PS A Comparative Study of the Continental Marginal Basins of the Northern South China Sea and Typical Passive Continental Marginal Basins*

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Abstract

After a comparative study of tectonic framework, basin type between the northern continental margin basins of Northern South China Sea and the typical passive continental marginal basins, both are found to have some basic characteristics in common, such as geomorphology, infilling succession of basin, crust characteristics and dynamics of formation. Whereas some differences also appeared, such as the characteristics of the spreading ocean basin, the activeness of their own crusts, tectonic evolution, slope morphology, and structure style of the basin base. So it is reasonable concluded that the northern continental marginal basin belongs to the ‘marginal sea’ type para-passive continental marginal basin.

In comparing the hydrocarbon geology features between them, we conclude that the continental margin basins of Northern South China Sea are non-deepwater reservoir basins. Therefore, the successful deepwater hydrocarbon exploration abroad cannot be applied in most areas of the northern part of the South China Sea, except for the Zhujiang deep-sea fan. So it is necessary to find a new exploration field.

The frontier uplift and associated slope in a complex continental slope setting may be an important and potential hydrocarbon perspective field in ‘marginal sea’ type para-passive continental marginal basins. Good hydrocarbons with large scale developed in this zone, and multiple combinations of reservoir and seal systems developed. The reservoirs in upper rifting sequence and slow depressing sequence are the best potential deepwater exploration areas.

Basic Characteristics of Typical Passive Continental Marginal Basins

To date, the majority of global deepwater hydrocarbon exploration has taken place in passive continental marginal basins, including the Atlantic continental marginal basins and the Gulf of Mexico. The basic characteristics of these basins are: (1) subsidence of the basins are mainly caused by the extension associated with oceanic plate spreading and drifting; (2) the basins are typically located in the junction of continental crust and oceanic crust; (3) tectonic sequences are well developed during drifting stage; (4) the geomorphology of continental shelf to slope and to the related deepwater are fully developed. The northern continental marginal basins of the South China Sea have all of these characteristics, and thus belong to the passive continental margin basin group.

Comparison of Basin Subtypes

Based on the nature of plate extension, passive continental margin basins can be classified into two types: intercontinental spreading basin and continental marginal spreading basin. The former refers to spreading between continental plates which were rifted from the Joint Pangea, while the latter refers to plate's marginal spreading between a micro block and a continental plate. Based on the spreading scale of the oceanic basins, they can be subdivided into two types: broad oceanic spreading basin (i.e., Atlantic) and finite oceanic spreading basin (i.e., Gulf of Mexico and South China Sea). In addition, the basement of these basins can be divided to three types: stable Precambrian cratonic basement, unstable Late Paleozoic Caledonian-Hercynian fold belt basement, and active Alpine fold belt basement. Based on these three types, global passive continental margin basins can be subdivided into four end-members:

Type 1 (South Atlantic): Basins of this type spread between two continental plates along with a broad oceanic and a stable cratonic basement. Their basement structures and seafloor geomorphology are simple and with little volcanic activity. The drift history of these basins is longer, from Cretaceous up to now. The filling sequences of these basins are incomplete, lacking the post-drifting sequences. This type of basin is mainly developed on the margins of the South Atlantic.

Type 2 (North Atlantic): Basins of this type spread between two continental plates along with a broad oceanic and unstable Caledonian-Hercynian fold belt basement. Because of relatively weak basement, basement structures and seafloor geomorphology are more complex than those of the South Atlantic type, with stronger volcanic activity. These basins are mainly developed on the margins of the North Atlantic.

Type 3 (Gulf of Mexico): Basins of this type spread between two continental plates along with a finite oceanic and unstable Caledonian-Hercynian fold belt basement. The spreading process took place very early (160 ma-150 ma) but had only a very short drift stage (10 ma). They were under balanced background for a long time and transformed towards the foreland basin during the

Laramie Orogeny. So, their evolution is more completed than that of the Atlantic type. The continental shelf-slope system is well developed in this type of basin due to significant subsidence. This type only occures in the Gulf of Mexico Basin.

