The structural evolution characteristics in the Beikang Basin

Liu Kaixuan[1,2]

[1]*School of Earth Sciences and Engineering, Xi'an Shiyou University, Xi'an, Shaanxi, China*
[2]*Shaanxi Key Laboratory of Petroleum Accumulation Geology, Xi'an Shiyou University, Xi'an, Shaanxi, China*
liukaixuanhm@126.com

Abstract: *The South China Sea is eminently rich in oil and gas resources, but its exploration degree is uneven, with the northern part of the South China Sea having a higher degree of exploration and the southern part having a lower degree of exploration. The Beikang Basin is one of the major petroliferous basins in the southern part of the South China Sea. The tectonic evolution simulation results show that the Beikang Basin was affected by intense regional tectonic activities (Late Paleocene-Middle Eocene, Early Oligocene, and Middle Miocene) through the rifting period, the fault and depression transition period, and the depression period, ultimately formed the present petroliferous-bearing rift basin.*

Keywords: *the Beikang Basin; tectonic evolution*

1. Introduction

The South China Sea is a Cenozoic marginal sea formed by the expansion of the Mesozoic continental margin background, and it is also the largest marginal sea in the Northwest Pacific [1-2]. Under the influence of the Pacific plate, the Eurasian plate and the Indo-Australian plate, the Cenozoic plate of the South China Sea underwent processes such as fragmentation, convergence and collision, and was jointly influenced by the Tethys and Pacific tectonic domains to trigger multi-stage tectonic movements [3-7]. The southern waters of the South China Sea contain rich oil and gas resources and are one of the four major Marine oil and gas accumulation areas in the world, known as "the second Persian Gulf in the world" [8-9]. The Beikang Basin is one of the large Cenozoic deepwater hydrocarbon basins in the southern South China Sea (Figure 1). The tectonic evolution of the Beikang Basin is influenced by regional tectonic movements and is closely related to two seafloor spreading and three major tectonic movements of the South China Sea Basin [6,10-11]. The Cenozoic tectonic evolution of the Beikang Basin has experienced rifting periods (late Paleocene-late Oligocene), fault depression periods (early Miocene - Middle Miocene), and depression periods (late Miocene - Pleistocene) [7,12].

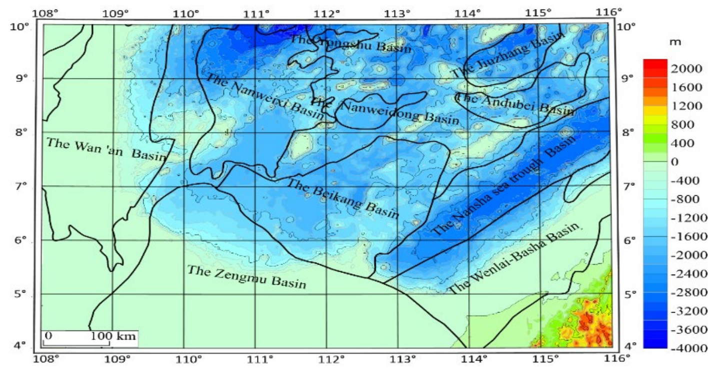


Figure 1: Regional tectonic location map of the Beikang Basin

2. Geological Overview

In the Beikang Basin, Cenozoic strata with complete Paleogene-Quaternary strata were deposited, with a thickness ranging from 1000 to 12000m and a maximum thickness exceeding 12000m [13]. From the end of Mesozoic to the present, the Beikang Basin has experienced six major regional tectonic movements, corresponding to the Liyue Movement, Xiwei Movement, Nanhai Movement, Nansha Movement, Wanan Movement and Guangya Movement [6,11,13-14]. The basement of the Beikang Basin is dominated by Cenozoic metamorphic rocks and medium-acid basic igneous rocks, among which igneous rocks are mainly distributed in the eastern part of the basin. Its basement was built on a stable crystalline basement and was in a state of uplift and denudation for a long time until it began to sink and receive deposits in the early Cenozoic era. It was a continental margin extensional basin formed by crustal stretching and rifting [12,14]. Faults and magmatic activities in the basin are relatively developed, and most of the faults are normal faults, mainly NE and NW trending faults [15]. Carbonate platforms in the basin are mainly developed on the top of volcanic uplift or fault blocks, and are mostly isolated platforms, and faults are often developed at the platform margins, especially in the depression area [8]. During the Miocene period, after the expansion of the South China Sea stopped, the southern part of the South China Sea experienced intra-plate volcanic activity and extensive volcanic uplift was developed in the Beikang Basin, which became the basis for the development of carbonate platforms and reefs. A few volcanic upwelling in some local areas penetrated carbonate platforms, which had a certain influence on the development and diagenetic evolution of the platforms. Nowadays, almost all islands and reefs have volcanic eruption or intrusion activities, so modern reefs also show the growth characteristics of developing on the top of volcanic upwelling [8,16].

