# CHAPTER 1

# Introduction

Seismic data analysis is a common and important tool to interpret and image the sub-surface. Nowadays the 3D seismic cubes are used to map the geological subsurface structures and to find optimum locations for drilling. Along with seismic data, well data provides ground trothing. Seismic inversion methods are finally used to determine rock and fluid properties and other characteristics of the subsurface using a simulation model.

Seismic interpretation is a technique to decipher geology from seismic data. Depositional environments, structures, and stratigraphy can be interpreted. The objectives of a seismic interpretation in petroleum geology can widely vary from identifying the petroleum system to the estimation of reservoir properties; the primary goal is in most cases a prediction of geologic information such as true reservoir depth, lateral extent, thickness, porosity, etc.

In general, seismic interpretation can be subdivided into two categories: quantitative and qualitative. In quantitative interpretation, physical parameters are extracted from pre-stack seismic data and for example amplitude versus offset (AVO) inversion can be performed to predict reservoir characteristics. In turn, qualitative interpretation is more a conventional and widely used technique that includes the mapping of laterally consistent reflectors and discontinuous features in various scales (space & travel time). Although much of the recent advancements in seismic data acquisition and processing use mathematically intensive techniques, the interpretation technique is still (mostly) a visual process, highly relying on the background geologic knowledge of the study area and the skill of pattern recognition of the interpreter giving rise to greater uncertainty in the exploration process. The mapping is done based on the geological logic to find out the probable hydrocarbon accumulation and the best location for the well drilling for production. Quantitative interpretation based on inversion techniques, in turn, can be a good tool to validate the geologic interpretation in order to reduce uncertainty and risk in predicting future hydrocarbon potential in prospect evaluation.

Around forty years ago, geophysicists began to introduce seismic inversion techniques, which aim to transform seismic reflection data into a quantitative rock-property description of a reservoir (Russell and Hampson, 2006). In last two decades the interest in seismic inversion techniques grew steadily because seismic inversion can provide some additional information from seismic data such as acoustic impedance (Veeken and Silva, 2004). Inversion methods can be used for well planning, reservoir characterization and monitoring changes in rock properties in the reservoir during fluid injection or production (Gavotti, 2014). It is also possible to estimate the impedance of the rocks from well logs (Alves et al., 2014) The inversion approaches can be either pre-stack or post-stack, and inversion methods are deterministic or probabilistic (Veeken and Silva, 2004). Old inversion techniques transformed the seismic data into P-impedance to predict the lithology and porosity. However, these predictions were often inaccurate and somewhat ambiguous because P-impedance is sensitive to lithology, fluid properties and porosity effects, posing difficulties in understanding the influence of each phase (Russell and Hampson, 2006). So, performing a full elastic inversion is required to get less ambiguous and influenced inversion results (Russell and Hampson, 2006).

The inversion for elastic properties can be treated as a deterministic or stochastic problem (Bosch et al., 2010). Various techniques are available of deterministic seismic inversion but there is no clear consensus that any particular inversion technique or algorithm is better than the others (Simm and Bacon, 2014). This study will emphasize on post-stack model-based deterministic inversion methods. It is the most popular broadband inversion technique, which is readily available in commercial software such as Hampson-Russell.

Model-based inversion techniques use a repetitive forward modeling and comparison procedure (Veeken and Silva, 2004). This procedure needs an initial or reference model that is verified against the interpreted model. The starting model might be interpolated well data or a general trend model based on geological knowledge.

Model-based inversion typically uses constraints or boundaries to suppress impedances which are too far from the initial model and geologically impossible. Constrains may be either hard boundaries where the solution is not allowed to cross, or soft constraints, whose vicinity a penalty is added to the synthetic error that is being minimized. The final inversion result is a solution in which the impedance model has been verified against the seismic traces and the errors calculated and minimized (Simm and Bacon, 2014).

After calculating the acoustic impedance the inversion is largely accomplished. The porosity can also be estimated as well as a porosity model can be derived from the acoustic impedance. A lithology prediction is also possible from the acoustic impedance and porosity estimation.

## 1.1 Study Area

The Karewa field is located in the Northern Taranaki Basin (Figure 1-1). The Taranaki Basin lies offshore on the north-west side of the North Island of New Zealand. It is the only hydrocarbon producing basin in New Zealand. It produces from about 20 fields, from the giant Maui gas-condensate field (original gas reserves 3.4 tcf), to a number of small oil and gas fields of about 10 mmboe (New Zealand Petroleum and Minerals, 2016). The producing fields are shown in Figure 1-2.

### 1.1.1 The Geological Overview of the Taranaki Basin

The Taranaki Boundary Fault System extends from the city of Nelson in the South Island to the west of Kawhia Harbour on the North Island (Figure 1-2). It follows the Rangitata Orogeny structural trends, and defines the boundary of the Taranaki basin in the east. In the west, the Challenger Plateau defines the south-western boundary of the Taranaki basin. The sedimentation history extends from the Upper Cretaceous to the present day. Since the origin of the basin, its tectonic activity has been continuous and some faults are still active. The active plate margin setting of New Zealand and major changes in the direction and amplitude of stresses through have strongly affected the development of the Taranaki basin. The basin has a complex fault style in the eastern part (Figure 1-3). At the western side of the basin, older Pre-Oligocene structures have undergone intense complex faulting; however, faults are reverse and normal when mapped at Oligocene level (Knox, 1982).