Type 4 (South China Sea): This type of basin spread between a continental plate and an island arc, along with a finite oceanic and active Alpine fold belt basement. Because of the very weak basement, the basement structures and seafloor geomorphology are more complex than those of the Atlantic type and the Gulf of Mexico type, with stronger volcanic activity. The spreading process took place late (30 ma-15.5 ma) and had only short drift stage (14.5 ma). This type only occurs in the South China Sea.

Obviously, there are significant differences between the northern passive marginal basin of the South China Sea and basins of the Atlantic type and the Gulf of Mexico type.

Comparison of Palaeogeomorphy

Because of their relatively stable basement, the Atlantic type basins or the Gulf of Mexico type basins developed, during drifting stage, simple slope with gentle palaeogeomorphy. Generally, water depth increases slowly from shelf, slope, and apron to abyssal plains.

On the contrary, a complicated slope developed during the middle and late stages of the depression phase in the South China Sea type basins. Water depth changes abruptly from continental shelf to abyssal plains (Figure 1 and Figure 2). From the north shelf break to the south abyssal basins, there are many undulating micro-geographic units such as troughs, platforms and seamounts. Based on the palaeotectonic characteristics, several palaeogeomorphic units can be compartmentalized, such as slope-depression intra-uplift ramp, slope-uplift, as well as extra-uplift ramp. The complicated slope is induced by the fact that the basins are located on the margin of the terrenes collage belts and the occurrence of strong basement activities.

Comparison of Sedimentary Facies

Sedimentary facies in the South China Sea marginal basins are similar to those in other typical passive margin basins. Lacustrine and neritic successions deposited in the rifting phase, as well as transitional and neritic successions developed in the early drifting phase or depression phase, are the main facies. Different from other passive margin basins, however, the South China Sea marginal basins lack the development of evaporates during their rifting phase and earlier drifting phase. Significant differences between the South China Sea type basins and typical passive margin basins also exit in the late drifting phase or late depression phase. The terrigenous deepwater deposits, such as submarine fans and abysmal mudstone, are dominant under simple slope background in typical passive margin basins. In the northern passive margin basins of the South China Sea, in contrast, two distinct sedimentary systems developed under the control of special palaeogeomorphology of the complex slope. Deepwater terrigenous clastic sedimentary systems developed in the northwest slope-depression, while shallow-water carbonates developed in the southeast slope-uplifts, such as the Xisha Platform and the Zhongjiannan Platform.

Comparison of Petroleum Geology Conditions

In typical passive margin basins, the majority of hydrocarbon exploration is carried out in slope-depressions, and their basic petroleum geological conditions can be summarized as follows: (1) Source rocks are mainly lacustrine mudstones deposited in the rifting phase. Part of the marine mudstones deposited in the early depression phase also contribute to source rocks; (2) Submarine fan sandstones developed in the late depression phase constitute the main reservoir; (3) The major type of source-reservoir-cap assemblage is generation lower and reservoir upper. The main migration pathways are faults and diapiric structures; (4) Large-scale composite traps related to deep gravity structure and gravity-flow sands are the primary trap types.

The petroleum geologic conditions of the slope-depressions in the northern part of the South China Sea are similar to those in typical passive margin basins mentioned above. Using the exploration models of typical passive margin basins, great discoveries have been found in the Miocene submarine fan sand in the structures of LW3-1, LH34-2, and LH29-1 and other structures in the deepwater areas of the Pearl River Mouth Basin. Previous studies have indicated that hydrocarbon was generated from Eocene-Oligocene lacustrine mudstones in the rifting sequence, and the main reservoirs are submarine fan sandstones. This suggests favorable exploration potential in the passive margin basins of the northern South China Sea.

