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Research paper

Gravity-flow deposits and their exploration prospects in the Oligocene Dongying Formation, northwestern Bozhong Subbasin, Bohai Bay Basin, China

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ABSTRACT

Gravity-flow deposits are important hydrocarbon exploration targets in most basins. In this study, an integration of geological, geophysical, and geochemical analysis is used to investigate the gravity-flow deposits and their petroleum prospects in the Oligocene Dongying Formation (E_3d), Bozhong Subbasin, Bohai Bay Basin. Mass-transport deposits (MTDs) and channel-lobe complexes are the main gravity-flow depositional units. The mass-transport deposits (MTDs) show hummocky and chaotic reflections with poor continuity and variable amplitude. The channels display linear geomorphology with weak root-mean-square (RMS) amplitude, and the lobes are dominated by high-continuous and high-amplitude reflection at the terminal channels. The formation of gravity-flow deposits is primarily controlled by high sedimentation rate during a relative lowstand of lake level.

The E_3d_3 source rock has TOC contents in the range of 0.6–3.1%, Rock-Eval S_2 values in the range of 0.7–19.8 mg HC/g rock, and Hydrogen indices (HI) in the range of 100–600 mg/g TOC. The $E_3d_2^L$ source rock has TOC contents ranging from 0.5 to 1.9%, Rock-Eval S_2 values from 0.4 to 7.8 mg HC/g rock, and HI from 40 to 480 mg/g TOC. Both E_3d_3 and $E_3d_2^L$ source rocks have good hydrocarbon-generation potential. The E_3d_3 and $E_3d_2^L$ source rocks have entered the oil-generation peak window with the vitrinite reflectance (R_o) higher than 1.0%. Oils generated from the underlying source rocks shortly migrated to the overlying gravity-flow lithologic traps. The gravity-flow reservoirs could serve as potential and effective hydrocarbon exploration targets.

1. Introduction

The Bohai Bay Basin is one of China's most petroliferous basins located on its east coast (Fig. 1), accounting for nearly one-third of the total oil production of the country (Hao et al., 2009). The Bozhong sub-basin is the largest generative kitchen in the offshore area (Hao et al., 2009) (Fig. 1). Previous petroleum exploration has mainly focused on the shallow Neogene reservoirs, and more than 25×10^8 tons (18.3×10^9 bbl) reserves have been proven in the Bozhong sub-basin (Hao et al., 2009; Gong et al., 2010). With exploration entering the mature phase, deep reservoirs, such as the Oligocene Dongying Formation (E_3d), will be important exploration targets in the future.

Deepwater gravity-flow deposits have received considerable attention in the petroleum industry. Most hydrocarbon reserves are within deepwater gravity-flow reservoirs, such as channel-fill, levee, sheets, and mass-transport deposits (Weimer et al., 2006; Shanmugam et al., 2009; Gong et al., 2014). Approximately 60% of the oil production in the northern deep Gulf of Mexico is from sheet sands, 25% is from channel-fill deposits, and 15% is from thin beds in levees (Lawrence and Bosman-Smits, 2000). Porosity and permeability in deepwater gravity-flow reservoirs are generally high, because they are commonly fed from mature river systems (Weimer et al., 2006). Lacustrine gravity-flow deposits are also effective hydrocarbon reservoirs (Feng et al., 2010; Zhang et al., 2016; Liu et al., 2016; Corella et al., 2016), although

