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Research paper

Velocity structures imaged from long-offset reflection data and four-component OBS data at Jiulong Methane Reef in the northern South China Sea

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A B S T R A C T

In this study, P- and S-wave velocity models were built based on two pre-stack depth migration (PSDM) profiles of long-offset reflection data and 25 four-component ocean-bottom seismometers (OBS) data at Jiulong Methane Reef off SW Taiwan in the passive margin of the northern South China Sea (SCS). According to the velocity models, the average P-wave velocity and Vp/Vs ratio of the free gas beneath the bottom-simulating reflector (BSR) are 1.52–1.58 km/s and 4.5–5.10, respectively. The depth of the BSR is found at 80–300 m below the sea floor and the sedimentary thickness of the hydrate and the free gas are about 50–100 m and 70–100 m, respectively. P-wave velocity of about 1.75 km/s in the hydrate-bearing sediment is southeastward increased to about 1.85 km/s above the BSR. Similarly, Vp/Vs ratio of about 3.06 in the hydrate-bearing sediment is increased southeastward to about 3.48 above the BSR. Based on the pseudo-3D map of gas-hydrate saturation estimated from the PSDM and OBS models, the average saturations of hydrate and free gas at Jiulong Methane Reef are about 7% and 0.9–2.4%, respectively. The highest hydrate saturation (11%) is located at 5–20 m above the BSR in the SE portion of the Jiulong Methane Reef. On the other hand, the highest gas saturation of about 2% is observed at 10–70 m below the BSR in the NW portion of the Jiulong Methane Reef. We suggested that several normal faults dipping southeastward beneath the continental slope provided conduits for gas migrating northwestward at Jiulong Methane Reef. Therefore, the highest gas saturation is observed below the anticline in the NW portion of the Jiulong Methane Reef and the highest hydrate saturation (high P-wave velocity and high Vp/Vs ratio) is identified above the BSR in the SE portion of the Jiulong Methane Reef.

1. Introduction

Gas hydrates in marginal seas have been found in Black Ridge off eastern USA, Gulf of Mexico (Paull et al., 2000; Dai et al., 2008), the continental slope off Norway (Andreassen et al., 2003; NDP, 2004), Krishna-Godavari Basin off eastern India (Collett et al., 2008), Ulleung Basin off eastern Korea (Ryu et al., 2009; Lee et al., 2013) and the continental slope of the northern South China Sea (Wu et al., 2011; Zhang et al., 2014). Troughs, seamounts, incised valleys, fan channels and fault systems provide structures to bear gas hydrates in these continental margins (McDonnell et al., 2000; Wu et al., 2007). In the continental slope of the northern South China Sea (Fig. 1), the diapiric structures at Shenhu in the depression of the Pearl River Mouth Basin (Wu et al., 2011), the deepest Cenozoic depression and slumping bodies in the Dongsha Slope (Yan et al., 2006), debris flow from the shelf break to the continental rise and erosional canyons in the Jiulong Slump (Han et al., 2008), and gas charged shallow sedimentary layers (Liu et al., 2006) and submarine ridges due to landslides and turbidites (Lin et al., 2009) in the northernmost South China Sea might be favorable for gas hydrates. Gas has migrated upward from normal faults, with rotated strata in the hanging wall (Lin et al., 2009) due to rifting in the South China continental crust (Wang et al., 2010), and are most concentrated underneath the slope ridges (Liu et al., 2006).

Gas hydrates were characterized geochemically and geophysically in the northern South China Sea. Cold seep carbonates at Shenhu (Suess, 2005), Dongsha Slope (Yan et al., 2006) and Jiulong

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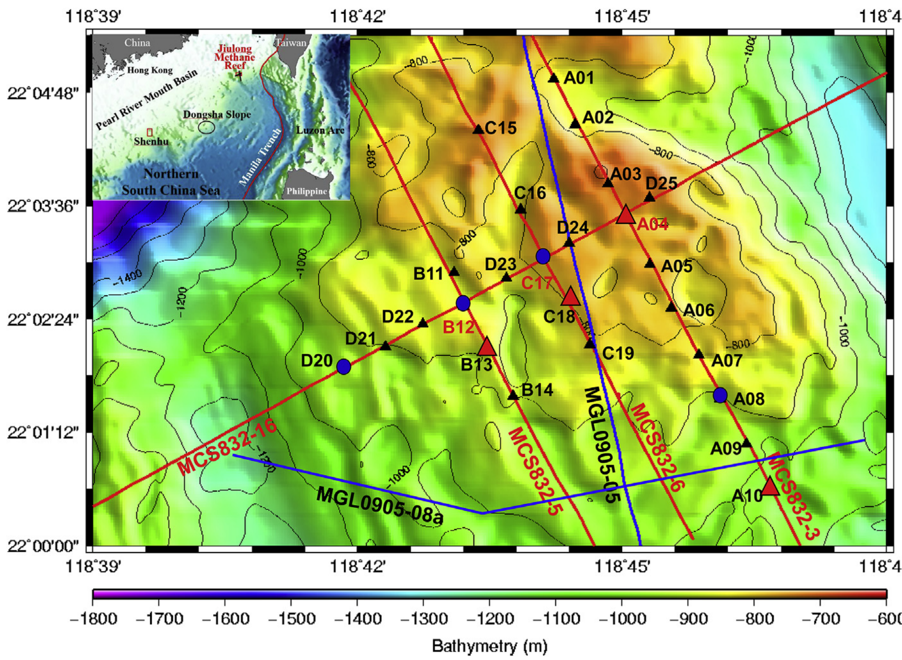