3. Analysis of structural evolution characteristics

The two-dimensional seismic data used in this paper comes from the seismic section used in the study of Lei Zhenyu et al [12]. On the basis of seismic section data, the equilibrium section simulation software 2DMove is used to simulate the typical section in the Beikang Basin, complete the structural evolution simulation, and deduce the structural evolution stage and evolution dynamics of this region (Fig. 2). The basic criteria of the software 2DMove's structural recovery are: (1) the rock volume during deformation is basically unchanged; (2) The volume of rock strata is only changed by denudation and sedimentation; (3) The dominant deformation mode is brittle fault; (4) Folds are related to faults. Then, de-compaction, fault spacing elimination, and layer leveling are carried out layer by layer [17]. In this simulation, the NWW-SEE and SSW-NNE profiles of the basin were simulated respectively (Fig. 3).

3.1. Late Paleocene-Middle Eocene stage

The study area was in the initial extensional rift stage during this period. In the early stage of the initial rifting of the basin, the initial maximum deposit is about 5km, and the sediments are mainly clastic sediments, which are generally in a strike-slip extensional state. Several faults are developed in the basin, and the early active faults are mainly developed in the North-East orientation and North-North east directions. Most of the faults are normal faults, the main basement faults and faults gradually slow down from south to north, and the number of second-order faults is small. Among them, the Tingjia fault divides the southeast depression area of the Zengmu Basin and the Beikang Basin. The Tingjia fault makes the north Zengmu Basin develop slowly in the direction of the southeast depression in a slope type, forming the early basic structural pattern of the southeast depression area [6]. At the same time, due to the influence of the Liyue movement [18], tectonic activities caused denudation, resulting in the absence of strata in some areas of the southwest bulge (Fig. 3). The NNE extension rate was about 6.58%, and the SEE extension rate was about 9.6%.

3.2. Middle Eocene stage - Early Oligocene stage

During this period, the study area was in a strong rift period, and was still experiencing the activity of SE-NE extension stress and the strong NE strike-slip effect. The uplift of strata led to the general denudation of the early sedimentary strata, forming an unconformity interface in the basin. The sedimentary volume of the unconformity strata reached about 3km, the sediment continued to fill, and the overall section extension increased, indicating that the tectonic activity was strong at this time. The NNE extension rate was about 5.11%, and the SEE extension rate was about 11.83%.

3.3. Early Oligocene stage - Early Miocene stage

In the Oligocene stage, the Beikang Basin entered the second peak rifting period, the faults formed in the early period were further strengthened and developed, the tectonic activities of the basin were further developed, and the basin area was continuously expanded. This period was the period of the South

ISSN 2616-5872 Vol.6, Issue 2: 20-24, DOI: 10.25236/AJEE.2024.060203

China Sea Movement, and at the same time, the dramatic decline of global sea level had a significant impact on the Beikang Basin [6,12]. Due to this, the early sedimentary strata in the Beikang Basin were denuded and formed a new unconformity profile with a maximum deposition volume of about 3km. The formation of the new South China Sea caused the basin to transform from fault depression to fault depression, and the basin fault depression further expanded. The NNE extension rate is about 3.12%, and the SEE extension rate is about 6.93%, which reflects that the extensional tectonic movement was still dominant in this period.

