CHAPTER 1

Introduction

The study area is located in the Vulcan Sub-basin, the Timor Sea, offshore the northern coastline of Western Australia (Figure 1-1). The Vulcan Sub-basin has proven oil and gas potential, with commercial production and estimated reserves of 357 MMBBL of oil, 31 MMBBL of condensate, and 1.3 TCF of gas. However, the study area is situated in a region of particular subsurface imaging difficulties, and limited well data are available to improve the delineation of the reservoir section. As a consequence, future exploration drilling in this area is associated with significant uncertainty. Additional reservoir information can provide considerable benefits to reduce exploration risks. This study will discuss some of these uncertainties, by attempting to detect the reservoir properties, including lithology and fluid type, within the area.

Primarily seismic reflection data provides amplitudes, frequencies and phases that are affected by the reflection coefficient of the interfaces separating different rock properties. However, additional supplementary studies are routinely used to analyze the amplitude information in seismic data, either through amplitude versus offset (AVO) or seismic inversion. These techniques can be used to reveal lithology and fluid type within the reservoir, and are essential tools when analyzing the potential of prospective areas in the petroleum industry.

A seismic inversion study is normally initiated with the understanding of how rock properties relates to elastic properties. Such information is normally obtained through a rock physics study. Properties derived from a seismic inversion study are acoustic impedance (AI), shear impedance (SI), Vp/Vs, and density. In turn, the parameters derived from seismic inversion can be used to define hydrocarbon related lithofacies (Singh, 2007).

To detect hydrocarbons based on seismic inversion depends on reservoir properties, fluid type and seismic data quality. The deterministic inversion process derives acoustic impedance and shear impedance directly using either full Knott-Zoeppritz or alternatively the Aki & Richard approximation (Aki and Richards, 2002). The products from simultaneous inversion can be used to estimate Vp/Vs, as this is a very useful property in the identification of lithology and fluid content of reservoirs (Maver and Rasmussen, 2004). The separation between fluid types (hydrocarbon and water) within the reservoir can be modelled by using Gassmann fluid substitution method (Gassmann, 1951).

Figure 1-1 Location of the study area, Timor Sea, Western Australia (modified from Oxygen Group, 2015).

1.1 Background of Study Area

1.1.1) Seismic data

The study area covered 354 square kilometres of 3D seismic data acquired by Petroleum Geo-Services (PGS) in 1998 and reprocessed in 2014, using a Beam pre-stack depth migration (PSDM) processing algorithm. The seismic acquisition parameters and processing workflow are presented in APPENDIX A. The seismic data comprised 712 sublines (subline range 6734-7445) and 2,980 crosslines (crossline range 14137-17116).

Beam PSDM reprocessing produced the final migrated gathers and is illustrated in the Figure 1-2. Three seismic partial angle stacks were near, mid and far angle stacks based on the stacking of seismic gathers in different angle ranges as shown in Table 1-1. Figure 1-3 shows an example of seismic section along crossline 14922 which was used as the main input of this study.