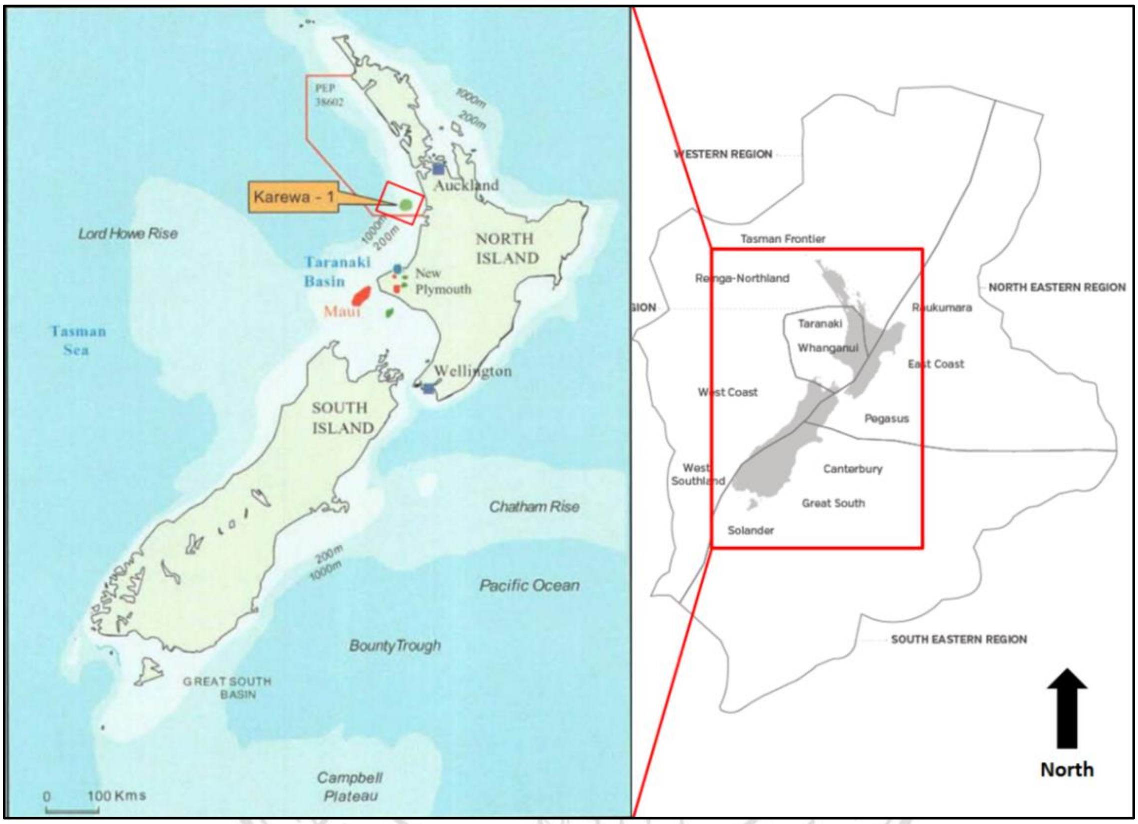

Figure 1-1: Location of Karewa field, offshore New Zealand (modified from Conoco Northland Ltd., 2002-2003)

According to Knox (1982), the Taranaki Basin can be subdivided into three units based on the deformation style (Figure 1-4). The western unit is 200 kilometers wide, and is largely stable since late Eocene. It coincides with parts of the so called Western Platform. The Southern Unit is predominated by reverse faulting and inversion. It includes the South Taranaki Graben and the parts of the Western Platform. The Northern Unit is formed by continuous subsidence defined by numerous normal and oblique strike-slip faults.

