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The gas hydrate potential in the South China Sea

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ABSTRACT

Based on the relationship among water depth, sea water temperature, geothermal gradient and geological setting, the gas hydrate potential in the South China Sea (SCS) is estimated. The thickness of the gas hydrate stability zone (GHSZ) and the minimum sea water depth in order to form the gas hydrate structures I (100% CH_4), II (95.9% CH_4) and H (90.4% CH_4) are calculated and defined by the relationship among sea water depth, seawater temperature, geothermal gradient and gas composition. The average thickness of the GHSZ in the SCS is estimated to be 225 m, 270 m and 365 m for the gas hydrate structures I, II and H, respectively. The calculation also shows that the gas hydrate accumulation is at the water depth equal to or deeper than 600 m, 400 m and 300 for gas hydrate structures I, II and H, respectively. Maximum thickness area of the GHSZ in the SCS is also defined in the water depth ranging from 1200 to 2300 m. By assuming that gas hydrate is distributed in one third of the calculated GHSZ area, the volume of gas hydrate reservoir is estimated to contain 1.38×10^{14} m^3, 1.41×10^{14} m^3 and 1.7 10^{14} m^3 of methane gas at the standard temperature and pressure (STP) for the gas hydrate structures I, II and H, respectively.

1. Introduction

Gas hydrate is an ice-like crystal mineral that is formed by water and hydrocarbon gas or non-hydrocarbon (but main composition is CH_4) at low temperature and high pressure (Milkov and Sassen, 2001). Since Makogon (1965) announced first time the presence of gas hydrates in the permafrost regions of the Soviet Union, gas hydrate has attracted massive scientific and, not least political attention ever since the last decades of the 20th century because of their duality as being a potential future energy resource and a threat of geo-hazard and climate change. Most published research indicates that gas hydrate is widely occurring everywhere in the ocean in deeper than 300–500 m water depth and also in permafrost results. Kvenvolden and Rogers (2005) compiled 89 gas hydrate sites in the world, in which consist of 23 locations recovered samples, 63 locations referred from Bottom Simulating Reflector (BSR) and 6 locations interpreted from geological settings. These figures are not totally reliable, but provide a first impression of gas hydrate in the world. While the total amount of hydrated gas is still a matter of dispute, researchers in the world (Klanda and Sandler, 2005) agree that the total amount of gas in this solid form may surpass the total conventional gas reserve, by an order of magnitude. Most current optimistic estimation of the U.S. Geological Survey stated that the global natural gas hydrate reserves are in the range from 100,000 to about 300,000,000 trillion cubic feet comparing with the 13,000 trillion cubic feet of conventional natural gas reserves (Devinder, et al., 2007). Many issues relating to gas hydrate research are investigated around the world, for instance, the global carbon cycle, long-term climate change effects, seafloor stability, hydrate formation and dissociation properties, future energy resource, physical and chemical properties, and global distribution of hydrate (Devinder, et al., 2007). Because hydrates concentrate methane (at STP) by as much as a factor of 164–144, and because less than 15% of the recovered energy is required for dissociation, and while methane is considered as clean energy compared to the other conventional energy sources, hydrate reservoirs have been considered as an important future energy resource.

The South China Sea (Fig. 1) is a region of interaction among three major tectonic plates: the Pacific, Indo-Australian and Eurasian. The collision of the Indian subcontinent with the Eurasian plate in the northwest, back-arc spreading at the center, and subduction beneath the Philippine plate along Manila trench in the east and the collision along Palawan Trough in the south have produced the South China Sea, the biggest margin sea in the western Pacific, about 32 Ma ago (Taylor and Hayes, 1983; Tapponnier et al., 1986; Briais et al., 1993). With the continental slope area of more than 10^6 km^2 and average water depth of 1.2 km, the SCS is viewed by many as a high potential gas hydrate region in the world. Gas hydrate investigation in the SCS has been carried out by Chinese and Taiwanese scientists since 1990s (Guoa et al., 2004). A number of research works presented the geological, geophysical and geochemical evidences of the gas hydrate occurrence in Hoang Sa, South Taiwan Basin and Palawan Trough (Chi et al., 1998, 2006; Chow et al., 2000; Jin and Wang, 2002; Yu et al., 2004; Wu et al., 2005; Wang et al., 2006 and Yang et al., 2006a, 2006b). In 2007, China announced the first time to recover gas hydrate samples at the water depth 1500 m and 200 m below seafloor level in

