The first marine gas hydrate drilling expedition (GMGS-1) of China was performed in the Shenhu Area, northern slope of the South China Sea (Fig. 1a) by Guangzhou Marine Geological Survey (GMGS) during April to June, 2007, to detect the occurrences of gas hydrates. The drilling results showed that the distributions of hydrates in the drilling area were heterogeneous. In the plan view, hydrates were only recovered at three of the eight sites, SH2, SH3 and SH7 with average saturations of 21.10%, 20.25%, and 23.09%, respectively (Wu et al. 2008). Vertically, hydrates occurred in the fine-grained sediments only above the base of gas hydrate stability zone (BGHSZ) with depths of 10 to 40 m.

Recently, several drilling results and investigations of marine gas hydrates around the world revealed good relationships between hydrates and deep-water deposits in the shallow strata. The marine gas hydrate explorations in the Gulf of Mexico (Boswell et al., 2009, 2012), the Nankai Trough (Noguchi et al., 2011), the Ulleung Basin (Riedel et al., 2012), New Zealand (Fohrmann and Pecher, 2012), and the offshore of Taiwan (Lin et al., 2014), have demonstrated that the turbidite deposits, buried deep-water channels and related levees, and the mass transport complex (MTC) acted as the host rocks, which could be regarded as the major controlling factors on the distribution of gas hydrates.

Using the discontinuous core samples from the Sites SH2 and SH7, Chen et al. (2011) and Liu et al. (2012) measured the grain size of the sediments, which were composed of fine-grained silt or silty clay. Also, from the measurements, less differences on the lithological characteristics and grain sizes between the sediments with hydrates and without hydrates could be observed (Chen et al., 2011). However, from the seismic profiles in the drilling area across sites in the west and east respectively, two different features above BGHSZ could be identified, thin-bedded chaotic reflectors with lenticular to irregularly shaped geometry at the bottom, and thick continuous moderate-to-high amplitude reflectors with spoon-shaped morphology at the top (Fig. 2). These distinct two sets of seismic reflectors here might be used to indicate the occurrences of two sedimentary units.

Through the sequence stratigraphy and sedimentary evolution in the Shenhu Area, in this study, the forming mechanisms about these two sedimentary units were analyzed. Thin-bedded unit at the bottom with chaotic reflectors (Unit I) was thought to be related with the small-scale deep-water channels at the lowstand system tract of Quaternary in the north. Due to the erosional ability of small-scale channels in the north, the underlying sediments might be scoured and re-transported down-slope from south to north. These sediments might re-deposit at the lower slope in the Shenhu Area. The fine-southwards variations of the grained sizes of the hydrate-bearing deposits from Site SH7 to Sites SH2 and SH3 (Liu et al., 2012) might be characterized as the results of near-source accumulations. Whereas, influenced by the sediment supplies from the north and the topographic features of the seafloor, the thick continuous seismic reflectors (Unit II) at the top were interpreted as the sediment failures at the highstand system tract of Quaternary. Hence, these two units associated with different formation mechanisms, implied that these Quaternary sedimentary deposits in the drilling area highlight spatio-temporal heterogeneities, although the lithology and grain size of the hydrate-bearing sediments were similar to the other sediments in the core samples.

Under the background of deep-water environment, influenced by erosional–depositional processes, fine-
grained sediments usually possess good reservoir properties (Schneider et al., 2011). For this reason,

Fig. 1. Location of the Shenhu area, northern slope of the South China Sea.
(a), Shaded relief map showing the Pearl River Mouth Basin (blue dotted line) and the Shenhu Area (black rectangle); (b) Distribution of the re-deposited sediments; (c), Topographic map displaying gas hydrate drilling area, the locations of the sites, BSRs and gas chimneys. BSRs, bottom simulating reflectors.

Fig. 2. Two SSE-trending seismic profiles across the sites showing the two sedimentary units with different reflectors. BSRs, bottom simulating reflectors.
sedimentary Unit I, the re-deposited sediments with chaotic reflectors, was suggested to act as the host rock for the gas hydrates in the Shenhu drilling area. In contrast, sedimentary Unit II, which is highlighted by sediment failures with continuous reflectors, could be regarded as a compact layer.

The depth of the SMI (sulfate–methane interface) at the Sites SH1, SH2, SH3, SH5, and SH7 illustrated the low upward methane flux in the study area (Wu et al., 2011). Gas-bearing fluids could be allowed migrating into the gas hydrate stability zone (GHSZ) through faults and gas chimneys (Su et al., 2014), and form hydrates in the sedimentary Unit II, the re-deposited sediments. Thick sediment failures (Unit II) with continuous reflectors and fine-grained sediments would impede the vertical migration of gases/liquids, causing no hydrates were discovered because of the extremely low methane concentration in this unit.

The identification the re-deposited sediments showed a good relationship with the heterogeneous distributions of hydrates in the Shenhu Area. Vertically, hydrates were only occur within sedimentary Unit I at the bottom, which could be used to explain why hydrates could be recovered at the Site SH2 but no hydrates were recovered at the Site SH5 (Fig. 2). Parallel to the erosional boundary of small-scale deep-water channels in the north, the distribution of re-deposited sediments in the Shenhu Area displayed as the NEE-trending belt (Fig. 1b). At the present day, after erosion by numerous submarine canyons, sedimentary Unit I might be only preserved as patches (Fig. 1b). In the drilling area, the re-deposited sediments are only reserved to the north of the canyon ridges (Fig. 1c), where the Sites SH2, SH3 and SH7 with hydrates located. Therefore, the Quaternary sedimentary conditions are proposed to be the critical controlling factor for the accumulation and distribution of hydrates in the Shenhu Area, northern continental slope of the South China Sea.

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