Marine and Petroleum Geology 77 (2016) 1125–1139

Contents lists available at ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Research paper

Three dimensional seismic studies of deep-water hazard-related features on the northern slope of South China Sea

Duanxin Chen [a, b, *], Xiujuan Wang [a, b], David Völker [c], Shiguo Wu [d], Lei Wang [e], Wei Li [f], Qingping Li [g], Zhenyu Zhu [g], Cuilin Li [a, b], Zhiliang Qin [h], Qiliang Sun [i]

[a] Key Laboratory of Marine Geology and Environment, Institute of Oceanology, Chinese Academy of Sciences, Qingdao, 266071, China
[b] Laboratory for Marine Mineral Resources, Qingdao National Laboratory for Marine Science and Technology, Qingdao, 266071, China
[c] Marum – Center for Marine Environmental Sciences, University of Bremen, Bremen, 28359, Germany
[d] Sanya Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences, Sanya, 572000, China
[e] Key Laboratory of Marine Hydrocarbon Resources and Environmental Geology, Ministry of Land and Resources, Qingdao Institute of Marine Geology, Qingdao, 266071, China
[f] Institute of Geosciences, Kiel University, Kiel, 24118, Germany
[g] Beijing Research Center, China National Offshore Oil Corporation, Beijing, 100027, China
[h] Tianjin Research Institute for Water Transport Engineering, M.O.T, Tianjin, 300456, China
[i] Faculty of Earth Resources, China University of Geosciences, Wuhan, 430074, China

A R T I C L E I N F O

Article history:
Received 2 January 2016
Received in revised form
30 July 2016
Accepted 15 August 2016
Available online 18 August 2016

Keywords:
Deep-water hazard-related features
Mass transport complexes
Fluid flow
Gas hydrate
Gas chimney
Mud volcano
Pockmark
South China Sea

A B S T R A C T

Mass transport deposits and geological features related to fluid flow such as gas chimneys, mud diapirs and volcanos, pockmarks and gas hydrates are pervasive on the canyon dominated northern slope of the Pearl River Mouth basin of the South China Sea. These deposits and structures are linked to serious geohazards and are considered risk factors for seabed installations. Based on high resolution three dimensional seismic surveys, seismic characteristics, distributions and origins of these features are analyzed. A distribution map is presented and geometrical parameters and spatial distribution patterns are summarized. Results show that various groups of the mapped features are closely tied to local or regional tectonism and sedimentary processes. Mass transport complexes are classified as slides near the shelf break, initially deformed slumps on the flanks of canyons and highly deformed slumps on the lower slope downslope of the mouth of canyons. We propose them to be preconditioned by pore pressure changes related to sea level fluctuations, steep topography, and fluid and fault activities. Gas chimneys are mainly located in the vicinity of gas reservoirs, while bottom-simulating reflectors are observed within the gas chimney regions, suggesting gas chimneys serve as conduits for thermogenic gas. Mud diapirs/volcanos and pockmarks are observed in small numbers and the formation of pockmarks is related to underlying gas chimneys and faults. This study aims at reducing risks for deep-water engineering on the northern slope of South China Sea.

1. Introduction

Since 2000, the Pearl River Mouth basin (PRMB) on the northern slope of the South China Sea has become an important target area for deep-water exploitation of energy resources (Pang et al., 2007; Zhu et al., 2009; Zhang et al., 2012). In 2006, the first deep-water gas field of China, the LW3–1 field with a proven resource of >50 billion m^3 was discovered in a water depth of about 1500 m (Zhu et al., 2009; Zhu, 2012). Over the last decade, more deep water oil and gas fields were discovered, such as the gas field LH34–2 in 2009, LH29–1 in 2010, LS22–1 in 2010, and LS33–1 in 2011 (Zhu, 2012). Three gas hydrate drilling expeditions were conducted in the PRMB and various types of gas hydrate samples have been acquired by the Guangzhou Marine Geological Survey (GMGS) in 2007 (GMGS-1), 2013 (GMGS-2) and 2015 (GMGS-3) (Zhang et al., 2007, 2014, 2015; Li et al., 2015; Yang et al., 2015a). The continental slope hosts a variety of dynamic sedimentary processes, such as sediment gravity flows, fluid flow and formation of gas hydrates (Hovland et al., 2002; Shanmugam, 2003; McConnell et al., 2012;

* Corresponding author. Key Laboratory of Marine Geology and Environment, Institute of Oceanology, Chinese Academy of Sciences, Qingdao, 266071, China.
E-mail address: chenduanxin07@qdio.ac.cn (D. Chen).

