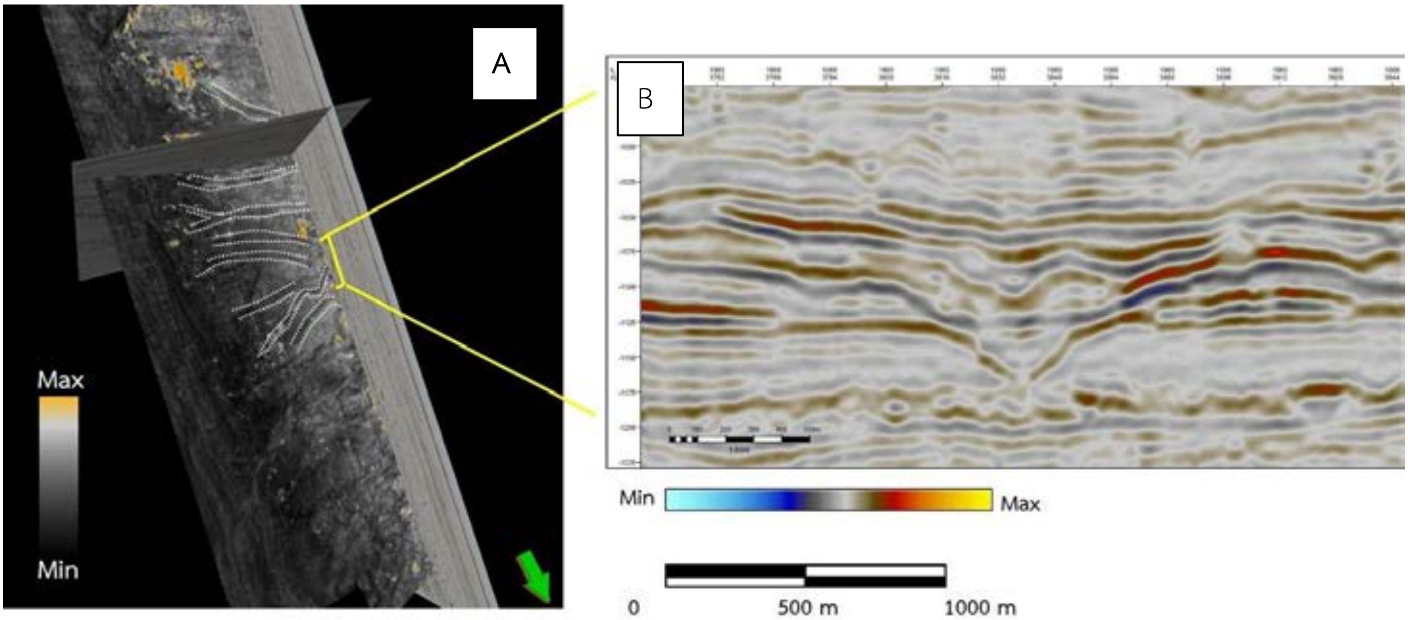


Figure 4.15 (A) Characteristics of channel in RMS amplitude attribute 3D map and (B) 2D seismic profile.

2. Slump scars

Slump scars are evidence of downslope movements of sediments which display as high amplitude anomalies in seismic data due to the difference of lithology. In this study area, slump scars are usually detected near the deltas and channels. This feature can be observed in some attributes such as RMS amplitude attribute, sweetness attribute, variance attribute, and especially spectral decomposition attribute.