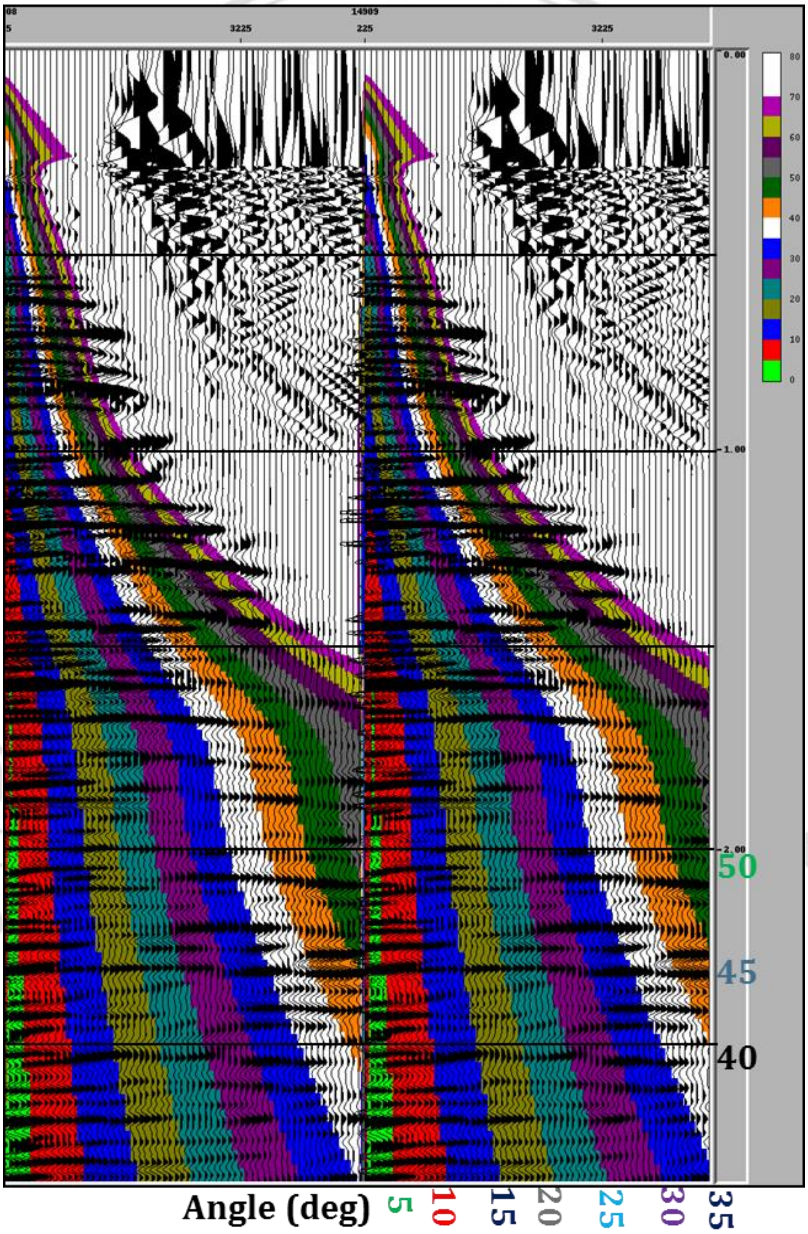

Figure 1-2 The example of seismic angle gathers on inline 7198.

Table 1-1 The angle ranges were used to produce the angle stacks, reprocessing in 2014.