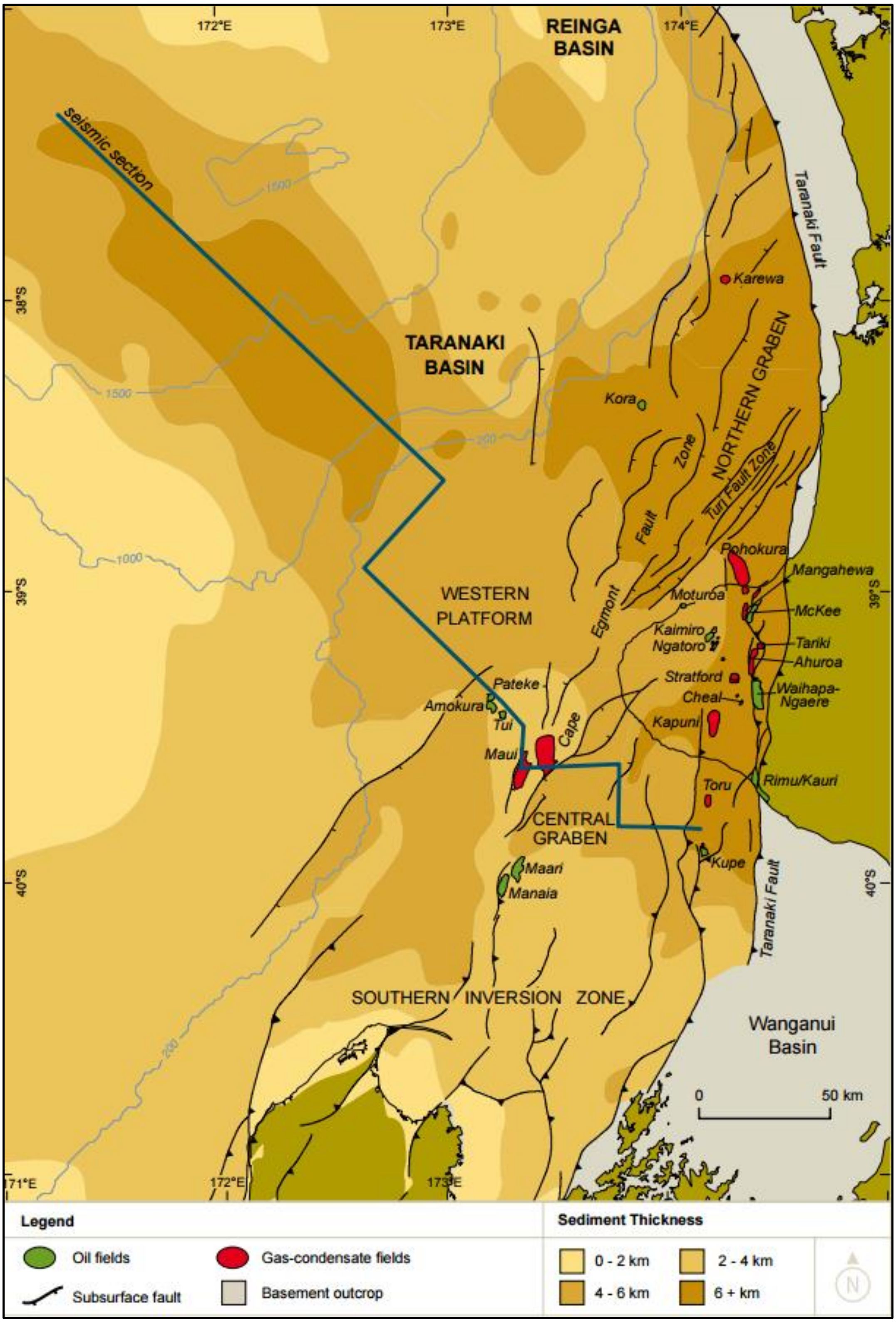

Figure 1-2: Producing fields of Taranaki Basin (New Zealand Petroleum and Minerals, 2016)