The slope-uplifts and ramps of the northern continental marginal basins of the South China Sea cover a large area, which is considered a new potential field for hydrocarbon exploration. This area has very thick Paleocene successions in the rift basins, and analysis of seismic facies indicates favorable hydrocarbon generation conditions. The lack of development of deepwater gravity-flow reservoirs in late depression phase suggests that successful deepwater exploration models from typical passive margin basins cannot be used in this area. However, during late rift stage and early depression stage high-quality reservoirs such as fan-deltaic sandstones, shoreline sandstones, and biological reef flats are developed. These reservoirs, combined with the regional mudstone cap rocks formed under several large-scale sea-level rise events, provide sets of favorable source-reservoir-cap assemblages. Since the late subsidence stage is short and the overlaying sediment is thin in the slope-uplifts, these reservoirs can be drilled at economic depth; this is the biggest difference from the conditions in slope-depressions. Large drape anticline traps and structural-lithologic composite traps more easily form in this area.

Conclusions

The northern continental margin basins of the South China Sea are a subtype of passive continental margin basins. They, however, have significant differences from typical passive continental margin basins. Petroleum geologic conditions of slope-depressions in the northern part of the South China Sea are similar to those in typical passive marginal basins. The slope uplifts with shallow water reservoir systems on the complex slope are an important new field for hydrocarbon exploration in South China Sea, and may be another important new area for ultra-deepwater exploration in typical passive marginal basins.

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Reference

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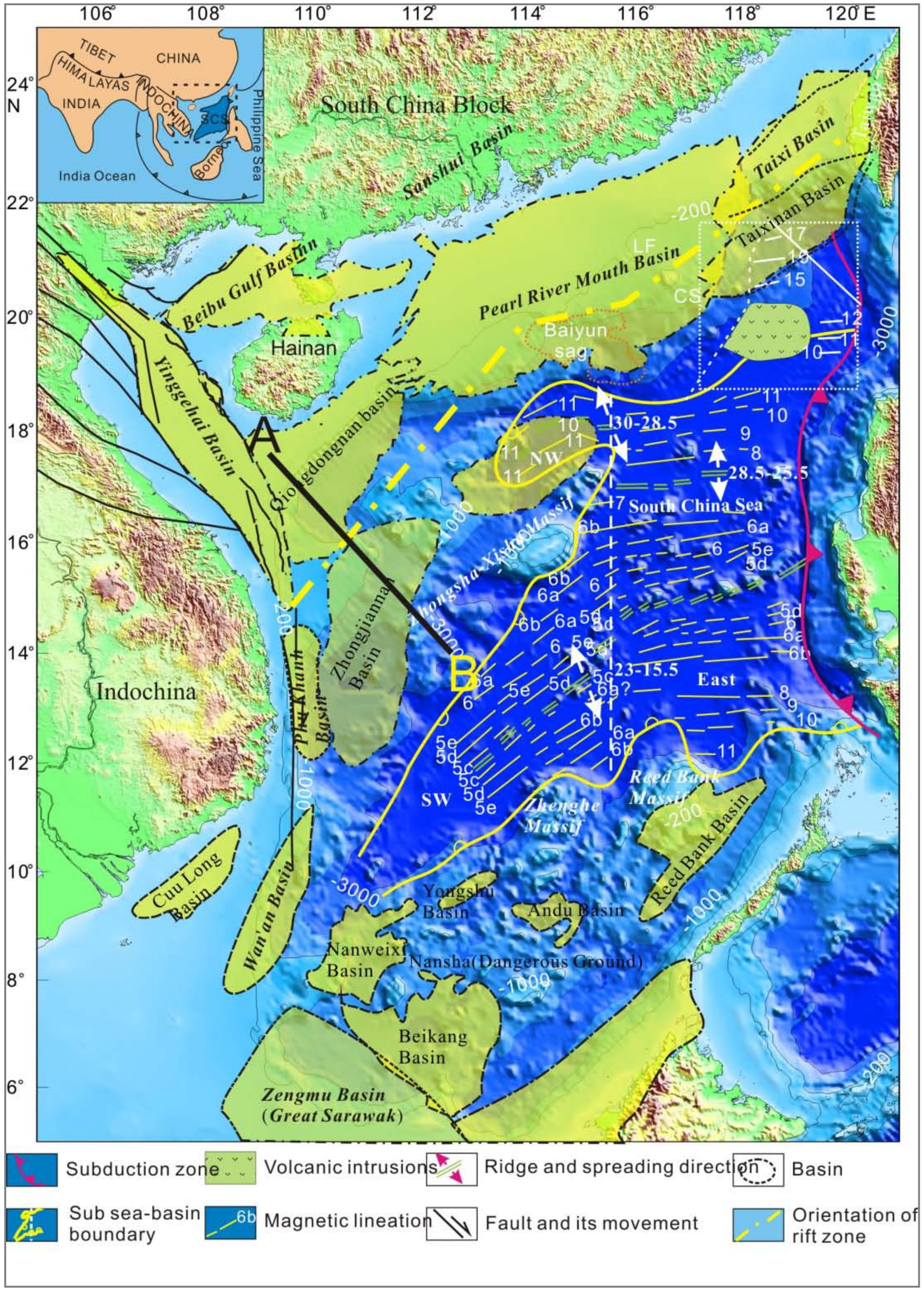