Stack	Angle (Degrees)
Near	6-19
Mid	19-32
Far	32-45

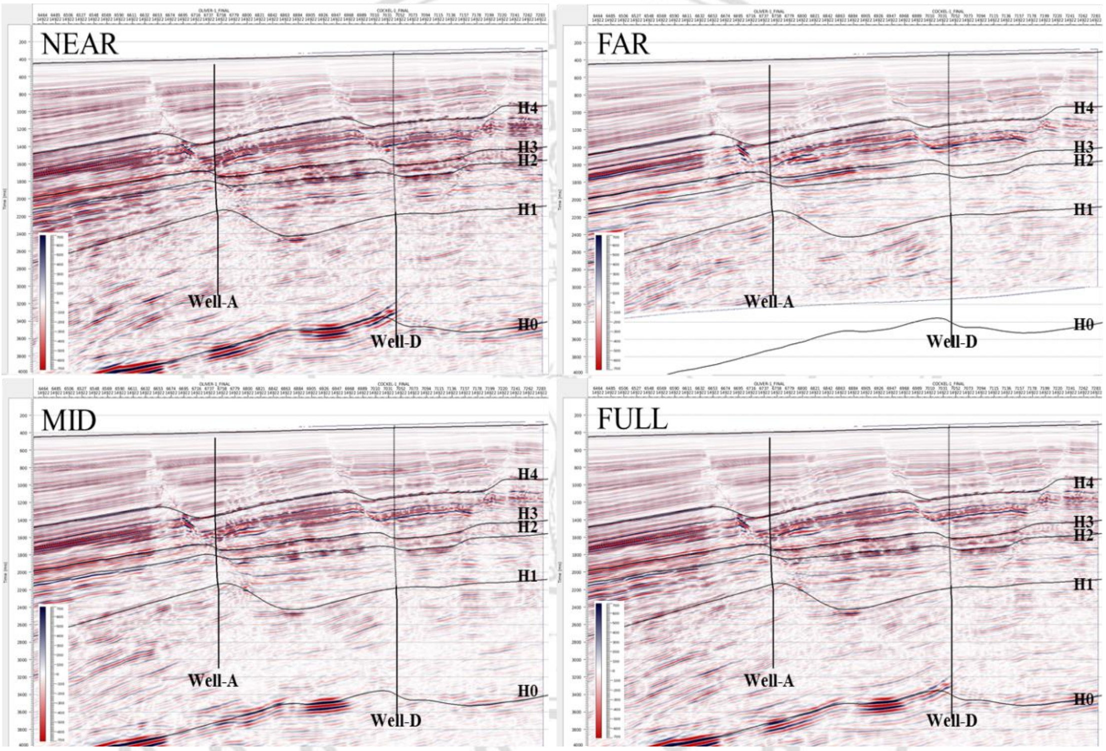

Figure 1-3 Near, mid, far and full angle range stacks along crossline number 14922.

1.1.2) Well data

Four exploration wells were drilled inside the study area: Wells-A, -B, -C and -D as shown in the Figure 1-4. Well-A and Well-B were both discovery wells while Well-C and Well-D were dry wells. Wireline and petrophysical interpretation logs were measured for all wells which are compressional sonic, bulk density, gamma ray, resistivity, water saturation, effective porosity, and volume of clay. However, with the exception of Well-A, which was drilled in 2009, shear sonic was not measured during previous drilling campaigns.

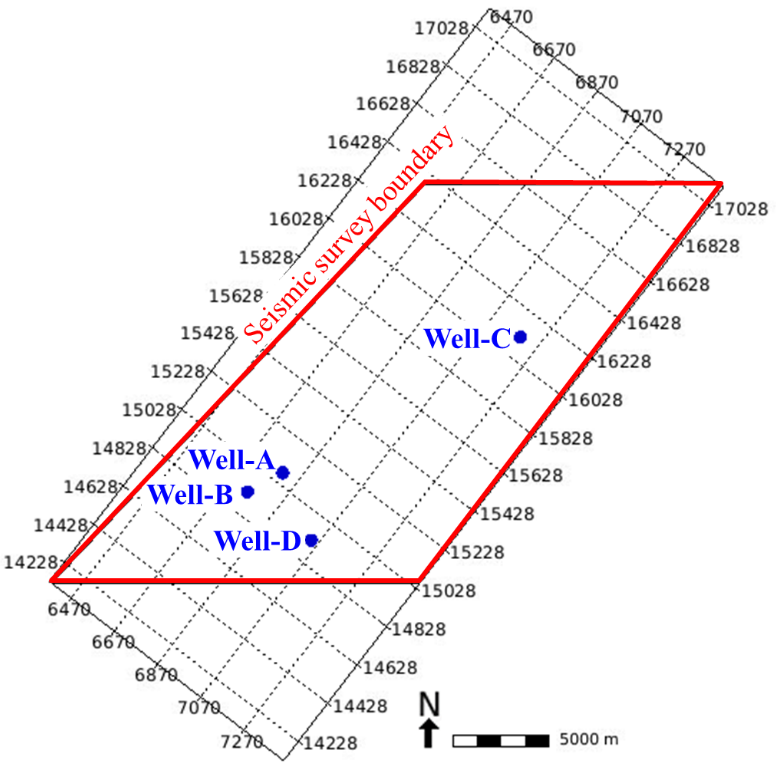

Figure 1-4 Well locations in the study area.