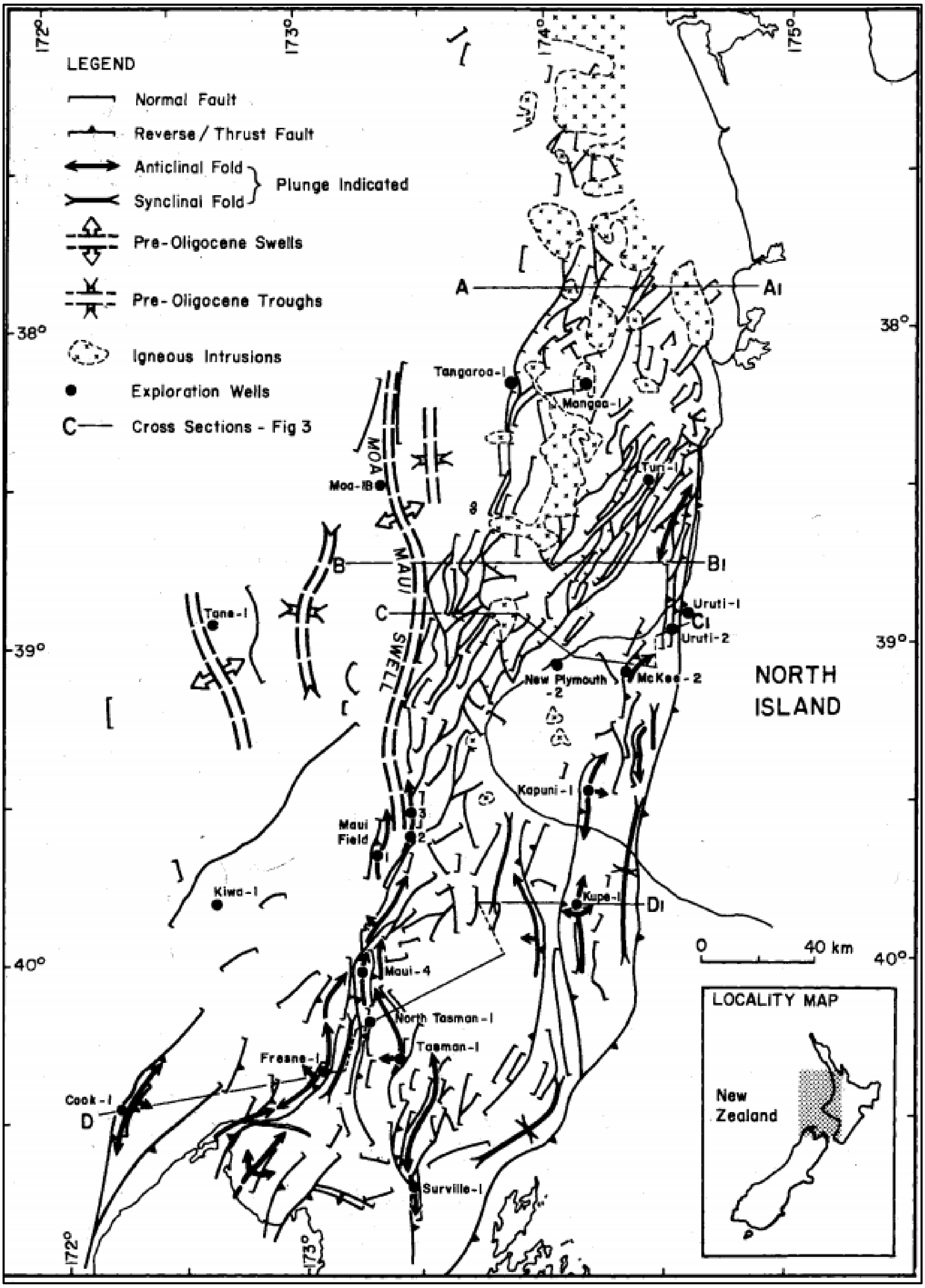

Figure 1-3: Structures features within Taranaki Basin (Knox, 1982)

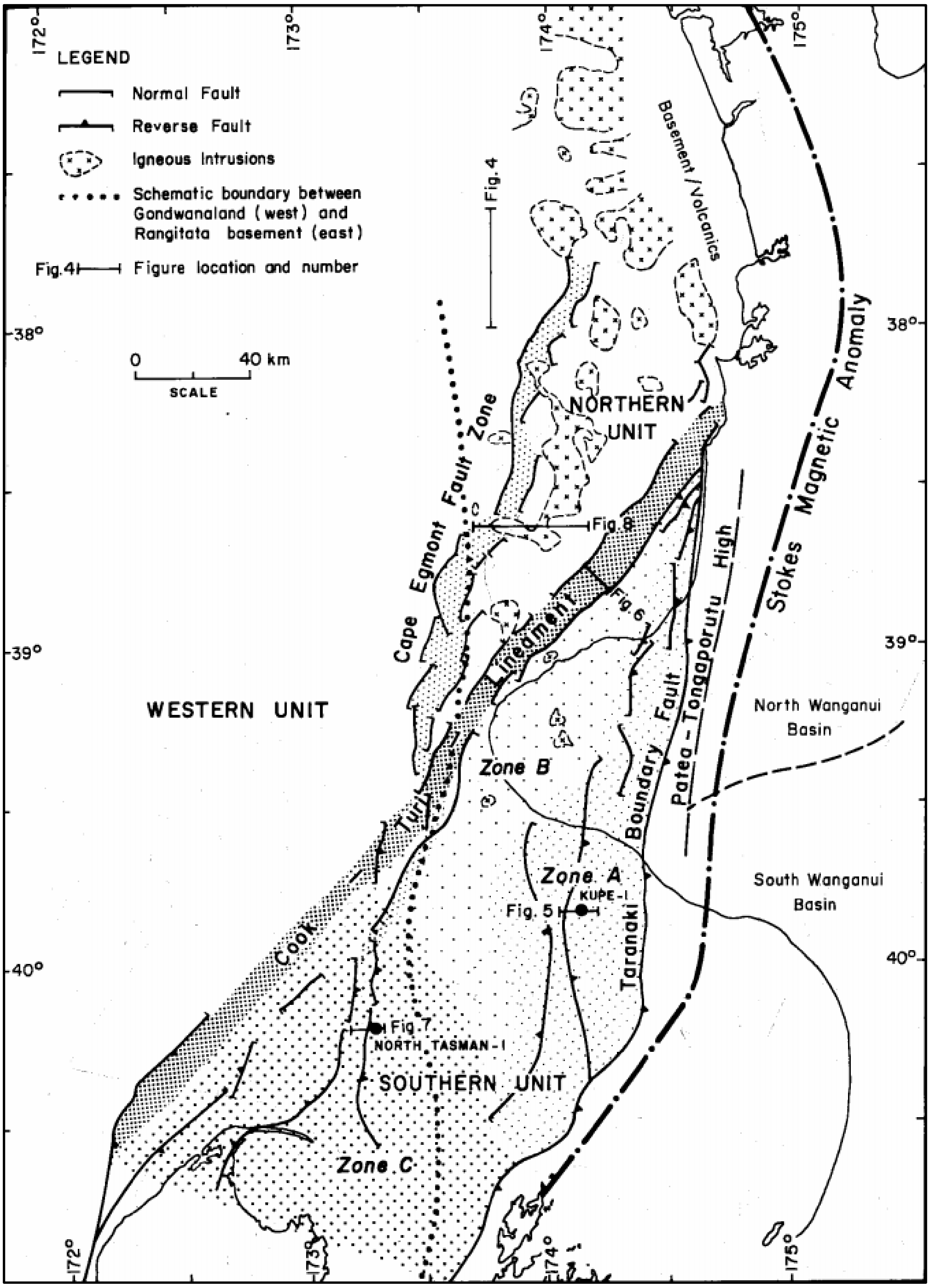

Figure 1-4: Structural subdivision of Taranaki Basin (Knox, 1982)

## 1.2 Dataset

The dataset used in this study incorporates a 3D seismic data cube and well logs data of the Karewa-1 well. The 3D seismic survey covers an area about 122.5square kilometers approximately which is 9.8 kilometers wide and 12.5 kilometers long. The

Karewa 3D data cube comprises 393 inlines (1001-1393 with step 1) and 1001 crosslines (2800-4800 with step 2). The basemap of the 3D data is shown in Figure 1-5.

