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Research paper

Source and accumulation of gas hydrate in the northern margin of the South China Sea

Gege Hui [a, b], Sanzhong Li [a, b, *], Lingli Guo [a, b], Guangxue Zhang [c], Yuehua Gong [c], Ian D. Somerville [d], Yong Zhang [a, b], Qiliang Zheng [a, b], Yibo Zang [a, b]

[a] Key Lab of Submarine Geosciences and Prospecting Techniques, Ministry of Education, Qingdao 266100, China
[b] College of Marine Geoscience, Ocean University of China, Qingdao 266100, China
[c] Guangzhou Marine Geological Survey (GMGS), Guangzhou 510075, China
[d] UCD School of Earth Sciences, University College Dublin, Belfield, Dublin 4, Ireland

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ABSTRACT

The northern South China Sea (NSCS) experienced continuous evolution from an active continental margin in the late Mesozoic to a stable passive continental margin in the Cenozoic. It is generally believed that the basins in the NSCS evolved as a result of Paleocene–Oligocene crustal extension and associated rifting processes. This type of sedimentary environment provides a highly favourable prerequisite for formation of large-scale oil- and gas–fields as well as gas hydrate accumulation. Based on numerous collected data, combined with the tectonic and sedimentary evolution, a preliminary summary is that primitive coal-derived gas and reworked deep gas provided an ample gas source for thermogenic gas hydrate, but the gas source in the superficial layers is derived from humic genesis. In recent years, the exploration and development of the NSCS oil, gas and gas hydrate region has provided a basis for further study. A number of 2D and 3D seismic profiles, the synthetic comparison among bottom simulating reflector (BSR) coverage characteristics, the oil-gas area, the gas maturity and the favourable hydrate-related active structural zones have provided opportunities to study more closely the accumulation and distribution of gas hydrate. The BSR has a high amplitude, with high amplitude reflections below it, which is associated with gas chimneys and pockmarks. The high amplitude reflections immediately beneath the BSR are interpreted to indicate the presence of free gas and gas hydrate. The geological and geochemical data reveal that the Cenozoic northern margin of the NSCS has developed coal-derived gas which forms an abundant supply of thermogenic gas hydrate. Deep-seated faults and active tectonic structures facilitate the gas migration and release. The thermogenic gas hydrate and biogenic gas are located at different depths, have a different gas source genesis and should be separately exploited. Based on the proven gas hydrate distribution zone, we have encircled and predicted the potential hydrate zones. Finally, we propose a simple model for the gas hydrate accumulation system in the NSCS Basin.

1. Introduction

Typical unconventional natural gas is stored in the fine pores and microfissures of reservoir rocks, as well as the gas still cages in the parent rocks (Holditch, 2013; McGlade et al., 2013). However, when the gas diffuses and migrates out of the gas source rocks such as coal, carbonaceous mudstone and mudstone, it will be trapped in reservoirs such as sandstone, conglomerate and limestone. Therefore, conventional industrial gas reservoirs can develop at different scales. Coevally, tectonic migration has not only influenced the formation and evolution of hydrocarbons in the process of rifting of the NSCS Basin (Zhang and Tanimoto, 1993; Suo et al., 2014), but also controlled the subsequent methane hydrate accumulation types and their distribution patterns. Structural styles have played a crucial role in the formation of various types of carbon hydrate gas with conditional factors such as temperature, pressure, saturated water and gas flow (Costa Campos Neto et al., 2011). This paper mainly discusses the formation, accumulation and migration of gas

* Corresponding author. Present address: College of Marine Geoscience, Ocean University of China, No, 238, Songling Road, Qingdao, Shandong, 266100, PR China.
E-mail address: sanzhong@ouc.edu.cn (S. Li).

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hydrate occurring in appropriate structures and the gas source in Mesozoic and Cenozoic strata. This paper focuses on the tectonic evolution of the oil- and gas-bearing basins to offer insights into the process of the occurrence and distribution of gas hydrate, as well as the dominant factors controlling the development of migration pathways and trap geometry associated with the slope and basin sediments. Finally, we will propose a schematic gas hydrate accumulation model presenting the process of hydrocarbon generation to migration.

2. Regional geological setting

The South China Sea (SCS) is surrounded by an extensional margin to the north, a subduction margin to the east, a compressional margin to the south and a transtensional or transform margin to the west (Xie et al., 1995; Yuan et al., 2009). The SCS basins developed and evolved as a result of the kinematics and interactions among the Eurasia Plate, the India–Australia Plate and the Pacific Plate in the Cenozoic (Honza and Fujioka, 2004; Yuan, 2007; Li et al., 2012a). The NSCS basins lie in the central part of the three plates, especially the complex impacts from the earlier collision and subsequent indentation of the India Plate to the Eurasia Plate since the middle Eocene (Li et al., 2013a). Although the division of the evolutionary stages of the NSCS basins is controversial, it is certain that the overall geomorphology of continental margin basins in the NSCS is basically dominated by extensional, strike-slip faults and depressions during the adjacent plate tectonic activities (Yuan et al., 1994a; Li et al., 2012b; Yan et al., 2014; Barckhausen et al., 2014). Cenozoic sedimentary basins controlled by plate motions and tectonic activities, especially by the extension and other dynamic events, are roughly parallel to the NW-striking faults (Li et al., 2013b; Suo et al., 2014). The NSCS is characterized by a wide continental shelf, and an extensive wide and gentle slope and flat land skirt. The NSCS faults and fractures are affected by the opening of the Neo-Tethyan and the Pacific oceans (Lin et al., 2006). Both the east and the west of the NSCS were reconstructed by the late multi-stage tectonic activities. The lithosphere of these basins underwent normal faulting and uplift, which not only generally presented a regular migration from north to south (Yuan et al., 1994; Barckhausen et al., 2014), but also was separated by the NW- and NE-striking faults into mosaic-like blocks, like a chessboard distribution pattern (Fig. 1).