3.4. Early Miocene stage - Middle Miocene stage

During the early Miocene, the Beikang Basin entered the fault depression transition stage. The South China Sea movement caused the Nansha Block to subduct southward under the Shaba Block [18], while the Zengmu Block moved northward, resulting in compressional uplift of the Beikang Basin and forming a new unconformity. The southwest margin of the Beikang Basin was uplifted strongly, the extensional activities in the basin gradually weakened, and most of the extensional structures ended in this period. According to paleoclimatic data, the Miocene period was mainly in a warm and humid climate, which was conducive to the development of carbonate platforms. Moreover, due to tectonic uplift, the water depth of the basin became shallower, and the carbonate rocks in the basin began to develop, mainly on the uplift or fault block [8]. The NNE extension rate and the SEE extension rate of the basin during this period are about 0.56% and 0.83% respectively, reflecting that the extensional tectonic movement was still dominant in this period, but most of the extensional structures ended in this period.

3.5. Middle Miocene stage - Late Miocene stage

During this period, the tectonic pattern of the Beikang Basin was affected by the Wanan Movement and the second Cenozoic global sea level decline [6], and intra-basin faults, magmatic activities and tectonic traps developed at their peak. The Beikang basin entered the compressional depression stage. A large number of sediments, carbonate platforms and reefs began to develop in the basin [8][12]. The NNE shrinkage rate is 4.09% and the SEE shrinkage rate is about 8.56%, which reflects that the depression and compression were dominant in the basin during this period.

3.6. Late Miocene stage - Early Pliocene stage

In the late Miocene, the Guangya Movement of the South China Sea occurred, during which the strike-slip and compressional effects of the basin gradually weakened, the extensional rate and subsidence gradually decreased, and the basin entered a relaxed depression stage [12]. At this stage, due to rapid sedimentation, the depth of the basin became larger, resulting in the inundation of a large number of carbonate platforms and reefs [8]. At this time, the sedimentary layer in the south and southeast direction of the basin gradually thickened, and a large number of igneous rocks developed. The NNE shrinkage rate is 0.29%, and the SEE extension rate is about 0.48%, which reflects that the basin was still dominated by the depression compression during this period.

3.7. Upper Pleistocene stage – present

At this stage, with the strengthening of subduction of the Philippine plate [6]. NW-SE compression occurred again in the study area, and the basin entered the compressional depression evolution stage again, and the strata were further folded due to compression, indicating strong tectonic activities in the basin. Sandstone and mudstone are mainly developed in the basin, with only a small amount of carbonate platform in the southeastern part of the basin [8]. At this time, the tectonic activity of the basin was still dominated by the depression compression.

