CHAPTER 1

Introduction

1.1 Background

Demanding of oil and gas in the globe is increasing day by day, therefore exploration companies are trying to explore more and more hydrocarbon reservoirs. Targets for hydrocarbon exploration and production at present focuses not only on onshore and shallow water reservoirs but also deep water reservoirs where exploration and production processes face various difficulties. One of the most initial methods for hydrocarbon exploration is seismic exploration. Seismic exploration is a set of geophysical methods of exploration based on a study of artificially induced waves of elastic vibrations propagating in the Earth crust. Seismic reflection is a major geophysical method using the fundamentals of seismology to assess the properties of the Earth's subsurface from reflected seismic waves.

The geological characteristics of the continental shelf of Vietnam are very complicated and new tasks always require detailed and accurate study. In order to solve these problems, applying geophysical methods, especially seismic technologies, plays a very important role and it is rapidly being developed. The seismic technologies are applied in variety of works in exploration and one of that is to provide understanding about reservoir characterization. Seismic amplitudes provide key information on lithology and fluids content, enabling interpretation of reservoir quality and likelihood of hydrocarbon presence (Simm and Bacon, 2014). There are many interpretation techniques using seismic amplitude analysis for reservoir characterization. Two of these techniques involved amplitude variations with offset or angle of incidence (AVO) and seismic attribute analysis is used in this study. This study is carried out in one of the most complicated gas field offshore Vietnam.

1.2 Principles and Theory

1.2.1 Basic AVO Theory

AVO is the comparison of seismic amplitude changes compared to offset (or angle) of traces from the source for example source points. AVO is first discussed by Ostrander (1984) as a method which potentially may distinguish between gas related amplitude anomalies and non - gas related amplitude anomalies. Zoeppritz equations allow us to relate seismic amplitudes to the reflection angle at single interface. However, the Zoeppritz equations are complicated, there are various approximations derived from the Zoeppritz equations that have been made such as Bortfield (1961), Aki and Richards (1980), but the most successful is approximation by Shuey (1985) in term of Poisson's Ratio rather than S-wave. Equations 1.1 and 1.2 express Shuey equations 3 terms and 2 terms accordingly:

$$R(\theta) = R(0) + Gsin^2\theta + F(tan^2\theta - sin^2\theta), \qquad (1.1)$$

where

$$R(0) = \frac{1}{2}\left(\frac{\Delta V_P}{V_P} + \frac{\Delta\rho}{\rho}\right),$$

$$G = \frac{1}{2}\frac{\Delta V_P}{V_P} - 2\frac{{V_S}^2}{{V_P}^2}\left(\frac{\Delta\rho}{\rho} + 2\frac{\Delta V_S}{V_S}\right),$$

$$F = \frac{1}{2}\frac{\Delta V_P}{V_P}.$$

$$R(\theta) = R(0) + Gsin^2\theta. \qquad (1.2)$$

In the Shuey equations, Vp is P-wave velocity, Vs is S-wave velocity, ρ is density, θ is incidence angle, ΔVp is P-wave velocity contrast across the interface, ΔVs is S-wave velocity contrast across the interface, Δρ is density contrast across the interface. R(0) is the reflection coefficient at normal incidence angle and is controlled by contrast in acoustic impedance (AI). G is AVO gradient, variations of amplitude with offsets. F is reflection at large offset, near the critical angle.

The AVO attributes can be interpreted by plotting the amplitude of the signal for a reflector against the offset of the trace, called intercept - gradient crossplot. Intercept term is where the amplitude measurement meets the zero – offset line while Gradient term is the slope of the curve made by the plot points (Figure 1.1).