The oil and gas reservoir zonations are closely associated with the tectonic migration. Tectonic subsidence had dominated both sedimentary centres and accumulation space, as well as the depositional capacity (Xie et al., 2014). The crustal thickness decreases from north to south (Yao, 1998). In addition, frequent sea-level changes also controlled the formation and regional distribution of Cenozoic lithofacies and sedimentary strata (Li et al., 2012a). Since the late Miocene, dextral strike-slip faults happened together with markedly thermal subsidence (Cui et al., 2008). These conditions support anomalous Cenozoic marine deposition, with a range from 2000 to 6000 m in thickness (Hu et al., 2014). In addition, a thick Cenozoic succession accumulated in the faulted depression basin. This enabled the preservation and transformation of organic matter, and the formation of reservoir types and traps overlain by

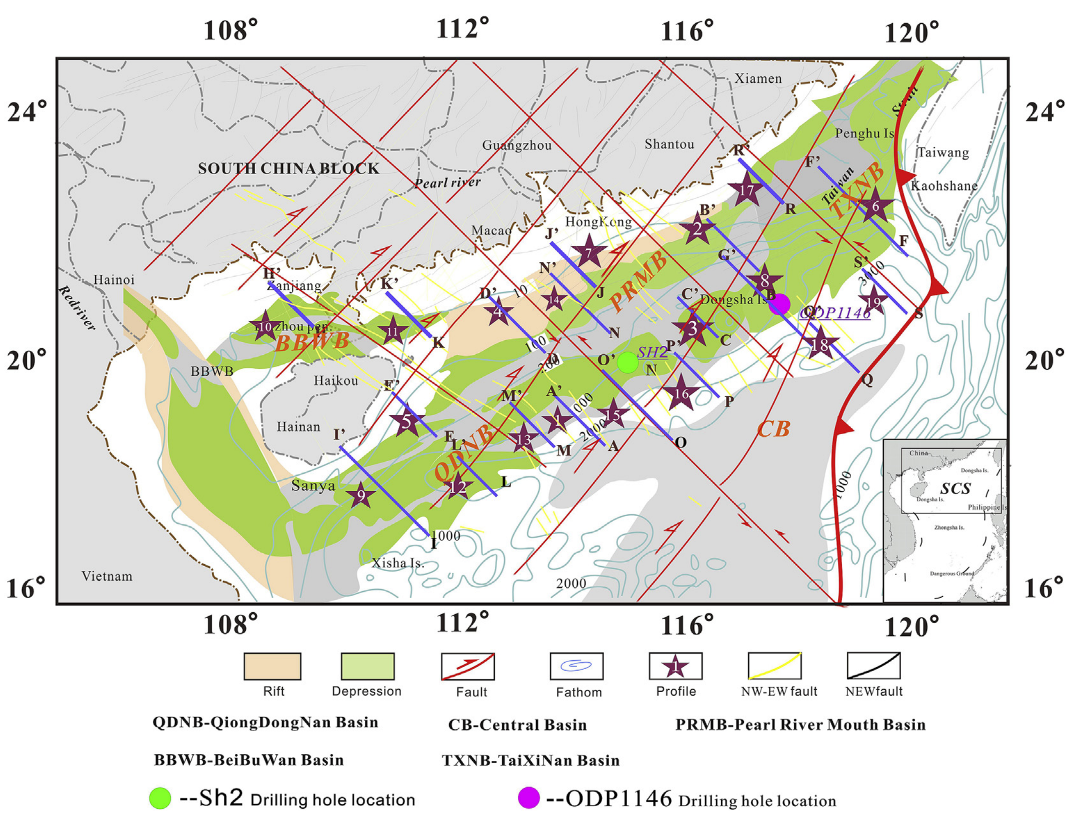

Fig. 1. Geographical location and tectonic settings of the NSCS Basin. Structural division of the basins are NE -and NW- trending faults and strike-slipping faults and resulted in the chessboard distribution pattern of the faulted blocks and basins in the NSCS (Boundary of the basins are after Li et al., 2012a). Depressions and rises in different colours. Numbered stars (1–19) represent the locations of the seismic profiles in the following maps. Green dot represents the drilling hole of SHA in ShenHu while the red dot represents the drill ODP1146 site. The black lines denote these seismic profiles used in this study while the bold red one denotes the main faults. PRMB: Pearl River Mouth Basin; QDNB: Qiongdongnan Basin; BBWB: Beibuwan Basin. The intermediate watermass shows the water moves along from northeast to southwest, northern slope of the SCS.The study area is located on the slope at water depths of 200 m–3000 m. (For interpretation of the references to colour in this figure legend).