Evaluation of methane hydrate based on attenuation parameter in seismic exploration

*川部 瑞貴[1]、三ケ田 均[1]、武川 順一[1]
*Mizuki Kawabe[1], Hitoshi Mikada[1], Junichi Takekawa[1]

1. 京都大学
1. Kyoto Unibercity

In recent years, methane hydrate (MH) has drawn attention as a new domestic energy resource in Japan. Although field production experiments have been conducted in real fields, some MH samples collected in real fields revealed the difficulty to evaluate the amount of MH based quantitative only with the evaluation of bottom simulating reflector (BSR). For efficient development of MH reservoirs, it is therefore important to estimate the thickness of MH concentrated zones accurately. Since MH layer has high attenuation that takes place as a function of propagation path through the attenuating medium, the evaluation of MH using seismic exploration could be an effective approach. However, the previous studies indicated that it is difficult to estimate attenuation structure even if the full-waveform information is utilized. On the other hand, the amplitude of seismic waves passing through MH layer must be affected by its high attenuation, but the approach of full waveform inversion (FWI) has been reported ineffective due to its back-propagation process. In the present study, we hypothesize that additional constraint enables us to estimate attenuation parameter of MH layer without any back propagation of residual wavefield. We assume that the layer structure in the subsurface is known, and the physical properties of MH layer are unknown. Based on the above assumption, we conducted numerical experiments to investigate the effectiveness of inversion based on utilization of full-waveform to provide information on estimation of the amount of MH resources based on the linearized general inverse theory.
In our numerical model, the seismic source and receivers are put in the sea water and on the sea bed, respectively. Synthetic waveforms are created by solving the visco-elastic equation using the finite-difference method. Our numerical experiments revealed that simultaneous inversion of the Lame’s parameter and attenuation parameter of P-wave (Qp) is difficult. To overcome this, we proposed a kind of the relaxation method, i.e. we separately solve the Lame’s parameters (and) and Qp in our inversion process. The proposed method can obtain the true value not only the Lame’s parameters but also Qp with sufficient accuracy. Our numerical results indicate that the seismic exploration can provide valuable information on MH layer by estimating physical properties including the attenuation parameter.

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