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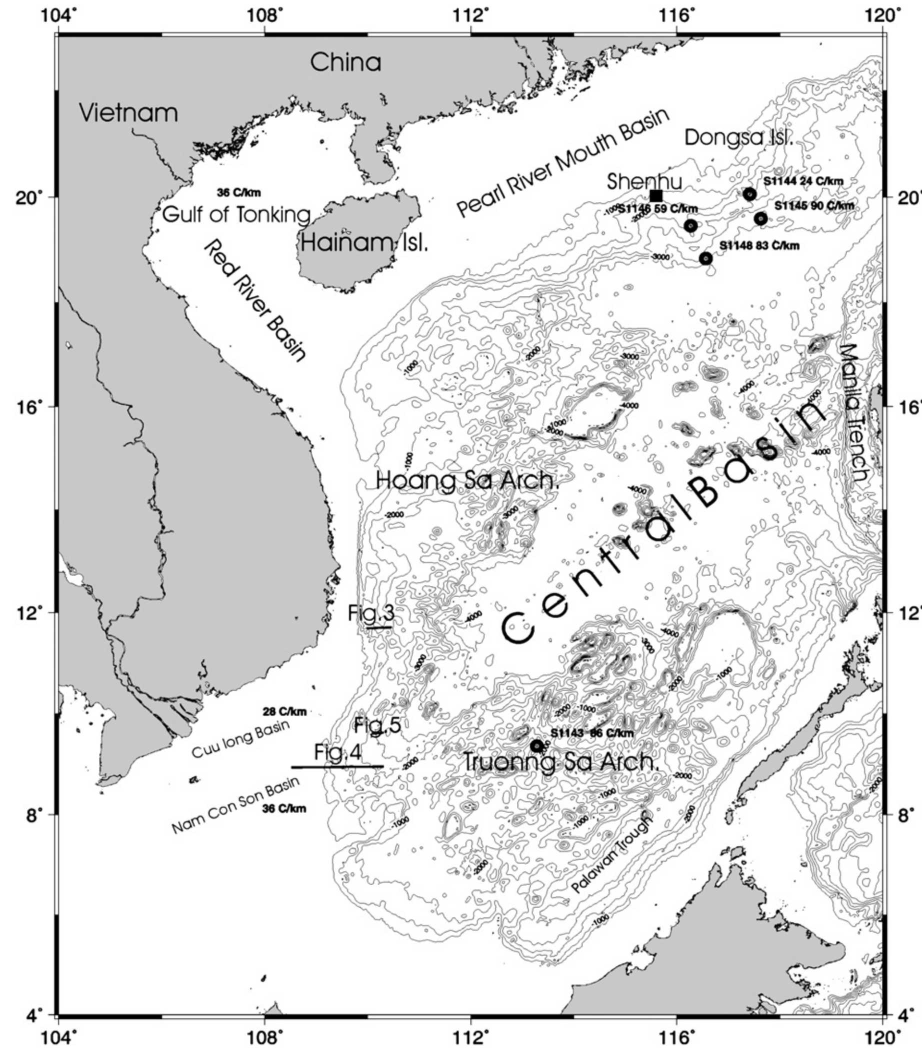

Fig. 1. Bathymetry map of the South China Sea (version 13.1 at http://topex.ucsd.edu/cgi-bin/get_data.cgi, 2009). The SCS has the area of 1.6×10^6 km^2 with a water depth greater than 300 m and the average depth of 1200 m. Lines and respective numbers indicate segments of profile shown in other figures. Black circles are well locations in the continental slope.

the Shenhu area, south of the Pearl River Mouth Basin (Zhang et al., 2007). Most gas hydrate samples so far collected in this area were bacterial methane gas hydrate type I. A number of works (Wang et al., 2006, Yao 2001; Zeng et al. 2003; Chen et al. 2004; Chi et al., 2006) estimated the thickness of the gas hydrate stability zone (GHSZ) and amount of gas hydrate in the SCS using a limited and not updated data of bathymetry, constant geothermal gradient.

New bathymetry data, linear geothermal gradient function and geological and geochemical information on gas hydrate (Smith and Sandwell, 1997; He et al., 2001; Yang et al., 2006a, 2006b; Zhang et al., 2007) allows improvement in the methodology for estimating the volume of gas hydrate methane in the SCS. Main objectives of this study are to: (1) model the thickness of the gas hydrate stability zone by the Milkov and Sassen's method (2001) using linear geothermal gradient function and new bathymetry data. The calculated results are compared to available drilling and BSR data in the region; (2) estimate roughly the volume of methane gas hydrate in the SCS.

2. Favorable geological and geochemical conditions

2.1. Geological setting

The SCS formed during Late Oligocene-Early Miocene (Taylor and Hayes, 1983; Hinz and Schluter, 1985; Tapponnier et al., 1986; Briais et al., 1993) as a result of the collision of Indian subcontinent and Eurasian plate in the northwest, back-arc spreading in the center and subduction beneath the Philippine plate along Manila trench in the east and along Palawan trough in the south. The SCS is a marginal sea bordered to the north and west by passive continental margins, to the east and south by convergent margins. It has an area of 1.6×10^6 km^2 with a water depth greater than 300 m and the average water depth 1200 m. A number of prominent submarine plateaus, submarine ridges, submarine fans, turbidity fans, accretionary wedges and mud diapirs are formed on the continental slopes that are favorable sites for gas hydrate formation, accumulation and conservation. The SCS has 16 Cainozoic hydrocarbon bearing sedimentary basins with the maximum sediment thickness 14,000 m surrounding the continental shelf and slope. Many oil and gas fields have been found in this area such as Red River Basin, Beibu Wan basin, Pearl River Mouth Basin, South Hainam Basin, Phu Khanh Basin, Nam Con Son Basin, Cuu Long Basin, Natura Basin, Sabah–Brunei Basin (Fig. 2). The thick organic-rich sediments may provide an important and necessary source of thermogenic gasses via channels and faults to form gas hydrate at shallower levels. We can see in Fig. 2, there are a lot of deep fault system oriented N–S, NW–SE, NE–SW and volcanoes occurring in the continental shelf and slopes, for example, the Meridian 110° Fault System (110°F, Tuy Hoa Shear Zone (THZ)) in the western margin, Hoang Sa Fault system (F1) in