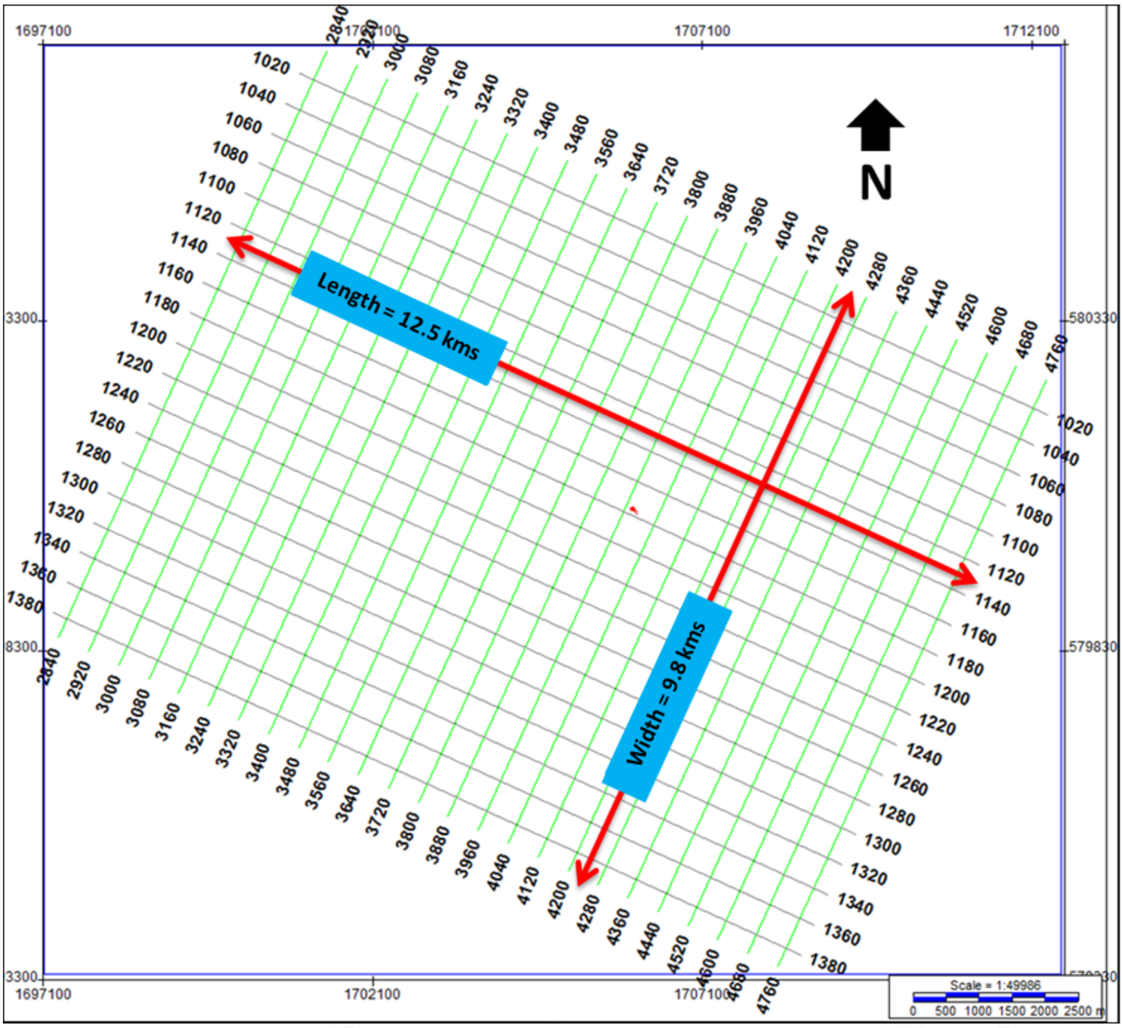

Figure 1-5: Base map of 3D Karewa seismic data

The used well in this study is Karewa-1 well. The available logs (Figure 1-6 and Figure 1-7) are Gamma Ray Induction (GRI), Gamma Ray Latero Log (GRL), Gamma Ray Neutron (GRNU), Bit Size (BIT), Spontaneous Potential (SP), Calibrated Downhole Force (CDF), Density Caliper (CLD), Resistivity Caliper (CLI), Density Correction (DRH), Density (FDC), Litho-Density (LDL), Compensated Neutron Porosity (CNL), Thermal Neutron Porosity (TNPH), Compressional Monopole (DTC), Shear Monopole (DTS), Shear Upper Dipole (DTSU), HALS Latero log Deep (HLLD), HALS Laterolog Shallow (HLLS), Deep Latero Log (LLD), Medium Latero Log

(LLS), Micro Inverse (MINV), Micro Normal (MNOR), Photoelectric (PEF), Flushed Zone Resistivity (RXO), and Tension (TNS).