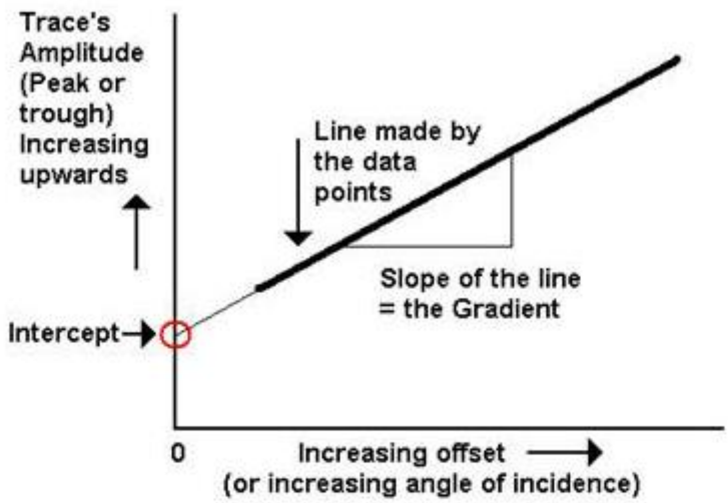

Figure 1.1: Intercept versus gradient crossplot.

1.2.2 AVO Classes Classification

The classification scheme for AVO anomalies was first defined by Rutherford and Williams (1989). They classified AVO anomalies trends for gas-saturated sand reservoirs. The classification scheme are then supplement by Ross and Kinman (1995) about class 2P and by Castagna and Smith (1995) about class 4. The classification scheme is shown in Figure 1.2, the polarity assumption is normal polarity as increase acoustic impedance is peak.

AVO class 1 represents high impedance sand with decreasing AVO, the sand layer has higher impedance than the surrounding shale. The amplitude decreases with positive value. AVO class 2P represents near zero impedance contrast between the sand and surrounding shale. The amplitude decreases with positive value at near offset, reverse phase and increase with negative value of amplitude at far offset, dimming the reflection on stacking. AVO class 2 also represents near zero impedance contrast between the sand and surrounding shale. The amplitude is low negative value that comes more negative, brightening the reflection on stacking. AVO class 3 represents low impedance sand with increasing AVO compared to surrounding shale. The amplitude is negative value that comes more negative, brightening the reflection on stacking. AVO class 4 represents low impedance sand with decreasing AVO. The amplitude is negative and becomes less negative with offset.