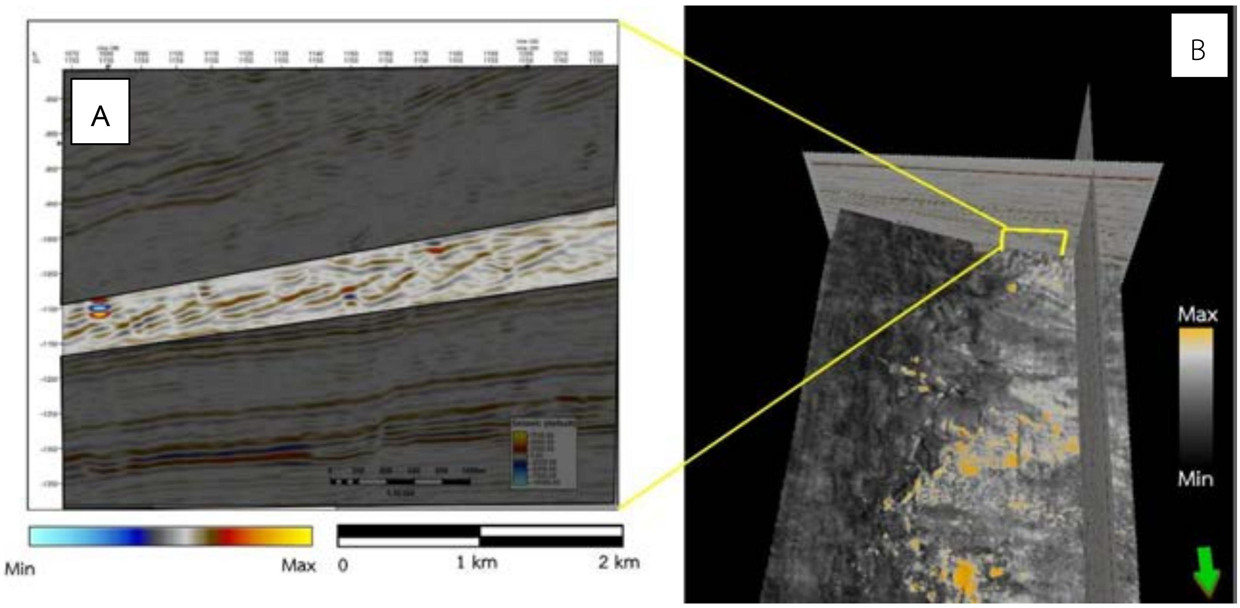


Figure 4.16 (A) Characteristics of slump in 2D seismic profile and (B) RMS amplitude attribute 3D map.

3. Sand bars

Sand bars in this study including point bars, mid-channel sand bars, and levees. This geomorphology feature displays as high amplitude anomalies in seismic data because of the contrast between lithology of sand which filled in channels and mud filled nearby delta. This feature is usually associated with channels. Seismic attributes that show great details of this geomorphology feature are RMS amplitude attribute and sweetness attribute.

After seismic geomorphology interpretation, this study images seismic geomorphology map into 2 horizons including horizon 2 (Figure 4.17) and top Pliocene horizon (Figure 4.18)