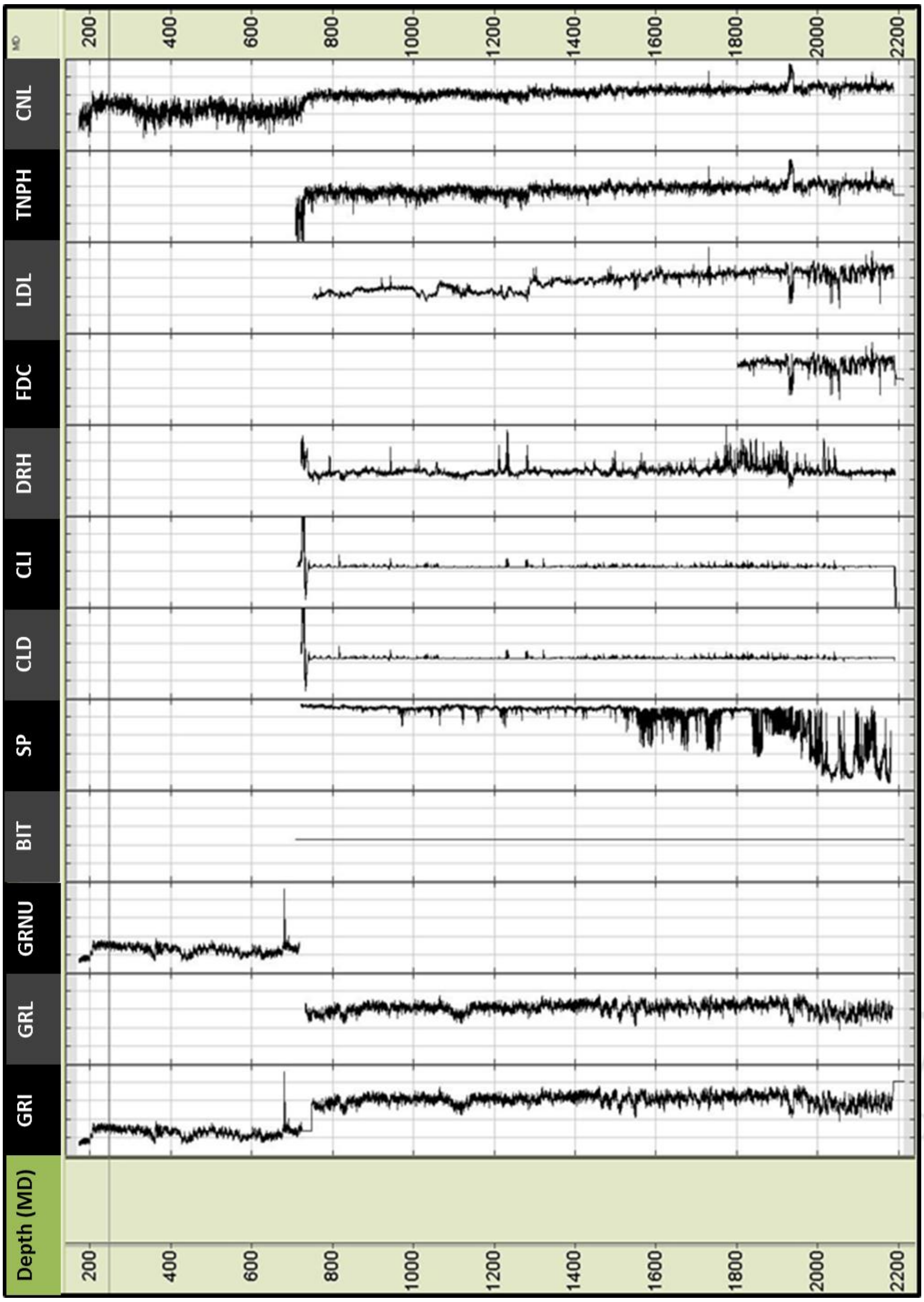

Figure 1-6: Available well logs of Karewa-1 (Gamma ray, Bit Size, SP, Caliper, Density, Density Correction, and Neutron Porosity)