ISSN 2616-5872 Vol.6, Issue 2: 20-24, DOI: 10.25236/AJEE.2024.060203

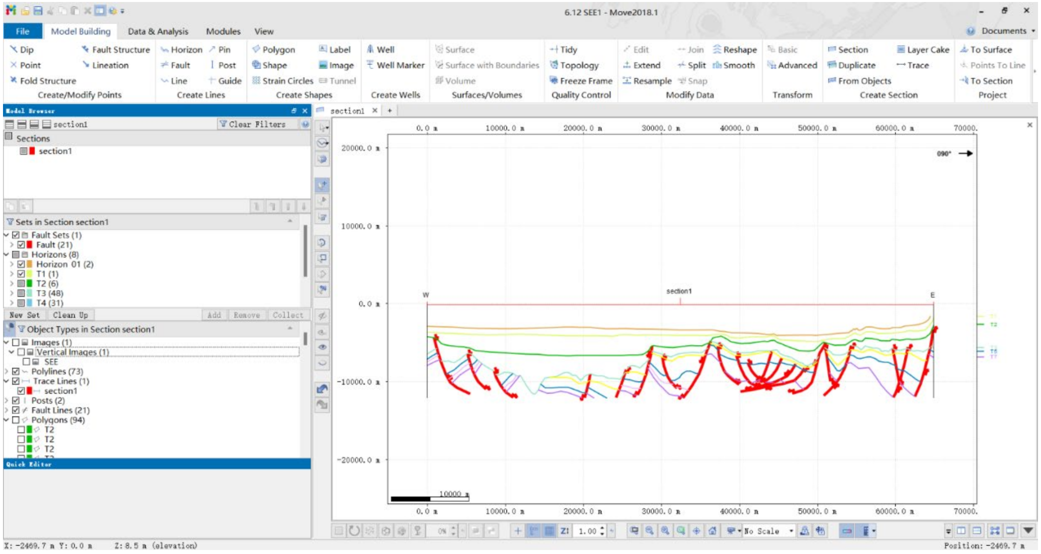
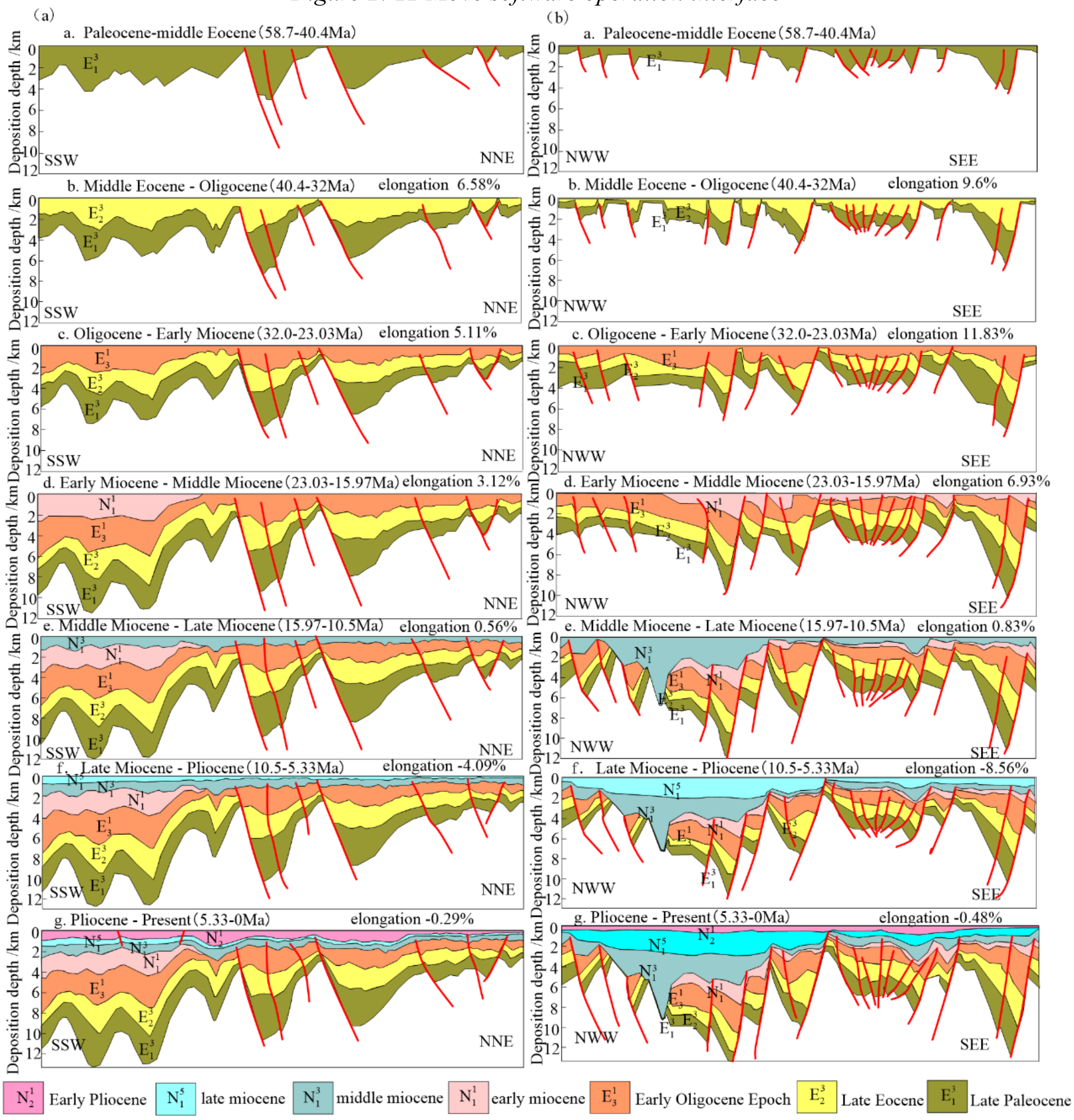


Figure 2: 2DMove software operation interface



(a) The structural evolution of A-A`; (b) The structural evolution of B-B`

Figure 3: The structural evolution of the Beikang Basin

ISSN 2616-5872 Vol.6, Issue 2: 20-24, DOI: 10.25236/AJEE.2024.060203

4. Conclusion

Through structural evolution simulation analysis, it is concluded that the Beikang Basin was affected by intense regional tectonic activities (late Paleocene-Middle Eocene, Early Oligocene, Middle Miocene), which had a profound impact on the formation of rifting basin, and the current tectonic activities in the basin are still dominated by depression compression. In the basin, there are strong volcanic activities and frequent faults, and the volcanic uplift becomes the basis for the development of carbonate platform, biological reef and igneous rock.