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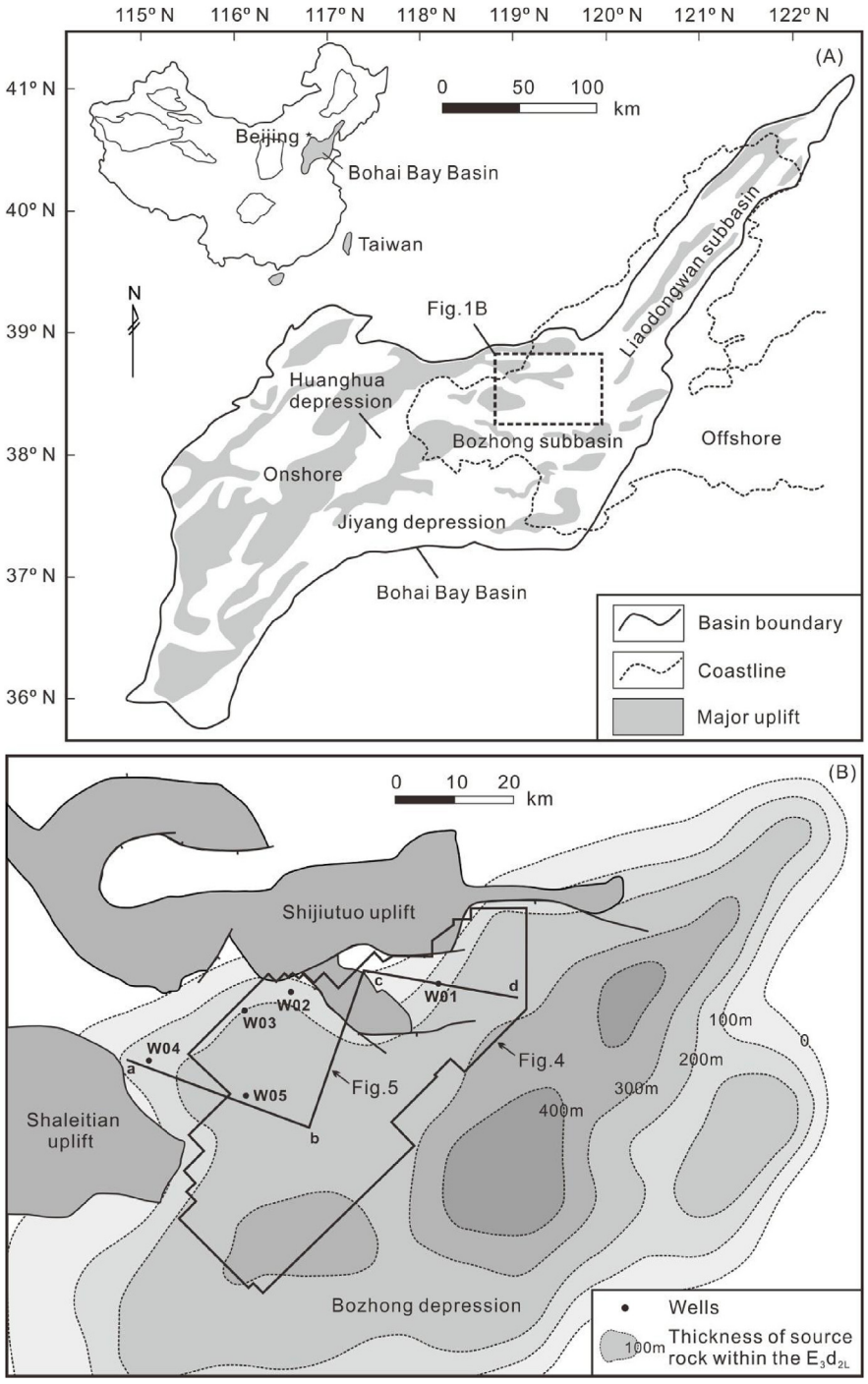

Fig. 1. (A) Location map showing the Bohai Bay Basin. (B) Location of the study area in the Bozhong subbasin, Bohai Bay Basin.

fluvial and delta sandstones are major reservoir types in lacustrine basin (Gong, 1997). For instance, Liu et al. (2016) recently recognized a channel complex in the Huanghua Depression, Bohai Bay Basin, and the channel sandstone has proven to be important hydrocarbon reservoirs. Zhang et al. (2016) described four sets of lacustrine mass-transport complexes, which could serve as potential exploration targets in the Songliao Basin, northeastern China.

In the Bozhong Subbasin, Bohai Bay Basin, the Dongying Formation (E_3d) was deposited in the deep to shallow lacustrine environments, containing a series of gravity-flow depositional systems (Gong, 1997; Dong et al., 2011). The purpose of this paper is to investigate the gravity-flow deposits and their petroleum prospects in the E_3d formations by integrated geological, geophysical, and geochemical data.

2. Geological setting

The Bohai Bay Basin has an area of approximately 200,000 km^2. Above the Cenozoic basement, this basin filling can be sub-divided into two tectono-stratigraphic units (Fig. 2): a rifting stage during the Paleogene and a thermal subsidence stage during the Neogene and Quaternary (Huang and Pearson, 1999; Yang and Xu, 2004; Qi and Yang, 2010; Huang et al., 2012). During the synrift stage (60.5–24.6 Ma), a series of grabens and half grabens developed along major NW and NE trending fault sets (Huang and Pearson, 1999). These grabens and half grabens progressively became one large basin during the late Oligocene, and the Bohai Bay Basin entered the thermal subsidence stage (24.6 Ma to the present).