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Identifying updip pinch-out sandstone in nearshore subaqueous fans using acoustic impedance and the instantaneous phase in the Liangjia area, Yitong Basin, China

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ABSTRACT

Drilling has shown that there is a large petroleum reserve in the Sheling Formation in the Liangjia area of the Yitong Basin from reservoirs of the nearshore subaqueous fan facies. To reduce the risk associated with exploration, the updip pinch-out or isolated sandstone in the nearshore subaqueous fan should be identified and described. Analysis of the 3D seismic reflection, instantaneous phase and acoustic impedance was conducted to identify and interpret the sandstone. Seismic reflection, instantaneous phase and acoustic impedance alone can not clearly identify the updip pinch-out of sandstone in the nearshore subaqueous fan. However, the combination data of acoustic impedance and the instantaneous phase has better detectability (it indicates the ability for identifying sandstone distribution) and is a more reliable indicator of the sandstone distribution than these seismic data alone. The sandstone and the updip pinch-out of the sandstone in the nearshore subaqueous fan can be identified more clearly and directly by the combination data of acoustic impedance and instantaneous phase than the 3D seismic reflection data alone. Combined analysis of the acoustic impedance and instantaneous phase in the sedimentary system is a valid approach for identification and description of the updip pinch-out sandstone or the isolated sandstone that can reduce the risk associated with exploration of lithological traps.

1. Introduction

With the change in exploration from structural traps to lithological traps in China, the ratio of identified lithological hydrocarbon reservoirs is increasing remarkably. Lithological traps have been the primary exploration target during exploration of the Yitong Basin, China (Cai and Li, 2004; Jia et al., 2004; Li et al., 2005). Many exploration cases have confirmed that most lithological traps in China are updip pinch-out reservoirs or isolated reservoirs deposited by nearshore subaqueous fans, fan deltas, river deltas and alluvial fans (Cai and Li, 2004; Jia et al., 2004; Pang et al., 2007; Li, 2008a,b). Therefore, identifying and describing the sandstone distribution in the sedimentary system has become the focus of studies conducted to investigate various aspects of lithological traps exploration (Cai and Li, 2004; Jia et al., 2004; Li et al., 2005; Li, 2008a,b).

It is well known that multi-periods of sandstones exist in the sedimentary system, but the distribution characteristics of these sandstones within the sedimentary system differs completely owing to changing depositional conditions such as sedimentary provenance supplementation, active structures, and changing hydrodynamic conditions. Some periods of sandstone might form litholigical traps characterized by an updip pinch-out or isolated sandstone, while others may not become lithological traps because of their open frame. In Yitong Basin, there are many nearshore subaqueous fans along the footwall of the boundary fault zone in the Sheling Formation (Wang et al., 2008a). Many drilling wells have confirmed that there is a great deal of oil and gas in these fans, but the production of oil and gas drilled by the wells varies from industrial amounts to only their presence. These findings indicate that the nearshore subaqueous fans are not completely filled with oil and gas, and that there are many isolated oil and gas reservoirs in each nearshore subaqueous fan. To reduce the risks associated with exploration, investigations of multi-thin sandstones (called

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sandstone packages in this paper) or single thick sandstone distributions in the sedimentary system have become important since several million tons of oil and gas were found in the Moliqing Depression.

3D seismic and drilling data comprise the primary information used to understand underground geological characteristics. With advances in seismic technology, seismic attributes are being widely applied to predict depositional facies (Wu et al., 2009; Xu et al., 2009; Zhang et al., 2009a), reservoirs (Wang, 2003; Huuse and Feary, 2005; Min et al., 2007; Zhang et al., 2009b; Mabrouk, 2010) and oil and gas reservoirs (Loseth et al., 2009), and these new techniques have improved the exploration efficiency and success rate. Exploration of lighological traps demands finer recognition of reservoir characteristics than is required for depositional facies to reduce the exploration risk; therefore, it is important to develop new ways of clearly and directly identifying updip pinch-outs or isolated sandstone. In this study, acoustic impedance and the instantaneous phase were used together to identify sandstone and updip pinch-outs of the sandstone in the nearshore subaqueous fan based on the identification analysis using the different seismic data alone, after which the updip pinch-out sandstone were interpreted and analyzed.

2. Geological background

The Yitong Basin, which is located in northeast China, is a typical strike-slip basin that belongs to the north segment of the Tanlu strike-slip faults (Fig. 1). The basin is about 300 km long (NNE-SSW) and 10–20 km wide (NW-SE), covering an area of approximately 3400 km^2 (Shi et al., 2008). The Yitong Basin was generated before the Cretaceous period, but was almost completely eroded by structural movement before the Cenozoic period. The basin is primarily filled with the Cenozoic strata of continental facies. The maximum sediment thickness in the basin is in excess of 8000 m in the Cenozoic strata. Drilling exploration has confirmed that there are abundant oil and gas resources in the Yitong Basin, and the updip pinch-out or isolated sandstone is the main exploration type, including millions of tons in Moliqing oil field found in 2008. As a result, lithological traps are the main exploration targets in the study area.