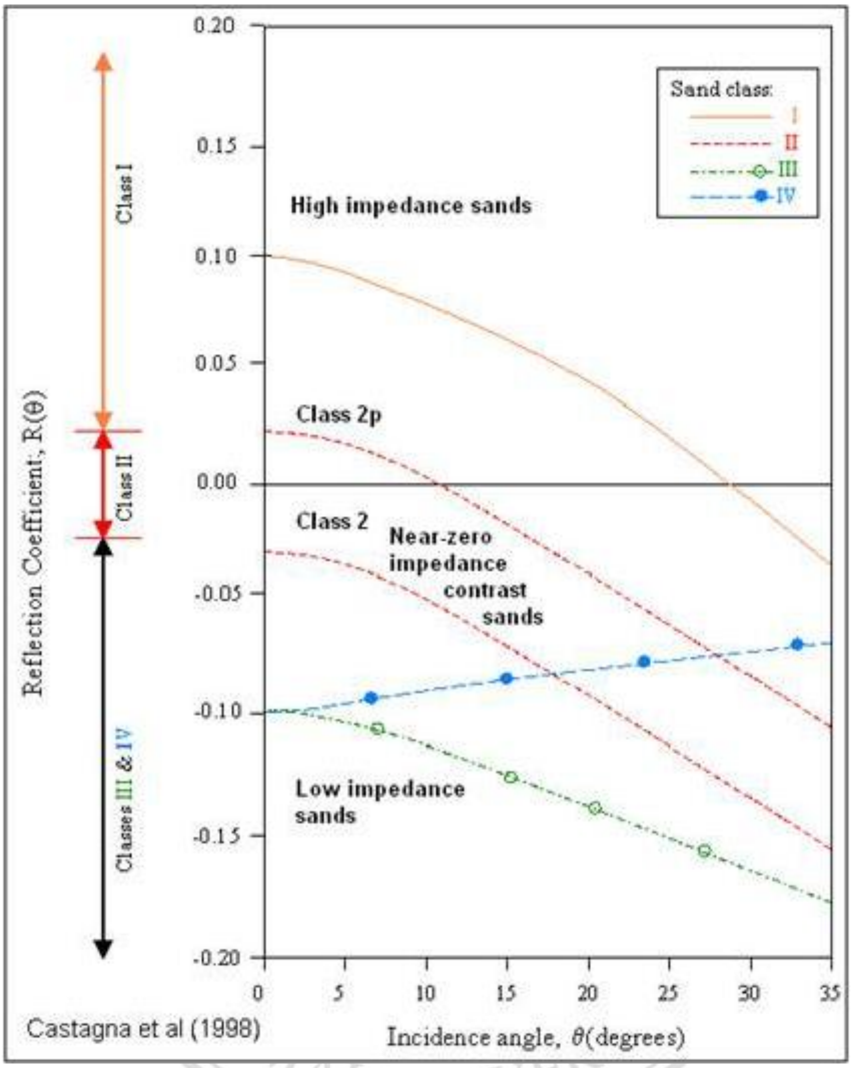

Figure 1.2: AVO classification scheme (Castagna et al.,1998).

1.2.3 Elastic Impedance Inversion

Seismic trace inversion is the process of extracting rock properties from seismic reflectivity. It could reduce the effects of the seismic wavelet from the data. In addition, inversion process could estimate the seismic properties of the layer such as impedances, Vp/Vs, density etc from the boundary reflections which relate to contrast between layers. Reflection coefficient is affected by the difference in acoustic impedance (AI) between rock layers. AI is the product of density and seismic velocity, typically P-wave velocity. However, the constraint of AI inversion is that it can be only applied for post stack seismic data that AVO analysis could not incorporate with inversion process. Therefore, to take into account fluid effects that affect amplitude variations with offset or angle, a pre- stack impedance inversion needs to be carried out.

Elastic Impedance (EI) mentioned by Connolly (1999) was initially developed by BP in the early 1990s to help exploration and development in the Atlantic Margins province, west of the Shetlands, where Tertiary reservoirs are typified by class 2 and class 3 AVO responses. EI is a generalization of impedance for variable incidence angle. It provides a consistent and absolute framework to calibrate and invert non-zero offset seismic data (Connolly, 1999). EI allows the well data to be tied directly to the high-angle stack seismic which can then be calibrated and inverted without reference to the near-offsets stack. The equation for EI is derived from the two terms linearization of Zoeppritz equations (Equation 1.2) and expressed as:

$$EI(\theta) = {V_P}^a * {V_S}^b * \rho^c, \qquad (1.3)$$

where

$a = 1 + tan^2\theta,$

$b = -8Ksin^2\theta,$

$c = 1 - 4Ksin^2\theta,$

$K = \left(\frac{V_S}{V_P}\right)^2.$

Continuing the development of elastic impedance from Connolly (1999), Whitcombe (2002) normalizes the EI function to remove the term incidence angle (θ) by introducing constants α_0, β_0, ρ_0. The new normalized function of elastic impedance allows the derived values that do not change with incident angle θ. These modifications allow for a direct comparison between elastic impedance values across a range of angle which are the constraints of previous formulation by Connolly (1999). The normalization is expressed as:

$$EI(\theta) = \left(\frac{\alpha}{\alpha_0}\right)^a \left(\frac{\beta}{\beta_0}\right)^b \left(\frac{\rho}{\rho_0}\right)^c, \qquad (1.4)$$

where α, β, ρ are P-wave velocity, S-wave velocity and density respectively, θ is incidence angle, a, b, c are exponents same as in Connolly (1999) equation above.

1.3 Objective

The main objective of this study is to use elastic impedance inversion to delineate lithology type and fluids content, therefore it is to improve understanding about reservoir characterization of an important gas field in offshore Vietnam. Another goal is proving the efficiency of elastic impedance inversion approach in pre-stack migrated data in order to exploit fluid effects as amplitude variations with offsets or angles. Results in the study can be used as the additional information to predict hydrocarbon reservoirs which is important in volumetric calculation and in any further development wells. Besides, AVO analysis workflow may apply to other areas which are identical subsurface conditions.