Fig. 1. Seismic study of gas hydrates at Jiulong Methane Reef in the top of the northern continental slope of South China Sea. Four OBS profiles (red lines) and two long-offset reflection profiles (blue lines) were collected in 2007 and in 2009, respectively. Blue circles indicate hydrophone and vertical components of OBS data displayed in Fig. 3. Horizontal components of OBS data (red triangles) are shown in Fig. 6. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Methane Reef (Han et al., 2008) were found. Methane emissions on the ridges at Shenhu (Suess, 2005) and chemoautotrophic bacteria on the Dongsha Slope (Yan et al., 2006) were also observed. Migration of methane, probably biogenic gases, up to the sea floor becomes a primary energy source for the chemosynthetic communities and the rapid sulfate reduction near the ridges in the continental margin off SW Taiwan (Lin et al., 2006, 2008; Chuang et al., 2006; Yang et al., 2006). From seismic reflection and chirp sonar profiles, fluid upwelling in the venting systems of gas hydrates has also been imaged (Chiu et al., 2006; Ryu et al., 2009). Bottom-simulating reflector (BSR) parallel and below the sea floor is a key indicator for the presence of gas hydrate (Ecker et al., 2000; Liu et al., 2006). Appearance of the BSR is due to the variation of the velocity impedance when seismic waves propagate through the gas hydrate-bearing sediments. Sediments above and below the BSR may be filled with hydrates (increased P-wave velocities) and the

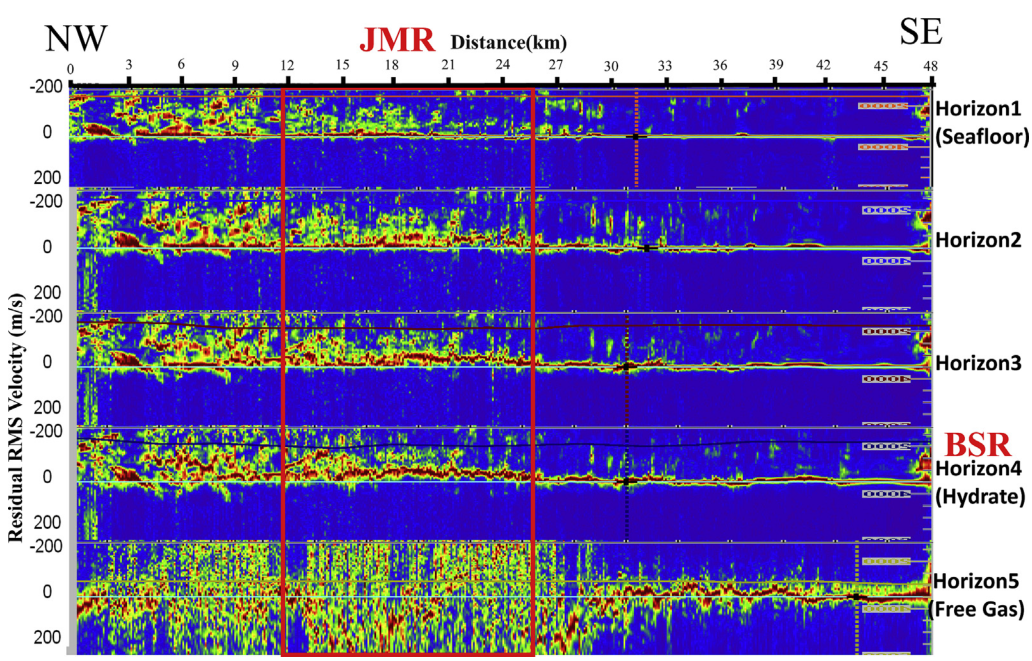

Fig. 2. Residual RMS velocity semblance of horizons along MGL0905-05. Red frame shows residual RMS velocity at Jiulong Methane Reef. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)