Toward the estimation of methane hydrate from seismic attenuation through field observation,experimental and theoretical studies

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In order to estimate the amount of methane hydrates (MHs) which form in marine sediments at water depths greater than a few hundred meters, using not only velocity information but also attenuation information can provide much more information about MH-bearing sediments. While the presence of MH increases seismic velocity in the host sediment, recent works on sonic logging data and VSP data show that sonic and seismic waveforms are also significantly affected by the presence of MH. These studies also showed a strong correlation of attenuation with velocity in the MH-bearing sediments. However, the increase of attenuation with increasing velocity is somewhat unintuitive. Thus, it is important elucidate the rock physical mechanism responsible for these phenomena.

The purpose of this study is to establish the methodology for the estimation of methane hydrate resources from seismic attenuation. The approach to complete this is divided to three parts: field observation, experimental and theoretical studies.

In field observations, I have used full waveform logs and VSP data from the Nankai Trough exploratory well off central Japan to estimate sonic and seismic attenuation in sediments containing methane hydrate. Regarding sonic data, both compressional and shear attenuation were estimated. This paper is concerned with attenuation at sonic frequencies of 10-20 kHz for compressional waves and 500- 1000 Hz for shear waves. I observed that the presence of MH increases the host sediments' seismic attenuation, and shear attenuation may be more helpful than compressional attenuation in detecting or characterizing MH-bearing sediments as compressional attenuation is affected by the presence of gas. Moreover, the ratio of compressional to shear attenuation is found to be a more sensitive indicator of the presence of low-saturation gas than the corresponding velocity ratio. On the other hand, daata from two vertical seismic profiles (VSPs) are used to estimate compressional attenuation in methane hydrate (MH)-bearing sediments at seismic frequencies of 30-110 Hz. To isolate intrinsic attenuation from total attenuation, attenuation is computed from multiples using one-dimensional synthetic VSP data from sonic and density logs. Macroscopically, the peaks of highest attenuation in the seismic frequency range correspond to low-saturation gas zones. This interpretation is supported by raw-level data such as the centroid frequency. No significant compressional attenuation was observed in MH-bearing sediments at seismic frequencies. In contrast, high compressional attenuation zones in the sonic frequency range (10-20 kHz) are affected by the presence of methane hydrates in the same well locations. Thus, this study demonstrated the frequency-dependence of attenuation in MH-bearing sediments.

In experimental studies, we conducted laboratory measurements to explain partially the reason for the physically unrealizable phenomenon. The ice generated from brine was assumed to be methane hydrate, namely, partially frozen brine was considered to be as an analogue for a mixture of methane hydrate and water present in the pore space of hydrate bearing sediments. We observed the variations of a transmitted wave with frequency content of 150-500 kHz through a liquid system to a solid-liquid coexistence system, changing its temperature from 20 C to -15 C. As a result, P-wave speed increases up to about 3700 m/s with changing in a solid-liquid coexistence system from a liquid system, while P-wave attenuation increases with changing in a solid-liquid coexistence system from a liquid system. Our observations indicate that the interaction in a micro scale of the solid and liquid causes the dissipation of transmitted wave energy.