1.4 Methodology

The workflow used in this study is shown in Figure 1.3. It is divided into five major phases with data pre-conditioning and quality control as the starting point. In this phase, both well logs dataset and seismic volume are edited, quality control and enhancement in order to achieve a good input data for later steps. The next phase is well log analysis and seismic interpretation, this step includes interpreting well logs data, generating and calculating new logs attributes and matching well to seismic data. Seismic interpretation of horizons and faults and seismic attributes extraction are also involved in this phase. It is followed by a phase called AVO modeling, the main jobs of this phase are identify AVO responses and construct AVO synthetic models to help identify fluids type in the formation through fluid substitution method. The fourth phase which is the major objective in this study is elastic impedance inversion. This stage involves extracting elastic properties of rocks from inverted dataset. Last step is integrating the results of seismic inversion and AVO modeling to get information about lithology and fluids content in the reservoir.

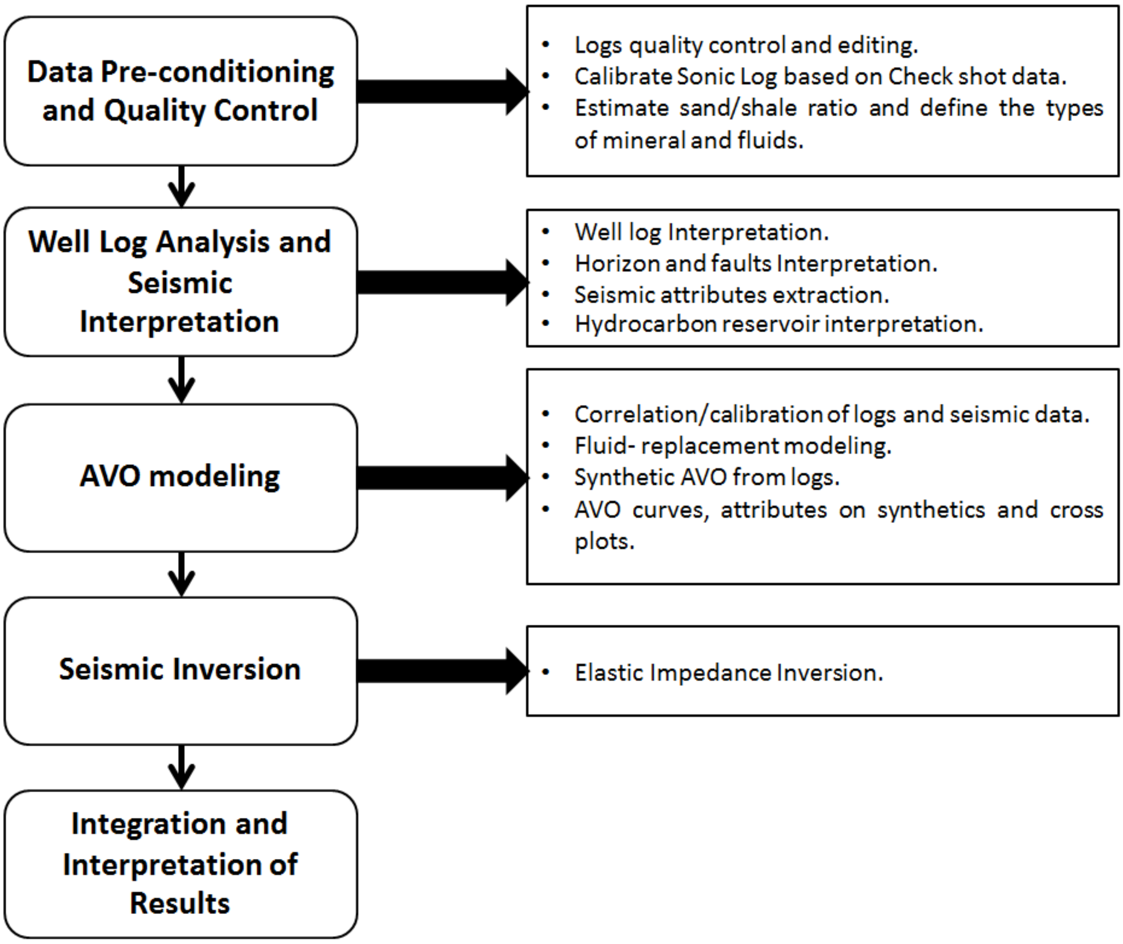

Figure 1.3: Main workflow.