The Yitong Basin is confined by the NNE-SSW boundary faults and crosscut by some NWW faults; therefore, it can be divided into three depressions, the Moliqing Depression, Luxiang Depression, and Chaluhe Depression (Liu, 2003; Sun et al., 2005) (Fig. 1). These three depressions can be further subdivided into ten structural units, including the Liangjia structural belts, based on the basement relief, thickness of sediment and fault activity (Fig. 1).

The geological and geophysical data indicate that the filled strata in the Yitong Basin from bottom to top consist of the Shuangyang Formation, Sheling Formation, Yongji Formation, Wanchang Formation, Qijia Formation, Chaluhe Formation and Quarternary Formation (Fig. 2), which belong to the lacustrine facies deposition. Among them, the Shuangyang Formation, Sheling Formation and Yongji Formation are the primary oil and gas reservoirs. The study area is located in the Liangjia area, which is an important source of oil and gas in the Yitong Basin (Fig. 1). There are

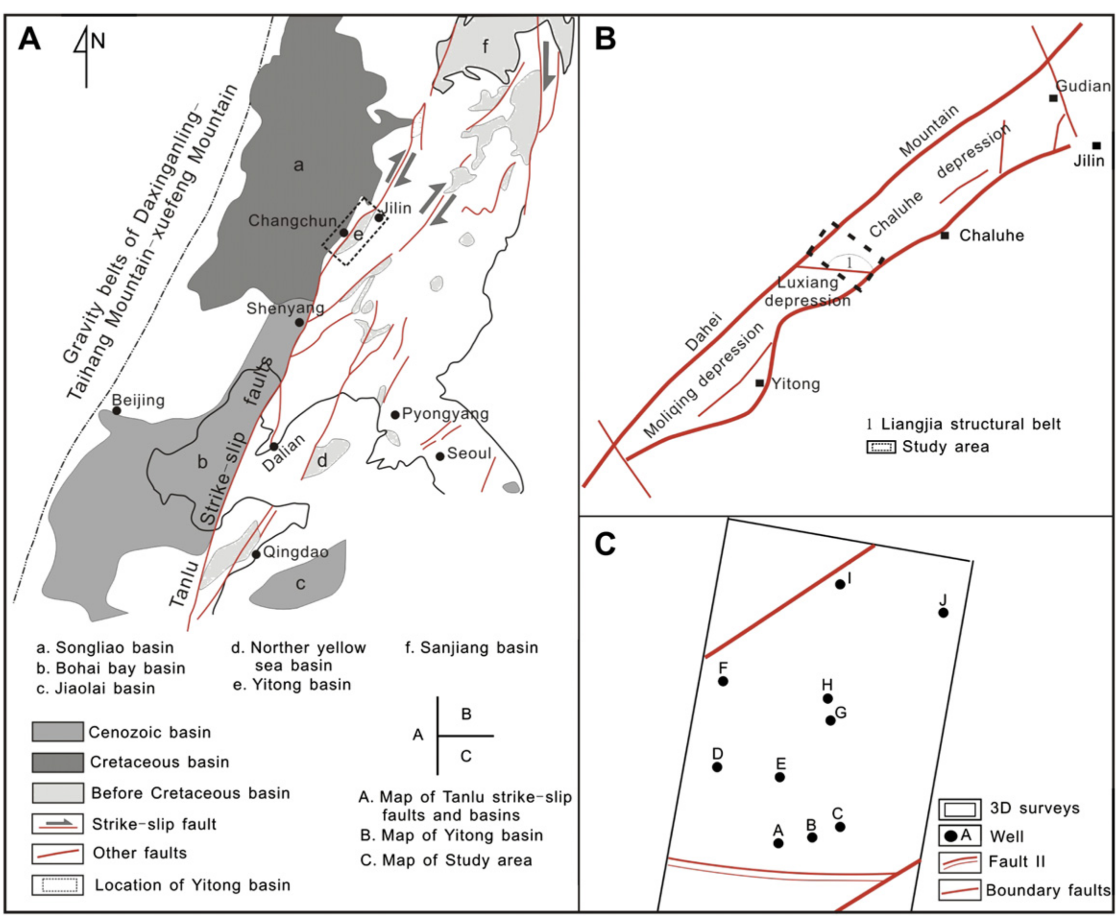

Fig. 1. Map showing the location of the Yitong Basin in eastern China (A), the structural units of the Yitong Basin (B), and wells in the study area (C).