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Characteristics of Cenozoic sedimentary formation and tectonic evolution of South China Sea

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Abstract: The Cenozoic sedimentary formation of South China Sea can be classified into three types, namely the stable, substable and unstable types, and two cycles, the Lower (E_1–E_2) and Upper (Q-E_3) cycles by the unconformity of Late Mid-Eocene. In the North and South Continental Margins two sedimentation cycles developed but only the upper one developed in the Central Ocean Basin.

By analyses of the sedimentary formation, it is suggested that Lower Cycle was fill sediment, and mainly fluvial-lacustrine facies; the Upper Cycle was onlap sediment, and was mainly shallow marine or deep ocean. It indicates that the Central Ocean Basin formed after Mid-Oligocene, and the nappe and obduction of Philippines Island-Arc and the counter-clockwise rotation of Kalimantan resulted in the gradual closing of Paleo-South China Sea.

INTRODUCTION

A sedimentary formation is an assemblage body of rocks and facies which had formed under the tectonic situation during a special and continuous time. So different assemblages of rocks and facies display different tectonic situations and sedimentation environments. The sedimentary formations can be classified into three types, namely stable, substable, and unstable. The stable type represents stable continental crustal zone, the substable type represents passive continental margin zone, and the unstable type represents active continental margin and oceanic crustal zone.

SEDIMENTARY BASIN AND SEDIMENTARY FORMATION

The distribution of Cenozoic sedimentary basins in the South China Sea and its adjacent areas is shown in Figure 1. On the basis of geological and geophysical data, the South China Sea can be divided into ten basins. The maximum thickness of the non-metamorphic Cenozoic strata is more than 10 km (Jin, 1989). Potential hydrocarbon traps have been found in some of them, such as, Zhujiangkou Basin, Yinggehai Basin, Beibuwan Basin, Zengmu Basin, Brunei-Sabah Basin and Wananxi Basin (Ho, 1978; Hinz *et al.*, 1985; Jiang *et al.*, 1989).

Based on the characteristics of the sedimentation cycles occurring in different regions, the basins can be classified as craton sedimentary basins (such as Beibuwan Basin), continental margin rift sedimentary basins (such as Zhujiangkou Basin of North Continental Margin), sea-floor spreading sedimentary basins (such as Central Ocean Basin), fore-land sedimentary basins which experienced extension to compression (such as Zengmu Basin of South Continental Margin), and island-arc type sedimentary basins (such as Central Valley Basin of Luzon Island) (Fig. 1). The first basins stand for the stable type, the second stand for the substable type, the third, the fourth and the fifth ones stand for the unstable type.

With the information from drilling (Fig. 2) and seismic strata, the unconformity of Late Mid-Eocene is usually found in the South China Sea (Zhou *et al.*, 1994; Miao *et al.*, 1983), which divided the Cenozoic sedimentary layer into two sedimentation cycles, that is, the Lower Tertiary Cycle or Lower Cycle (Paleocene-Eocene, some including the top of Upper Cretaceous in some areas) and Upper Tertiary Cycle or Upper Cycle (including Upper Oligocene). The Lower Tertiary System in the North Continental Margin of the South China Sea is the continental facies. In middle area of the South China Sea, only the Upper Tertiary System was developed (Fig. 3).

Section AA' (Fig. 3) shows that (1) the North and South Continental Margins are both continental crust; (2) North and South Continental Margins developed two sedimentation cycles; but the Central Ocean Basin only developed the upper one (Late Oligocene-Quaternary sediments), which indicates that Central Ocean Basin formed after the Mid-Oligocene Epoch (Taylor *et al.*, 1980).

