TANG Wu, ZHAO Zhigang, XIE Xiaojun, LIU Shixiang, SONG Shuang, WANG Long, WANG Yibo and GUO Jia, 2018. Variations on Petroleum Geology among Major Basins and Their Formative Mechanisms, Central and Southern South China Sea. *Acta Geologica Sinica* (English Edition), 92(supp.2):103-104.

Variations on Petroleum Geology among Major Basins and Their Formative Mechanisms, Central and Southern South China Sea

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1 Abstract

The South China Sea (SCS), one of the largest marginal seas in West Pacific, has experienced two marginal sea tectonic cycles, the pro-SCS and Neo-SCS, forming a tectonic trend of "compression in the south, extension in the north, subduction in the east and strike in the west", with various kinds of sedimentary basins developed. The Central and Southern South China Sea (CSSCS) mainly has Zengmu, Brunei-Sabah, Wanan, Zhongjiannan, Nanwei, Beikang, Reed, Palawan and Nansha Trough basins (Fig. 1). Since the exploration in the early 20th century, hundreds of oil and gas fields have been discovered in the CSSCS, making it one of giant oil and gas provinces in the world. However, the oil and gas potential of the CSSCS varied a lot, even among adjacent basins. Oil and gas resources in the southern Zengmu and Brunei-Sabah basins are huge in scale, with recoverable reserves of nearly 5.3 billion tons of oil equivalent, which is ten times of that the Wanan basin in the west. The oil and gas discoveries in the Beikang basin on the Nansha block are only one three-hundredth of Zengmu basin. No commercial discoveries have been made in the Reed and Nanwei basins. Although several studies have focused on the petroleum geology of separate basins, no systematical comparison has been made among various basins to reveal their differences and gain an overall perspective, largely due to limited datasets. The present study aims to investigate these aspects, using 90,000-km 2D seismic profiles, 34 well logs, three cores, 36 outcrops, as well as paleontology, gravity and magnetic data.

Results show that based on the difference in the fault system characteristics, the basement lithology and gravity-magnetism-seismic combined inversion of the Cenozoic thickness, the main basins of CSSCS could be divided into three basin groups, each of which display

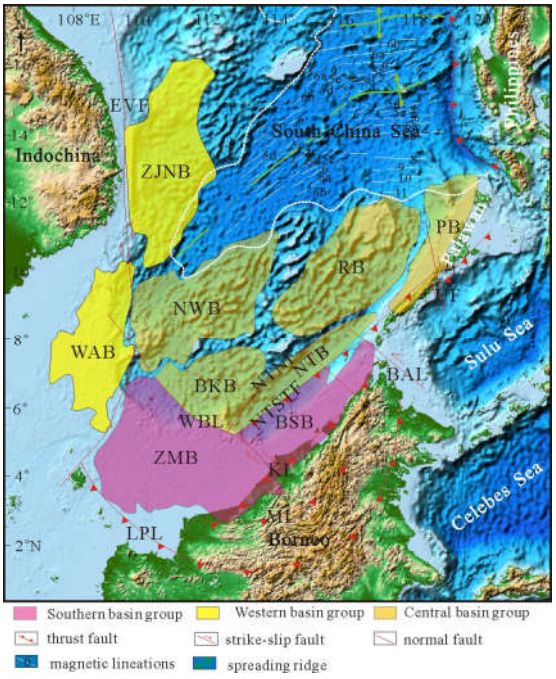

Fig.1 Regional setting map of Central and Southern South China Sea

BSB, Brunei-Sabah Basin; ZMB, Zengmu Basin; WAB, Wanan Basin; ZJNB, Zhongjiannan Basin; NWB, Nanweixi Basin; BKB, Beikang Basin; RB, Reed Basin; NTB, Nansha Trough Basin; PB, Palawan Basin; EVF, East Vietnam Fault; LPL, Lupar Line; ML, Mersing Line; KL, Kanowit Line; NTSTF, Nansha Trough Thrust Fault; NTNF, Nansha Trough Northern Fault; BAL, Balabac Line; UF, Ulugan Fault.