Figure 1. Map showing the tectonic elements of the South China Sea and its neighboring areas (from Sun et al., 2009).

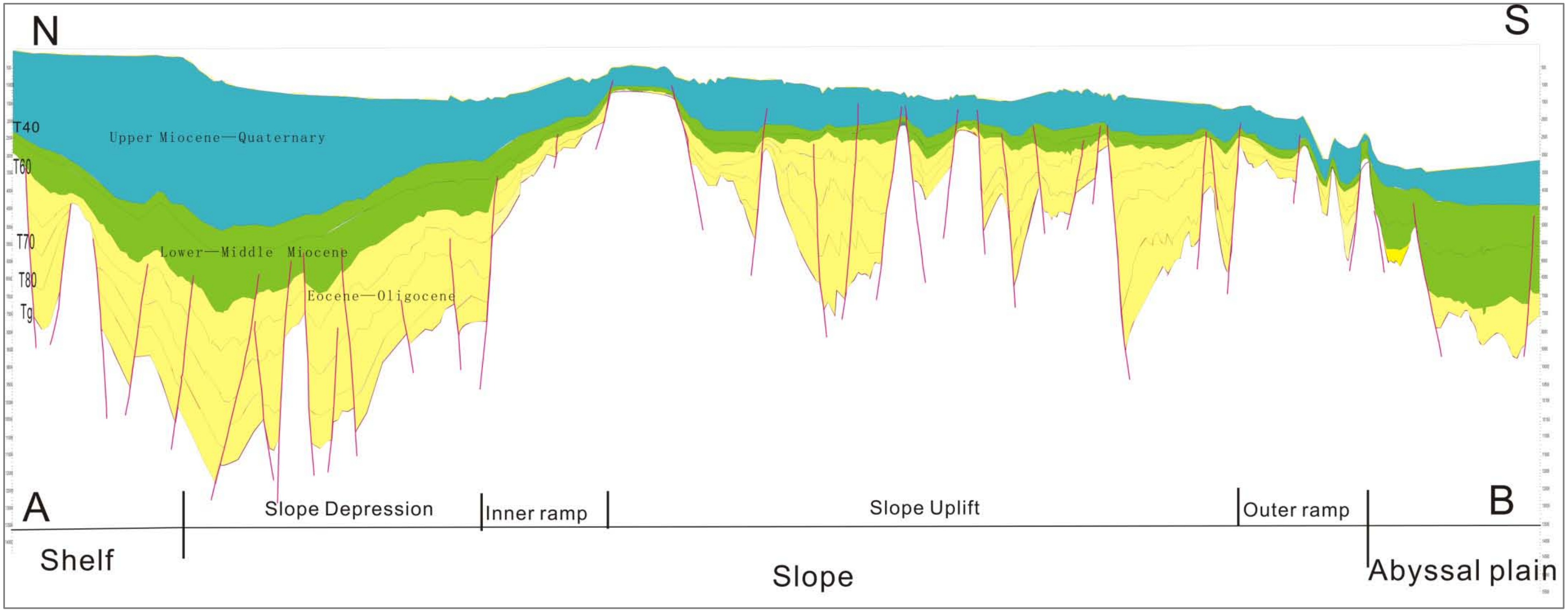

Figure 2. Cross section showing the geological framework of the northern margin of the South China Sea; see Figure 1 for location.