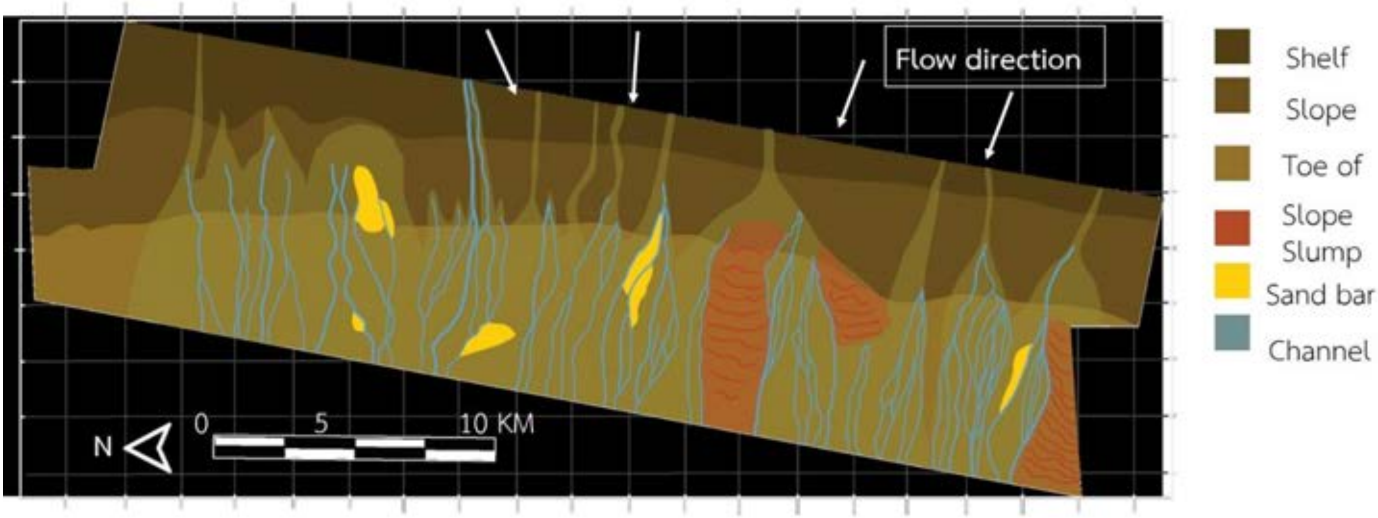


Figure 4.17 Seismic geomorphology map on the horizon 2

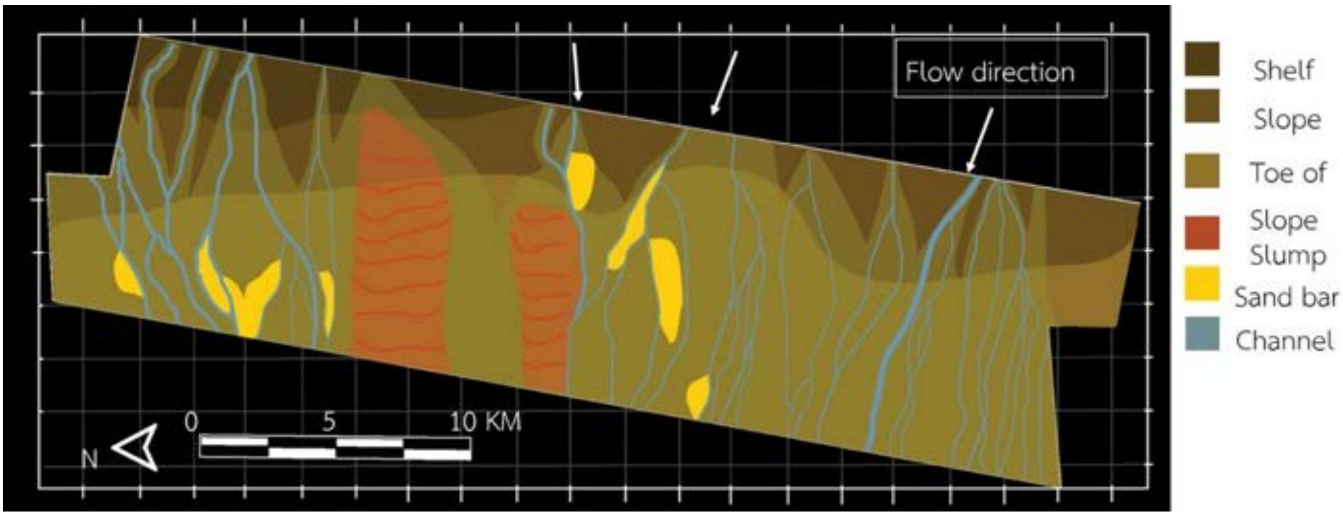


Figure 4.18 Seismic geomorphology map on the top Pliocene horizon

CHAPTER 5

Discussion and Conclusion

5.1 Depositional environment

The seismic geomorphology maps within the study area show geomorphology features including shelf area, slope, deltas, channels, sand bars, and slump scars. The characteristics of channels that have flow directions from East to West and show straightly to low sinuosity channels are should be controlled by the slope system. According to seismic geomorphology maps (fig 4.17- fig 4.18) show depositional of deltas which have many lines source of delta associated with multiple channels and slump, it can be supposed that depositional environment in this study area is slope aprons (Galloway, 1998) which shows in figure 5.1.