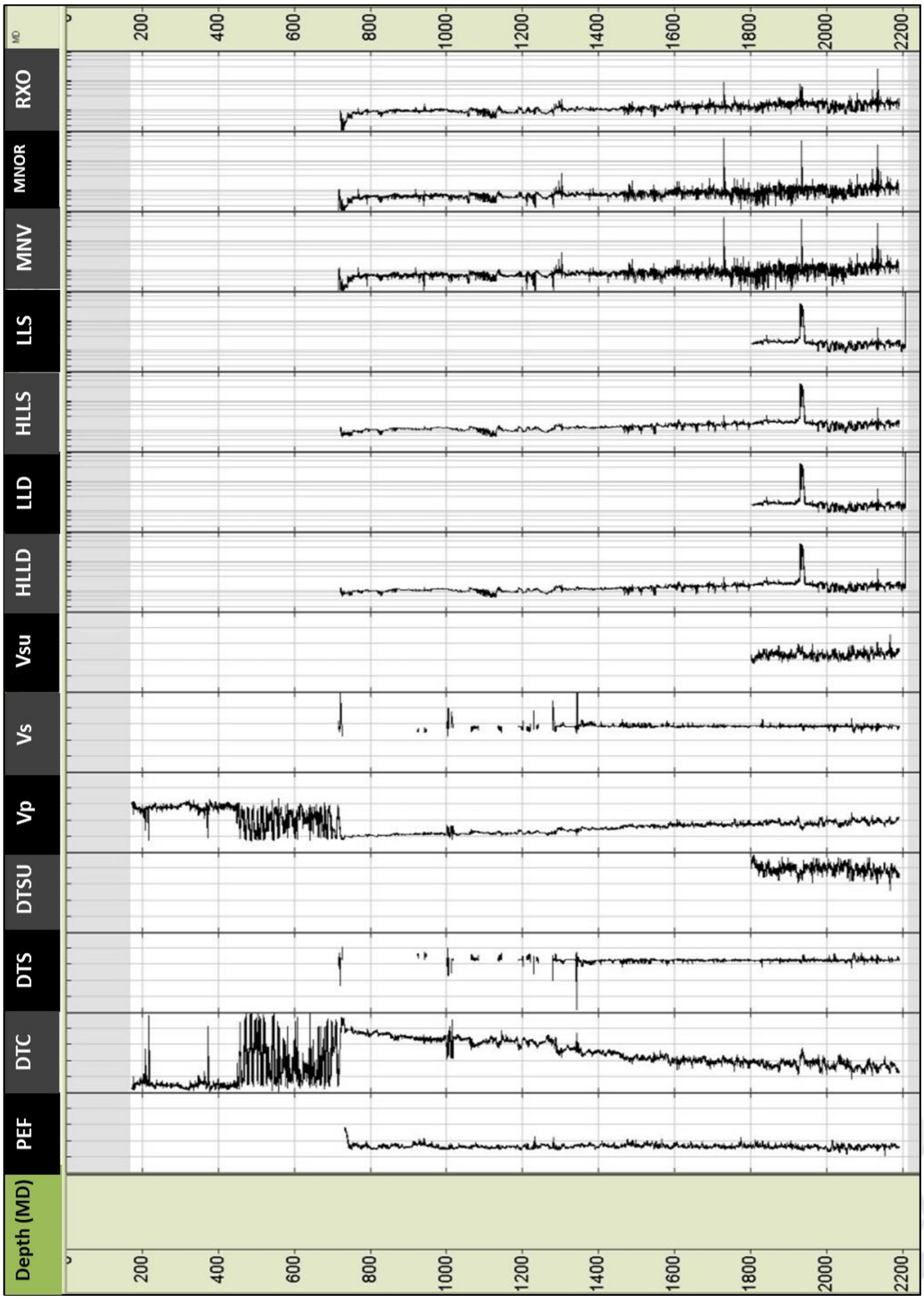

Figure 1-7: Available well logs of Karewa-1 (Photoelectric, Sonic, Shear Sonic, Sonic Velocity, Shear velocity, and Resistivity)

A stacked section of seismic data on inline 1177 in Figure 1-8 shows that the large growth fault (Karewa Fault) and a large normal faults made the seismic interpretation difficult. A reverse fault is formed due at the toe of Karewa Fault. The reservoir sand (Mangaa-C1) is also shown.The interested working interval of this study is between Plio-Pleistocene marker and last continuous reflection.