1.1.3) Seismic Interpretation

Seismic interpretation were consisted of six interpreted horizons: H0, H1, H2, H3, H4 and seabed reflector, which were constructed based on 3D PSDM full angle seismic data by PTTEP Australasia (see Figure 1-5). Horizon H1 is interpreted as a key target that corresponded with a stratigraphic unconformity. The time structural maps of H1 horizon (Figures 1-6) show structural highs at Well-A, Well-B and Well-C which were three-way dip closure against the faults.

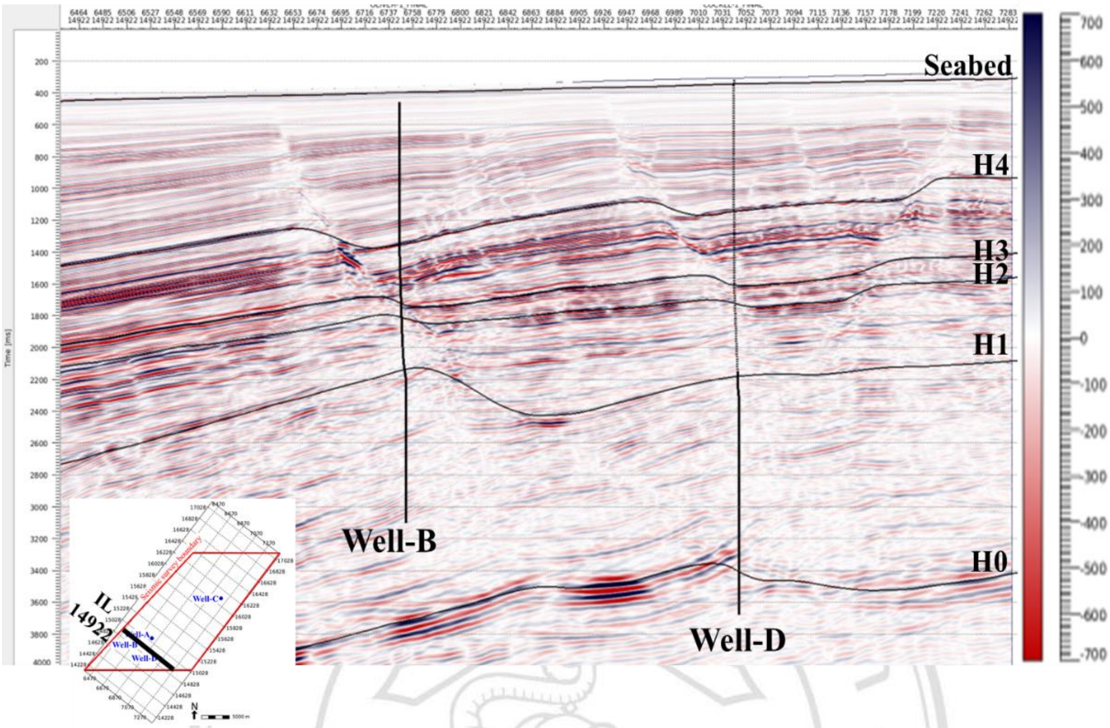

Figure 1-5 Interpreted horizons overlain on full seismic PSDM data.