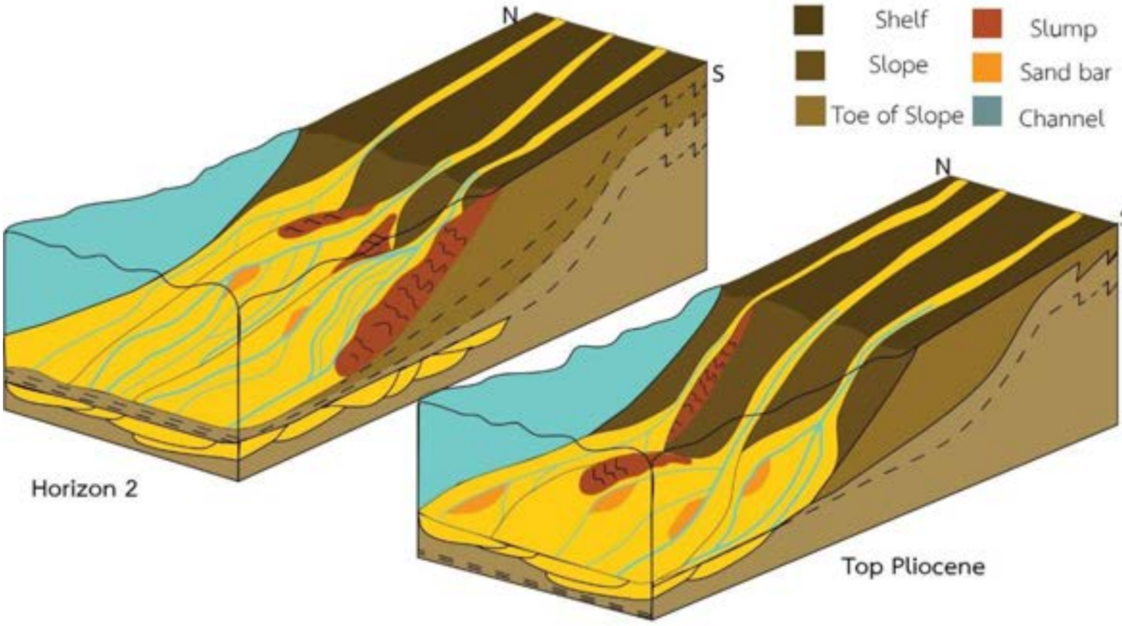


Figure 5.1 Depositional environment models of horizon 2 (left) and top Pliocene horizon (right)

According to the comparison of top Pliocene horizon and horizon 2 depositional environment models (Figure 5.1), the older horizon or top Pliocene horizon (Figure 4.1) has sand bars more than horizon 2 because of increasing slope angle and decreasing accumulation area in horizon 2. After the top Pliocene period, the sedimentary supply is rise causing horizon 2 increase shelf edge to seaward. The previous study of the depositional environment in nearby area has similar depositional environment in the same time (Baur and Jan Robert, 2012) and shelf edge can be correlated with this study area (Figure 5.2).