http://dx.doi.org/10.1016/j.marpetgeo.2016.08.012
0264-8172/

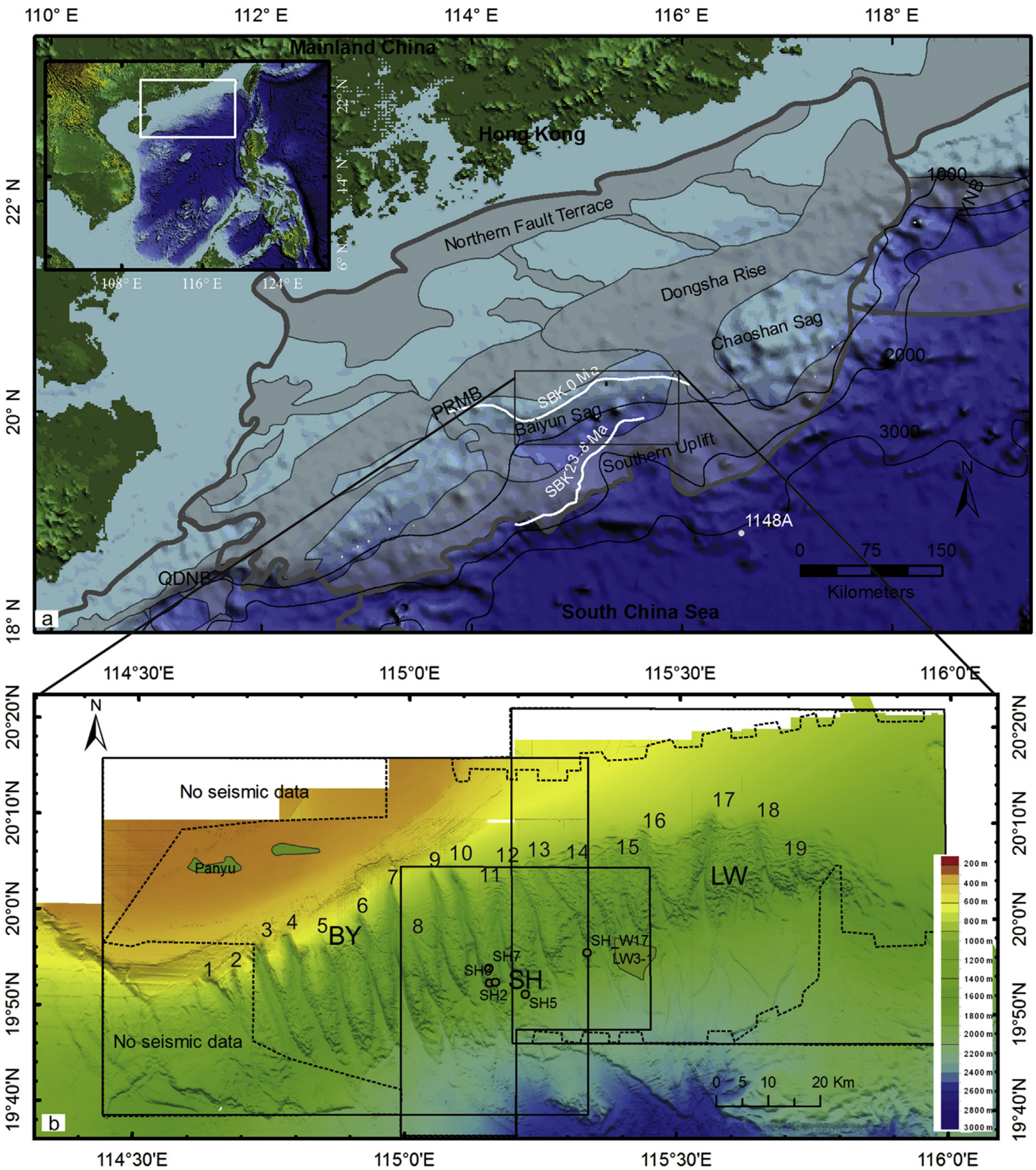

Fig. 1. The location of the study area in PRMB. **a** The study area is centered in the Baiyun sag of PRMB, on the continental slope of northern South China Sea. The shelf break line before 23.8 Ma (SBK 23.8 Ma) is drawn according to Liu et al. (2011) and the present shelf break line (SBK 0 Ma) is delineated based on the high resolution bathymetric map. **b** The locations of three 3D seismic surveys, Liwan—LW, Baiyun—BY and Shuihewu—SH are indicated by two rectangles and one polygon with solid lines. The study area is amplified on the high resolution bathymetric map derived from 3D seismic data. Areas with green color represent the locations of gas fields. Partial sites of gas hydrate sites during GMGS-1 are labelled and gas hydrates are successfully sampled at sites SH2, SH3 and SH7. Site SH_W17 was drilled during GMGS-3. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Vanneste et al., 2014). These processes are potentially linked to geohazards and are considered as risk factors for drilling.

More specifically, mass transport complexes (MTCs) are products of gravity-driven transport, and include slides, slumps and debrites (Dott, 1963; Moscardelli and Wood, 2008). Debrites are difficult to identify in low resolution seismic data, but slides, lightly deformed slumps and highly deformed slumps are well distinguishable in seismic profiles (Weimer and Slatt, 2007; Moscardelli and Wood, 2008). Buried MTCs are generally overcompacted, which can cause a decrease in drilling rate as well as problems with the conductor pipe. Additionally, differential degrees of consolidation between MTCs and the overlying and underlying sediments can also cause trouble with pipeline layout (Shipp et al., 2004; Weimer and Slatt, 2007). Mud diapirs/volcanos are commonly produced by the release of high-pressure fluids (Vanneste et al., 2014) which can seriously reduce the sediment shear strength and cause shallow sediment deformations, potentially damaging seabed installations and triggering submarine slope failure. Gas chimneys and pockmarks show us there is focused fluid flow, which could compromise seafloor stability and bring serious risks to seabed foundations and pipeline security (Hovland et al., 2002; Judd and Hovland, 2007). The presence of gas