# Chapter 1

# Introduction

Amplitude variation with offset (AVO) is the variation in the amplitude of a seismic reflection with source-receiver distance (Sheriff, 1991). AVO analysis is based on the Zoeppritz equations that satisfy boundary conditions for the continuity of normal and tangential stresses and displacements for a plane wave at a plane interface between two half-space elastic media. The Zoeppritz equations relate a reflection coefficient to rock properties as a function of an incident angle. The variation of reflection coefficients with incident angles is referred to as offset-dependent reflectivity, and is the fundamental basis for AVO.

The idea of AVO has been used in petroleum exploration for many years as a direct hydrocarbon detection technique. A high-amplitude feature on stacked data, in general, can be a primary indicator for hydrocarbon accumulation, especially for gas. Gas within a pore space of a clastic rock reduces the compressional wave (P-wave) velocity of the rock, but leaves the shear wave (S-wave) velocity relatively unaffected. This P-wave velocity contrast at a lithologic boundary due to gas in a reservoir often causes a high amplitude anomaly, i.e. a bright spot. A change in the ratio of P-wave velocity to S-wave due to a gas reservoir often causes an AVO anomaly. Thus, the techniques of bright spot and AVO generally have contributed positively in finding gas sands in clastic sedimentary environments. However, many seismic amplitude anomalies (bright spots or AVO anomalies) could be caused not by gas reservoirs but rather by other high or low velocity layers that have no gas accumulation.

An AVO analysis can be divided into two steps. The first step relates seismic amplitude response on a common-depth point (CDP) gather to rock properties such as P-wave velocity, S-wave velocity, density and Poisson's ratio. The second step relates these rock properties to lithology and fluid types. A CDP gather of a gas-related amplitude anomaly could show a positive AVO trend (absolute amplitude increase with offset) while CDP gathers of other amplitude anomalies (coal, wet sand) show a negative trend (absolute amplitude decrease with offset). Nevertheless, it could not be assumed that all positive AVO responses would relate to gas reservoirs. There could be many positive AVO anomalies coming from non-hydrocarbon-bearing formations. Furthermore, there are many pitfalls in AVO analysis. So AVO modeling is an integral part of AVO studies. AVO modeling based on local velocities and densities is necessary to confirm more likely amplitude variations for target reservoir formations in a prospect area, and distinguish them on surface seismic data.

This study aims to characterize the AVO trends on gas sand reservoirs that were discovered recently in the Gulf of Thailand. It is hoped that this AVO characterization would help find more gas sands in the adjacent areas that have similar geologic features.

### 1.1 Study objectives

The objectives of this study are described below:

1) To characterize gas sand AVO trends based on angle stacks of surface seismic data that go through the discovery well.

2) To characterize gas sand AVO trends based on the correlation of surface seismic data with the Zoeppritz and full elastodynamic AVO modeling results.

3) To determine the desirable approaches in AVO analysis and interpretation in the study area and adjacent areas.

### 1.2 Study scope

For this study, the surface seismic data were processed through pre-stack time migration and Radon demultiple. Also, the data were wavelet-phase matched with zero-phase synthetic data. After evaluating the current wavelet phase and amplitude spectra, an optimum phase rotation and a frequency filter were applied. Three constant angle-band stacks (0-15 degree, 15-30 degree, and 30-45 degree) were generated from the final CDP gathers. These angle stacks were subtracted from each other to evaluate the AVO trends of the gas sands.

AVO modeling was carried out to evaluate theoretical AVO responses and characters for the gas sands and other high amplitude lithologic units such as coal, wet sands, and organic shale. The Zoeppritz reflection coefficients and synthetic CDP gather were correlated with the real surface seismic data.

The AVO characterization was based on the angle stacks, different sections, correlation of synthetics with real CDP gathers, and interpretation. To derive useful results, other lithologic units in the area that give strong amplitude responses, such as coal and wet sands were also thoroughly evaluated.

### 1.3 Literature review

Ostrander (1984) explained the effects of Poisson's ratio on plane-wave reflection coefficients for gas sands at non-normal incidence angles. Two basic conclusions were; 1) Poisson's ratio has strong influence on changes in reflection coefficients as a function of incidence angle, and 2) in many cases, analysis of seismic amplitude versus offset can distinguish between gas-related amplitude anomalies and other types of amplitude anomalies.

Rutherford and Williams (1989) stated that the two factors that most strongly determine the AVO behavior of a gas-sand reflection are the normal incidence reflection coefficient $R_0$ and the contrast in Poisson's ratio at the reflector. They defined three classes of gas sands. Class 1 is high-impedance gas sands that have higher impedance than the encasing shale with relatively large positive values for $R_0$. Class 2 is near zero impedance sands that have nearly the same impedance as the encasing shale and characterized by values of the $R_0$ near zero. Class 3 is low impedance sands that have lower impedance than the encasing shale with negative, large magnitude values for $R_0$.

Hilterman (1990) described various amplitude anomaly examples using AVO modeling. Main points were; 1) AVO responses for a sand package depend not only on the degree of shaliness but also on the shale distribution within the sand package, and 2) AVO modeling is equivalent to 1-D synthetic seismogram generation for correlating seismic data to the well log lithology.

Armstrong and others (1995) concluded that there are two main reasons why log-derived models often fail to explain AVO effects observed on surface seismic data. The first relates to difficulties in processing the surface seismic data for true amplitude. The second relates to log information having a very short range and being acquired at frequencies much higher than seismic data.

Julien and others (1997) studied the use of acoustic impedance trend-curves in seismic reservoir characterization. These trend curves allow better understanding of well log data and also allow better determination of a strategy for seismic reservoir characterization.