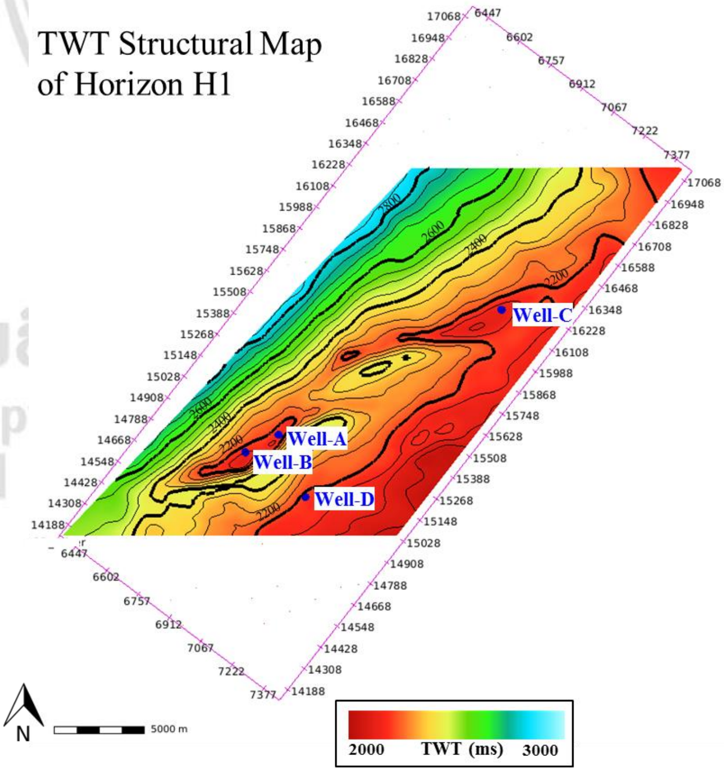

Figure 1-6 Time structural map of Horizon H1, respectively, with the well location in overlay.

1.2 Literature Review

1.2.1) Vulcan Sub-basin

The Vulcan Sub-basin is a major northeast-trending Upper Jurassic extensional depocenter in the western Bonaparte Basin (Figure 1-7). The sub-basin comprises a complex series of horsts, grabens and marginal terraces. They are flanked by the Permo–Triassic platforms of the Londonderry High to the southeast and the Ashmore Platform to the northwest. The structurally significant and proven hydrocarbon source provinces of the Swan Graben and Paqualin Graben dissipate in the northeast beneath the Neogene Cartier Trough (Figure 1-8). The Montara Terrace flanks the Swan Graben to the east, while the Jabiru Terrace borders the eastern margin of the Cartier Trough (Commonwealth of Australia, 2015).

The Bonaparte Basin still has the potential for significant hydrocarbon discoveries. Some petroleum systems are oil-prone, but collectively, the Bonaparte Basin is gas-dominated (Barrett et al., 2004). Two Upper Jurassic hydrocarbon source pods have been identified within the Swan and Paqualin grabens. Hydrocarbons may have migrated to the Ashmore Platform, but there is little evidence of hydrocarbons being trapped; the retention efficiency of most traps is very low (Barrett et al., 2004).

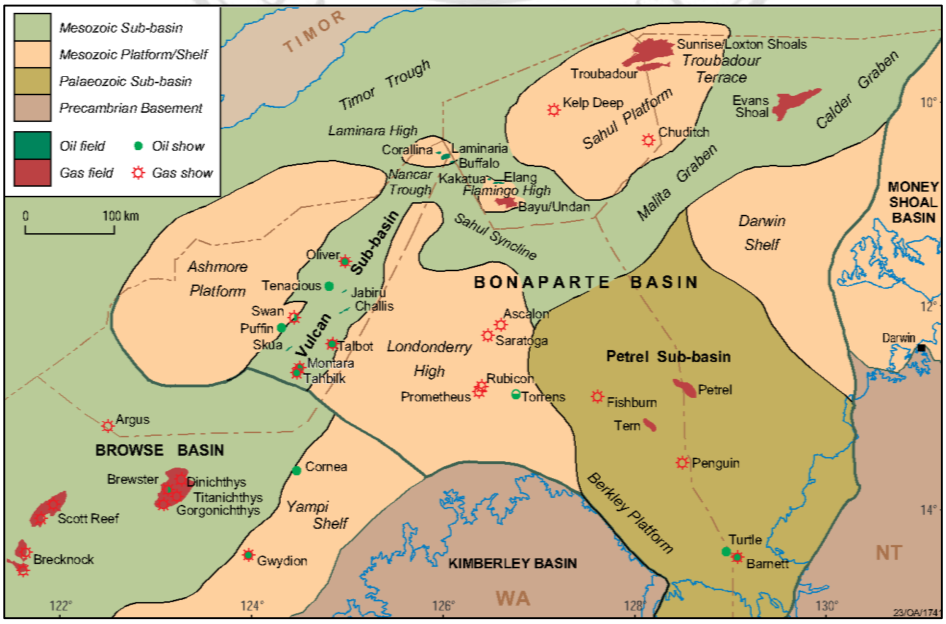

Figure 1-7 Location of Bonaparte Basin and associated sub-basin, colored by geological time (Barrett et al., 2004).