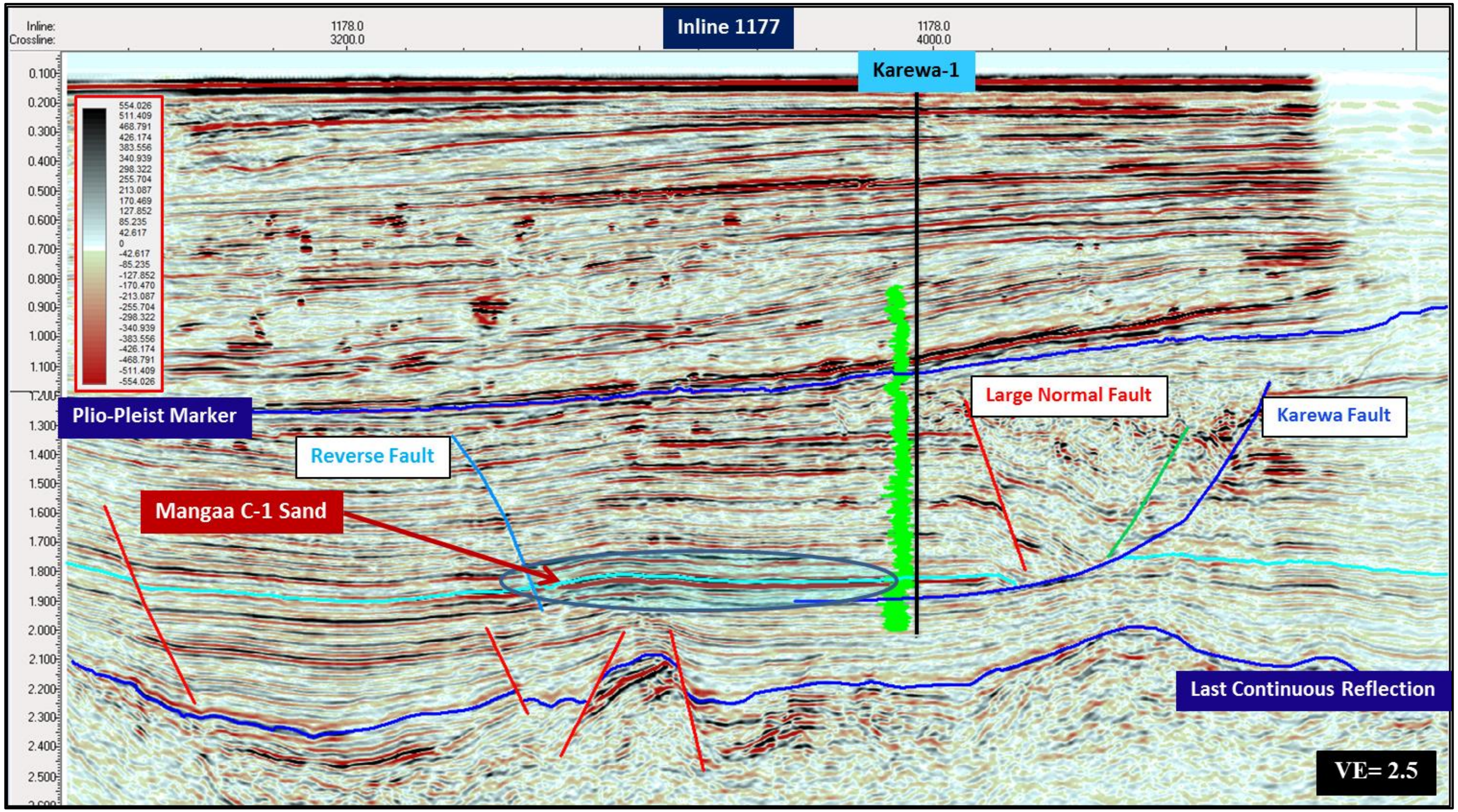

Figure 1-8: A seismic section on inline 1177

## 1.3 Literature Review

### 1.3.1 Model-based Deterministic Inversion

In 1983, Cooke and Schneider introduced a generalized linear inversion algorithm that assumes that the seismic trace and the wavelet are known and that attempts to modify an initial model until the resulting synthetic matches the seismic trace. This method is effective if there is considerable knowledge about the geology and a reliable model is created. This algorithm is used by the *Hampson-Russell* software.

The concept of model-based deterministic inversion technique is first introduced by Russell and Hampson (1991). They divided post-stack inversion methods into three categories: classical recursive or band limited, sparse-spike, and model-based. According to their conclusion, the band-limited approach gives robust result but it tends to produce a smoothed, frequency limited estimate of the impedance and failed in the case of a very “sparse” model. The sparse-spike approach produced superior results for a complete “sparse” model, but produced lower resolution than model-based inversion when applied to real data. Model-based inversion appears to be the most intuitively appealing, but it has to be carefully constrained to minimize the problem of non-uniqueness (Russell and Hampson, 1991).

Gavotti (2014) evaluated the influence of broadband seismic data in model-based inversion studies. Lateral variations in the inversion results are associated with the presence of low-frequency signal in the seismic data suggesting that the seismic reflections are controlling the impedance response.

### 1.3.2 Karewa Field, Taranaki Basin

The Taranaki Basin lies in offshore on the western side of the North Island of New Zealand. The study area Karewa Field is located in the Northern Taranaki Basin. Northern Taranaki basin has a thick sedimentary succession of Pliocene-Pleistocene which is known as Giant Foresets Formation (Hansen and Kamp, 2006). In 1996, King and Thrasher worked on the structural development of the Northern Taranaki Basin. It is subdivided into two distinct tectonic regions. One is the tectonically active Eastern Mobile Belt including the Northern Taranaki Basin which has undergone overthrusting, folding and uplifting. The other one is the Western Stable Platform, located in the western part of the Taranaki Basin, is considered as a relatively stable and structurally simple region.

The 3D seismic data of Karewa Field acquired by Todd Petroleum Mining Company Limited in 2006. Before that a high resolution seismic survey acquired by Conoco showed a hydrocarbon amplitude anomaly at the E-1 Prospect which is 27.5 kms north of the Manga-1 well. This amplitude anomaly coincides with a structural closure of the E-1 Prospect. The trap is a relatively late structure associated with slope failure within the prograding Plio-Pleistocene Giant Foreset Formation (Conoco Northland Ltd., 2002-2003). The deeper source rocks in the Cretaceous and earlier Mesozoic are not effective oil source rocks for this prospect. The oil prone Paleocene Waipawa shale is the inferred source rock (Conoco Northland Ltd., 2002-2003).

## 1.4 Research Objectives

The focus of this study is to interpret the 3D seismic data to identify the structures, to estimate the fluid and rock properties using the post-stack model-based deterministic inversion technique, and finally improve the interpretation result using the inversion results.