Application of AVO Method to Analyze the Seismic Characteristics of Gas Hydrate Offshore Southwestern Taiwan

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Abstract

Marine seismic reflection data collected from offshore southwestern Taiwan show prominent seismic bottom simulating reflectors (BSRs) that indicate the existence of gas hydrate in the seafloor sediment with free gas zone underneath. For the purpose of understanding the methane hydrate system (generation, migration and accumulation) as well as to delineate the methane hydrate reservoir properties, we used Amplitude Versus Offset (AVO) analysis of the seismic reflection data. AVO analysis is successfully used to discriminate between the presence of gas and lithologic variations in Bright Spot analysis. The theory behind AVO analysis finds its roots in Zoeppritz equations. These equations relate reflection coefficients and propagation angles. Qualitatively, seismic wave mode conversion is responsible for the dependence of amplitude anomalies in seismic data with respect to wavefront incidence angle or offset. This mode conversion is most evident with a large change in Poisson's ratio, and this, for example, occurs when gas saturated rock meets water saturated rock. AVO analysis after migration has long been recognized as advantageous, since the migration process better preserves the amplitudes of the wave field and collapses diffractions. Further more, the incidence and emergence angles of the reflection can be approached more accurately when using ray-tracing methods in depth domain, rather than ray-path approximations in time domain based on RMS velocities. The amplitude of the reflected wave $R(\theta)$ can be decomposed into so-called 'AVO attributes', P (intercept) and G (gradient). P and G can be computed by Least Square method applied to the pre-stack seismic data. By simple mathematical operation such as a product and /or a linear combination using P and G, we can reconstruct physically meaningful and gas-identifiable sections. For the case of gas-saturated sediment below the methane hydrate layer, Poisson's ratio and

P-wave velocity of the gas-saturated sediment should be lower than the methane hydrate layer producing Class-3 AVO response. Finally, we show AVO attribute and attribute crossplot to identify anomalous regions needing further investigation.

Introduction

In the context of understanding the methane hydrate system, it is very important to know gas occurrence just below methane hydrate-bearing zone, gas distribution, and gas concentration status. Where no direct measurements are available, detailed knowledge of compressional and/or shear wave velocity distribution in marine sediments may be used to derive quantitative estimates of gas hydrate and free gas. In order to obtain good velocity values, we apply pre-stack depth migration method to analyze two seismic lines (EW9509-35 and EW9509-46) where prominent BSRs are observed through the use of iterative migration velocity analysis (residual moveout method). This technique can overcome restrictions due to lateral velocity inhomogeneity. Velocity structures derived from pre-stack depth migration show that the hydrate-bearing sediments generally have velocity ranges from 1750 to 2000 m/s, with most values around 1900 m/s. Low velocity zones observed beneath the gas hydrate bearing sediments clearly indicate the presence of free gas below.

AVO analysis has become widely used in oil exploration as a powerful delineation tool for lithology and pore fluid type within the reservoir by analyzing the P-wave reflections from the interfaces of the reservoir and surrounding sediment. The AVO technique has been developed by many researchers such as Ostrander (1984) and Rutherford and Williams (1989) and all of them were started from the Aki-Richards equation (Aki and Richards, 1980), which is a practical approximation to the Zoeppritz equation (Zoeppritz, 1919) for the reflection coefficient at the reflection interface. BSR is generally interpreted as the base of the gas hydrate stability zone (BSHS) (Shipley *et al.*, 1979), which separates the sediments containing gas hydrate above and the sediments containing free gas below. The elastic property contrasts between the gas hydrate bearing and the free gas bearing sediments lead to BSR amplitude variations with incident angles.

The Zoeppritz equation were approximated ($\theta \leqq 30^{\circ}$) by Shuey (1985) as :

$$R(\theta) = P + G\sin^2\theta$$

Where R(θ)is the reflection coefficient; θ is the incident angle; P is the P-wave reflection coefficient at normal incidence; and G is the gradient.

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