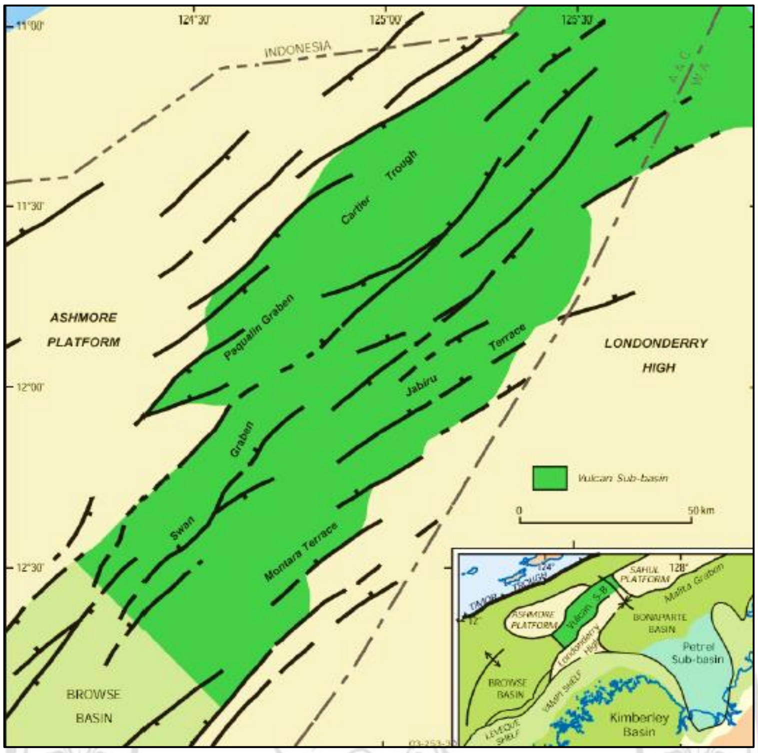

Figure 1-8 The structurally significant were presented in the Vulcan Sub-basin (Commonwealth of Australia, 2015).

1.2.2) Pre-stack simultaneous inversion

Ardakani et al. (2014) explained in lithology discrimination using elastic rock properties and simultaneous seismic inversion in the Leduc Reservoir, NE Alberta. The workflow of the study was divided into 4 main steps; 3D crossplot analysis, seismic data conditioning, seismic simultaneous inversion and rock physics analysis. The study demonstrated the value of elastic rock properties for detailed mapping of reservoir lithology in the Leduc Formation. After applying constrained pre-stack simultaneous inversion to the seismic 2D profile, the compressional impedance, shear impedance, and density profiles were simultaneously generated. The calculated outputs were recognized as the best attributes in dolostone-limestone discrimination.

Chatterjee et al. (2013) studied the hydrocarbon bearing lower Tarkeshwar sands which were almost invisible on normal reflectivity data sets but were obviously exposed on Vp/Vs data sets created from simultaneous inversion. Hence, Vp/Vs is a good discriminator of the lithology and is also being used effectively to delineate the reservoir geometry.

1.3 Objectives

1.3.1) To determine the rock properties comprising elastic properties, lithology, and fluid type of a reservoir in the Vulcan Sub-basin using well data and rock physics principles.

1.3.2) To carry out a deterministic pre-stack simultaneous inversion using 3D seismic data, interpreted horizons and well log data.

1.3.3) To carry out seismic reservoir characterization by application of probability density functions (PDF) defined by rock physics analysis.