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Table 1 Variations on petroleum geology among major basins, Central and Southern South China Sea

Basin group	Basin	Basin type	Basement	Cenozoic thickness (km)	Main filling strata	Main Sedimantary facies	Main source rocks	Main Reservoirs	Main traps
Southern	Zengmu	Extension-extrusion	Early Cenozoic	3-17	Miocene	Delta-shallow sea	Miocene transitional and terrestrial marine facies (Ⅱ -Ⅲtype kerogen)	Sandstone-carbonate	Structural -stratigraphic or stratigraphic traps
	Brunei-Sabah			5-9					
Western	Wanan	Extension-strike	Mesozoic	2-10	Miocene-Oligocene	Lake-delta-shallow sea	Oligocene-Miocene transitional facies($Ⅱ_2$-Ⅲtype kerogen)	Sandstone	Structural traps
	Zhongjiannan			2-6					
Central	Nanwei	Extension-drifting	Mesozoic -Paleozoic	1-6	Oligocene-Eocene	Shallow sea-Deep sea	Eocene- Oligocene terrestrial marine facies (Ⅲtype kerogen)	Carbonate	Stratigraphic traps

obvious petroleum geology differences(Table1). According to the location, they are southern, western and central basin groups, with superimposed basins mainly developed. The southern basin group (SBG) includes Zengmu and Brunei-Sabah basins which are mainly extension-extrusion type basin developed on the Early Cenozoic folded basement, with commonly thrust nappe structures. The Cenozoic strata of SBG are thick (mainly the Miocene), reaching 10km in average and up to 17km at maximum. The delta, shallow sea and semi-deep sea sediments are developed within SBG, and it has the sedimentary characteristics of “early deep and late shallow”. The source rocks are dominated by the Miocene transitional facies and the terrestrial to marine facies, with II-III type kerogen developed, and the sandstone and carbonate reservoirs are all developed. The near-shore is dominated by structural traps, and the offshore is dominated by tectonic-stratigraphic or stratigraphic traps. The western basin group (WBG) consists of Wanan and Zhongjiannan basin which is mainly extension-strike type basin and the extensional and strike faults are common, formed on the Mesozoic basement. The Cenozoic strata of WBG are relatively thick, ranging 6 to 10 km, with a dominance of Oligocene to Miocene. Lacustrine, deltaic, shallow sea, and bathyal sea sediments are developed within the WBG, displaying a pattern of “early lake and late sea”. The source rocks are dominated by the Oligocene to Lower Miocene transitional facies and II2-III type kerogen, with II1 type kerogen of lake facies locally eloped. Reservoirs are mainly sandstones and the accumulation traps are dominated by structural traps. The central basin group (CBG) consists of Reed, Palawan, Beikang, Nanwei and Nansha trough basins which belong to extension-drifting type basin formed on the Mesozoic and Paleozoic complex basement, with the extensional faults developed. The Cenozoic strata of CBG are relatively thin, the thickness of which ranging 3-6 km, dominated by Eocene to Oligocene. The shallow sea and deep-sea sediments are developed within the CBG, showing a sedimentary patten of “early sandstone and late limestone”. The source rocks are dominated by Eocene to Oligocene terrestrial marine sediments with III kerogen. Limestone reservoirs and stratigraphic traps dominate.

A scissor-style collision of the pro-SCS from west to east during the Eocene to the Early Miocene, together with the opening of the SCS in a serial propagation fashion from east to west during Late Oligocene to Early Miocene, control the petroleum geology difference of three basin groups in the CSSCS. Prior to the Late Eocene, the whole SCS was under the extension stress due to the changes in the direction and rate of subduction of the Pacific plate. Later on, under the joint action of the scissor-pattern closure of proto-SCS and the progressive open of the SCS, the SBG was compressed by the collision of the blocks, and the WBG experienced the strike-slip transformation due to the relative displacement between the blocks, while the CBG split from the southern margin of the South China continent under the continuous extension and drifted to the present position. As a result, the three basin groups significantly vary in basin types, main filling strata, sedimentary environments, ages of the source rocks, types of organic matter, ages and types of reservoirs, formation times and types of traps. This leads to the overall enrichment of oil and gas resources in the south, the less in the west and the least in the central.

Key words

Central and Southern South China Sea; Petroleum geology; Difference; Formative Mechanism; Pro-South China Sea; South China Sea.