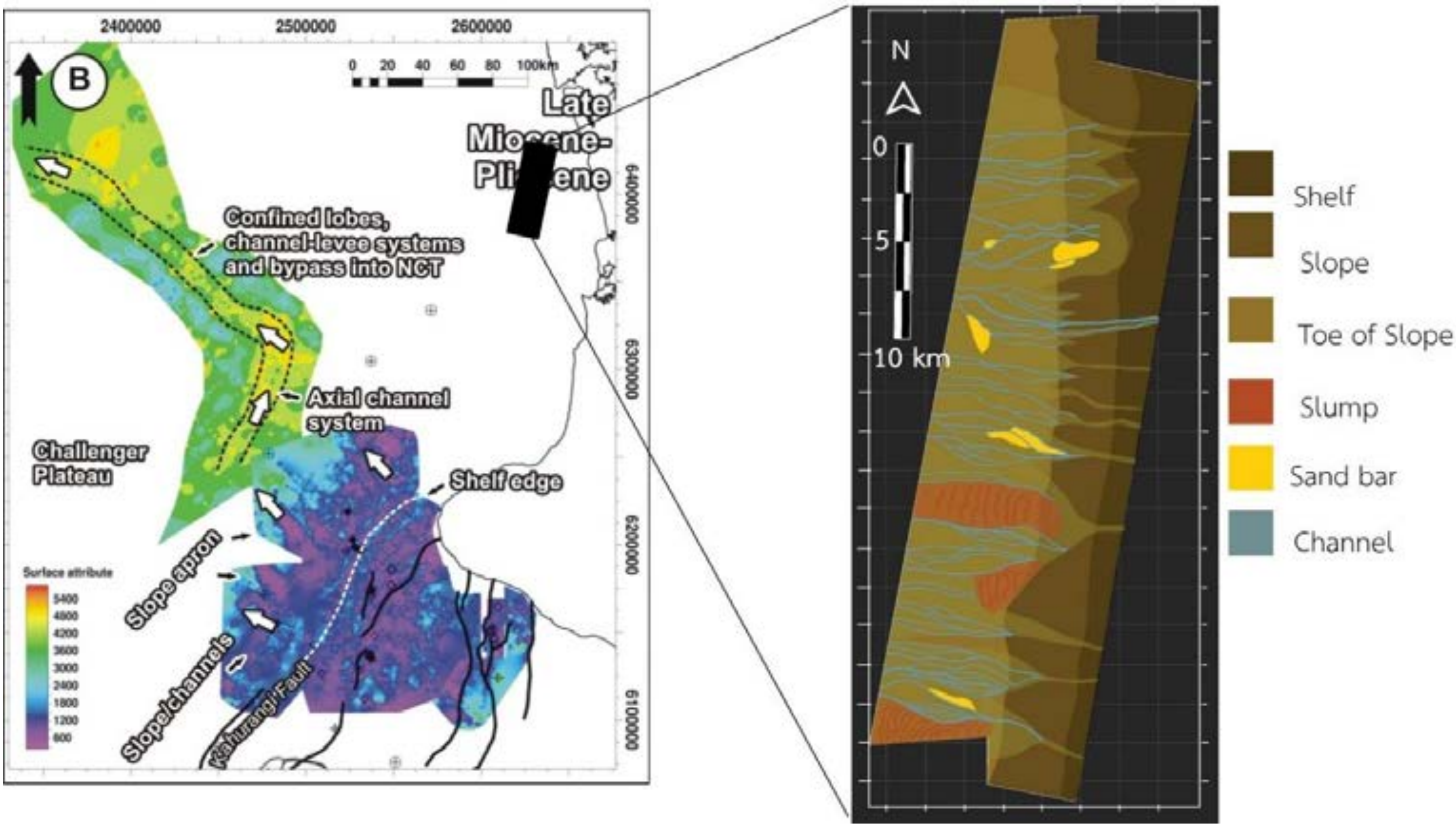


Figure 5.2 Depositional environment in nearby area (left) and shelf edge (Baur and Jan Robert, 2012) that can be correlated with depositional environment model of horizon 2 (right)

5.2 Seismic attributes

According to this study, using seismic attribute can extract more information from the seismic data such as geomorphology features and especially small-scale channels. In this study, the ability of seismic attributes can be divided into two types including lithology detection and structure detection. The first type seismic attributes which is good for observing the difference of lithology including RMS amplitude, sweetness, instantaneous frequency and spectral decomposition attribute. These seismic attributes can provide sand distribution imaging, sand body geometry (edge), and hydrocarbon zone. By using RMS amplitude and sweetness attribute, the detected features are easily observed as high amplitude anomalies causing by the contrast between sand filled in channels or sand bars and mud filled in the nearby delta. Therefore, these seismic attributes are effective tools to determine major channels and image depositional environment. Moreover, sometimes the high amplitude anomalies in these seismic attributes and the lower frequencies which display on instantaneous frequency attribute can relate with hydrocarbon fluid in pore space such as gas.

The spectral decomposition attribute is an important role in solving the tuning effect that can detect minor channels which not display in the other seismic attributes. The second type seismic attribute includes variance attribute which good to detect discontinuity seismic data or geological structure. The detected features are easily seen as probably be faults, slump scars, and channel edges.

5.3 Conclusion

According to this study, seismic geomorphology of Giant Foresets formation including channels, deltas, sand bars, and slump scars. The domain geomorphology feature is channel which have straightly to low sinuously pattern that corresponds with slope aprons environment. Moreover, theses feature such as sand bar and delta are well displayed in RMS amplitude, sweetness, instantaneous frequency and spectral decomposition attribute. In addition, geological structures such as faults are clearly displayed with variance attribute.

From comparison the ability of seismic attributes used in this study, it can be divided into two major groups according to their dominant detected features; lithology and structure detection. In addition, the difference seismic attributes have different resolutions to observe seismic geomorphology features. For example, the smallest width channels that RMS amplitude and sweetness attribute can detect is 150 Meter. In the other hand, spectral decomposition can detect minor channels that have width range approximately 50 – 150 Meter. As a result, the combination of seismic attributes analysis can help the interpreter to extract information from conventional seismic data which can support the seismic geomorphology and depositional environment interpretation.

The slope aprons depositional environment derived from geomorphology features that can be observed by seismic attributes in this study area. The main feature such as channels pattern, delta shape, sand bars distribution, and slump scars are common for this environment.

For further study, this area can be used to study more seismic attributes to extract useful details such as AVO analysis or pre-stack seismic inversion and knowledge of using seismic attributes might be beneficial for applying with the deeper petroleum explorations either.

