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Re-examination on The Contribution of Deep Thermogenic Gas to Shallow Hydrate in The Shenhu Area, Northern Continental Slope of South China Sea

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1 Introduction

In April-June of 2007, the Expedition GMGS-1 was completed successfully in the Shenhu Area of the South China Sea. Gas hydrate was detected at three (Sites SH2, SH3 and SH7) of the five sites that were cored. The Shenhu gas hydrate drilling area is located in the central Baiyun sag.

Previous oil and gas exploration confirmed Baiyun sag a huge hydrocarbon generating sag. the large LW3-1 gas field away from the gas hydrate drilling area about 25 km, with about 100 billion m^3 estimated reserve, suggested the good hydrocarbon generating potential in the deep. According to the geochemical analysis of hydrate-bearing sediments and headspace gas samples, gases are composed of 99.89% to 99.91% methane, with minor amount of ethane and propane. The carbon-isotopic composition of methane in two hydrate-bearing zones are about -56.7 ? and -60.9? respectively（Wu et al., 2011; Zhu et al., 2013）, and the $C_1/(C_2+C_3)$ ratios of the gases are 911.7 and 1094, respectively. The carbon-isotopic composition of methane ($\delta^{13}C_1$) for the 14 headspace gas samples from surface sediments in the adjacent sites falls within a range of -46.2? to -74.3? with an average of about -60.9? Thus, the results of geochemical analysis indicated the natural gas hydrates in the Shenhu Area are predominantly composed of gases of microbial origin, with minor contribution of deep thermogenic gases（Wu et al., 2011; Zhu et al., 2013）.

2 Discussion

As indicated by the isotopic and compositional features of hydrated gases in Shenhu area, the deep hydrocarbon generating sag did not contribute significantly to the gas hydrate formation. Why? Based on the seismic interpretation in the Baiyun Sag, Chen et al. (2013) thought the Dongsha Tectonic Movement might be the cause. Due to this regional tectonic movement, the vertical migrations of gases/fluids in the study area might be characterized as being active in multiple episodes. Before the middle Miocene, diapiric structures and active faults were good conduits for vertical migration of gas-bearing fluids from deep reservoir to shallow sediments. The Dongsha Tectonic Movement caused extensive basement uplifts and developed NW-/NNE-trending oriented faults which induced the release of overpressured fluids in deep strata. Vigorous gas releases through the basin produced large-scale gas eruption structures such as gas chimneys, which facilitated the path for the migration of high flux thermogenic gases from deep layers to shallow sediments (Chen et al., 2013). With the Dongsha Movement fading away,, in addition to pressure decreasing fluid pathways also became inactive and the flux of thermogenic fluids dropped. As a result the gases sampled in the gas hydrate zones in recent investigations were the mixture of biogenetic gas, produced from organic matter in the shallow strata, and small amounts of thermogenic gas, from the gas chimneys.

However, it is worth a reexamination of the explanation suggested by Chen et al. (2013) in this study. Firstly, based on the interpretation of 2D/3D seismic data, large-scale faults, gas chimneys and diapirs did exist and could serve as the vertical migrating conduits for gases/fluids in the Shenhu Area (Su et al., 2014), as suggested by the chimneys identified in the drilling area. These conduits could be found downwards below the Boundary T7 (about 32 Ma), and traced upwards above the Boundary T3 (about 11.6 Ma), even penetrated the seafloor. Moreover, among these vertical migrating pathways, no significant

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differences in seismic features form deep to shallow provide evidence that multiple-stage vertical migration of gases/fluids from the deep strata happened in geological history. Secondly, in industrial boreholes in the Pearl River Mouth Basin, the geochemical analysis recognized the presence of thermogenic methane in the shallow sediment sections. For instance, in the strata with depth of less than 1500 m at the Boreholes PY30-1-1, LH19-1-1 and LH19-3-1, the values of $\delta_{13}C_{CH4}$ are higher than -45? and the ratios of C_1/C_{2+} are much less than 1,000. These features indicated that thermogenic gases might migrate upwards into shallow strata along these vertical pathways.

3 Conclusion

Gas hydrate explorations in recent years around the world revealed that thermogenic gases in deep strata can migrate into shallow layers through the vertical pathways with relatively high flux, implying the possible contribution to gas hydrate formation in the shallow strata (e.g. Porangahau Ridge, New Zealand, Atwater Valley, Texas-Louisiana Shelf, and Gulf of Mexico) (Coffin et al., 2014). Unfortunately, it seems that thermogenic gases in the deep strata (Wenchang and Enping Formations) in the Baiyun Sag was not the predominant methane source for the hydrates in the shallow strata recovered during 2007 in the Shenhu Area. On the other hand, gas chimneys played a role of main vertical conduits for the migrations of thermogenic gases with relatively low flux through the comparison with the adjacent LW3-1 oilfield as proposed by Qiao et al. (2013). The low upward methane flux also could be inferred from the depths of SMI (sulphate methane interface) at the Sites SH1, SH2, SH3 and SH5 (Wu et al., 2011). Also, the Dongsha Tectonic Movement during the middle Miocene could weaken the vertical migrating abilities of these pathways because of extensive releases of overpressured fluids (Chen et al., 2013). All these factors could result in a bad association among the thermogenic gases in the deep, the vertical migrating conduits and the hydrates in the shallow.

Recently, laboratory analysis and numerical simulation results showed that molecular fractionation of hydrocarbons and stable carbon isotopic fractionations of methane would take place when hydrocarbons migrated upwards through the sediment into the shallow gas hydrates（Chanton, 2005）, as shown in the Black Sea (Pape et al., 2010). Thick bathyal/abyssal fine-grained sediments since Late Miocene in the Pearl River Mouth Basin might lead to the low permeability for the upward migrations of gas-bearing fluids, which reduced vertical transportation efficiency of thermogenic gases from the deep. Also extensive releases of overpressured fluids caused by Dongsha Tectonic Movement further decreased the vertical migrating velocity of thermogenic methane. All these conditons indicated the possibility of fractionation of carbon isotopes during the migration of thermogenic gases upward into the shallow gas hydrates. Therefore, the thermogenic gases in the deep might have contributed indirectly to the shallow gas hydrate in the Shenhu Area, and it should be reviewed in more detail.

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