References

[1] CHEN Jie, GAO Dezhang, WEN Ning,et al. Characteristics of the Geomagnetic Field in the South China Sea[J]. Progress in Geophys, 2010, 25(2): 376~388.

[2] YAO Bochu. Tectonical evolution on the southern margin of south china sea[J]. Geological Research of South China Sea, 1994(00): 1-15.

[3] Hall R, van Hattum M W A, Spakman W. Impact of India–Asia collision on SE Asia: the record in Borneo[J]. Tectonophysics, 2008, 451(1-4): 366-389.

[4] Zheng H, Sun X, Wang P, et al. Mesozoic tectonic evolution of the Proto-South China Sea: A perspective from radiolarian paleobiogeography[J]. Journal of Asian Earth Sciences, 2019, 179: 37-55.

[5] LIU Baoming, XIA Bin, LI Xuxuan, et al. Southeastern extension of the Red River fault zone (RRFZ) and its tectonic evolution significance in western South China Sea[J]. Science in China (Series D: Earth Sciences), 2006(08): 839-850.

[6] YAO Bochu. Tectonic Evolution of The South China Sea in Cenozoic[J]. Marine Geology & Quaternary Geology, 1996(02):1-13.

[7] SHUAI Qingwei, ZHANG Li, LEI Zhenyu, et al. Age Dating of Main Geological Interfaces and its Significance in Oil and Gas Geology in Beikang Basin[J]. Marine Geology Frontiers, 2020, 36(10):32-41.

[8] YAN Weil, ZHANG Guangxue , ZHANG Li, et al. Seismic responses and distribution characteristics of the Miocene carbonate platforms in the Beikang Basin of southern South China Sea[J]. Marine Geology & Quaternary Geology, 2018, 38(06):118-126.

[9] WAN Ling, YAO Bochu, ZENG Weijun, et al. Lithospheric structure and petroleum distribution in the South China Sea[J]. Geology in China, 2006(04):874-884.

[10] BAI Zhilin, WANG Houjin, GAO Hongfang, et al. Study of local structural features and configuration in major sedimentary basins in the south part of South China Sea[J]. Geophysical Prospecting for Petroleum, 2004(01):41-48+2.

[11] YAO Bochu, WAN Ling, LIU Zhenhu, et al. Tectonic significance and its petroleum effect of the wan'an tectonic movement in the south of the south china sea[J]. Marine Geology & Quaternary Geology, 2004(01): 69-77.

[12] LEI Zhenyu, LIU Xiaofeng, ZHANG Li, et al. Structural Styles and Evolution of Beikang Basin. Southern South China Sea[J]. Geotectonica et Metallogenia, 2021, 45(05):861-874.

[13] LEI Zhenyu, ZHANG Li, SU Ming, et al. Middle Miocene Deep-Water Sediments in The Beikang Basin: Types, characteristics and implications [J]. Marine Geology & Quaternary Geology, 2017, 37(06) :110-118.

[14] WANG Hongbin, YAO BoChu, LIANG JinQiang, et al. Tectonic characteristics and division of The Beikang Basin[J]. Marine Geology & Quaternary Geology, 2001(02):49-54.

[15] LIN Zhen. Interpretation of gravity and magnetic anomalies in the Beikang basin of central Nansha[J]. Gresearch of Eological South China Sea, 2002(00):69-76.

[16] YANG Zhen, ZHANG Guangxue, ZHANG Li, et al. The style and hydrocarbon prospects of reefs in the Beikang Basin, southern South China Sea[J]. Geology in China, 2017, 44(03):428-438.

[17] WEI Kejia, SONG Lijun, WANG Xianhui, et al. Structural characteristics and evolution of the Fairway Basin [J]. Haiyang Xuebao,2020,42(7):139-146.

[18] PEI Jianxiang, ZHANG Cheng, WANG Yahui, et al. Tectonic evolution and depositional response in southern continental marginal basins of South China Sea during period of rift-drift-foreland: A case study from the Liyue Basin[J]. Bulletin of Geological Science and Technology, 2021, 40(2):42-53.