References

Bache, F., Mortimer, N., Sutherland, R., Collot, J., Rouillard, P.,Stagpoole, V., Nicol, A., 2014. "Seismic stratigraphic record of transition from Mesozoic subduction to continental breakup in the Zealandia sector of eastern Gondwana." Gondwana Res. 26, 1060–1078

Balance, P.F. 2009. New Zealand geology: illustrated guide. Geoscience Society of New Zealand GSNZ Miscellaneous Publication 148.

Baur, and Jan Robert. "Regional Seismic Attribute Analysis and Tectono-Stratigraphy of Offshore South-Western Taranaki Basin, New Zealand." Handle Proxy. Universidade da, January 1, 1970.

Bradshaw, J.D., Andrews, P.B, and Adams, C.J. 1981. "Carboniferous to Cretaceous on the Pacific margin of Gondwana: The Rangitata phase of New Zealand." In Cresswell, M.M. and Vella, P. (eds.), Gondwana Five, pp. 217-221. Balkema, Rotterdam.

EPPO: Energy Policy and Planning Office, Ministry of Energy, Thailand, n.d. http://www.eppo.go.th/index.php/th/energy-information.

Galloway, W. E. "Siliciclastic Slope and Base-of-Slope Depositional Systems: Component Facies, Stratigraphic Architecture, and Classification." AAPG Bulletin, 82 (1998), 1998

Hansen, Kamp, Peter J.J., and Rochelle J. "Evolution of the Giant Foresets Formation, Northern Taranaki Basin, New Zealand." Handle Proxy. Universidade da Coruña, February 18, 2010.

King, G.P. Thrasher, "Post Eocene Development of Taranaki Basin, New Zealand." DSIR Geology and Geophysic. Lower Hutt. New Zealand. 1996.

McAlpine, A., 2000: "Basin modelling of oil plays northwest of Maui: results, constraints and calibrations." 2000 New Zealand Petroleum Conference Proceedings.

New Zealand Petroleum Basins. New Zealand Petroleum & Minerals, Ministry of Business, Innovation and Employment, 2014.

Peter R. King (2000). "Tectonic reconstructions of New Zealand: 40 Ma to the Present." New Zealand Journal of Geology and Geophysics, 43:4, 611-638,

Petroleum Engineering and Exploration Departments, Shell BP Todd Oil Services Ltd, 1981: "Well resume Tangaroa-1 PPL 38038 offshore." Ministry of Commerce, New Zealand. Unpublished Petroleum Report PR 793.

Sarma M., R. Kellet, S. Pryde, and G. Reynolds, 2014, Petroleum Systems Modelling: "Charge Evaluation of the Eltham Area (PEP 51150), Onshore Taranaki Basin": New Zealand Energy Corp, Wellington, New Zealand, 6 p.

Satarugsa P. Exploration geophysics. Khon Kaen: Department of Geotechnology, Faculty of Technology, Khon Kaen University; 2007

Sutherland, R, King, P.R., and Wood, RA, 2001. "Tectonic Evolution of Cretaceous Rift Basins in South-Eastern Australia and New Zealand: Implications for Exploration Risk Assessment." In Petroleum Exploration Society of Australia. Eastern Australasian Basins Symposium, pp. 3-13. Carlton, Australia: Australasian Institute of Mining and Metallurgy.

Todorovic-Marinic1, Dragana. "Advanced Seismic Techniques Help in Characterizing a Challenging Jean Marie Carbonate Play, NE Briti." CSEG RECORDER Magazine, October 1, 2011.

Uruski, C., and Wood, R. 1991. "A new look at the New Caledonia Basin, an extension of the Taranaki Basin, offshore North Island, New Zealand." Maine and Petroleurn Geology 8:pp. 379-391.

Uruski, C.; Baillie, P. 2004: "Mesozoic evolution of the Greater Taranaki Basin and implications for petroleum prospectivity". APPEA Journal V 44(1) pp. 385-396.

Uruski, C.I. 2007. Geological setting, "In Seismic interpretation Report Deepwater Taranaki." pp. 7-21. Wellington, New Zealand; Ministry of Business, Innovation and Employment.

Uruski, Chris.2014. "The Contribution of Offshore Seismic Data to Understanding the Evolution of the New Zealand Continent." Geological Society, London, Special Publications, vol. 413, no.1