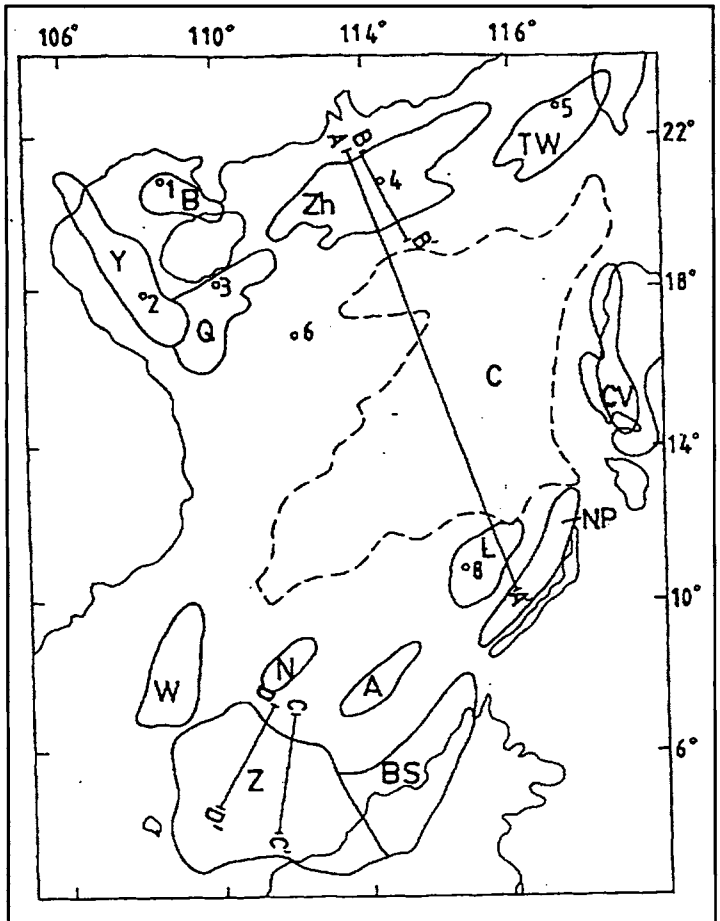
Section BB' (Fig. 4) is the structural section of the Zhujiangkou Basin. The basin is formed by two sedimentation cycles. The lower one was a fluvial-

lacustrine facies, while the upper one was a coastal and shallow marine facies.

Section DD' (Fig. 5) and CC' (Fig. 6) are the structural sections from the Nanwai Uplift to the southern Zengmu Basin. They revealed the upper, middle, and lower structural layers. The upper structural layer corresponds to the Upper Cycle, the middle one the Lower Cycle. The middle structural layer, however, consists of coastal and shallow marine facies, and is different from that of North Continental Margin.

CHARACTERISTICS OF THE SEDIMENTARY FORMATIONS AND THEIR TECTONIC DISTRIBUTION

From the characteristics of the development of strata of the sedimentary formations, the South China Sea can be divided into the five sedimentary zones given below.



Scale: 1:19,000,000

1.	B	—	Beibuwan Basin,	2.	Y	—	Yinggehai Basin,
3.	Q	—	Qiongdongnan Basin,	4.	Zh	—	Zhujiangkou Basin,
5.	T	—	Taixinan Basin,	6.	W	—	Wananxi Basin,
7.	C	—	Central Ocean Basin,	8.	L	—	Liyue Basin,
9.	Z	—	Zengmu Basin	10, 11.	BS	—	Brunei-Sabah Basin,
12.	NP	—	N. Palawan Basin,	13.	CV	—	Central Valley Basin,
	N	—	Nanwei Basin,		A	—	Andu Basin

Figure 1. Cenozoic sedimentary basins of South China Sea and its neighbouring regions.

Beibu sedimentary Zone

This includes the Beibuwan and North Continental Margin sub-zones.

Beibuwan Sedimentary Zone

The Lower Tertiary System comprises sediments of continental facies of lake basins. The Upper Tertiary System comprises sediments of littoral-shelf sea, and there was volcanic sediments. It is a simple zone of single terrigenous debris formation and carbonatite formation and represents the sediments of stable continental craton basins.

North Continental Margin Zone

The Lower Tertiary System involved the sedimentation of isolated lake basins. The Upper Tertiary System comprises sediments of littoral-shelf sea facies, and have obvious characteristics of rhythmic and cyclic sedimentation, and comprises terrigenous debris, carbonatite, paralic coal-bearing strata, continental volcanic rocks, and sea-bottom volcanic rocks, etc. It represents the sedimentation of the substable type and passive continental spreading-rifting basins.

Middle Zone of South China Sea

Only the Upper Cycle was developed, and comprises mainly unconsolidated deep-sea ooze and basic volcanic rocks (the unconsolidated formation of oceanic ooze and oceanic basalt). It represents the sedimentation of the unstable type and oceanic crustal zone.

South Continental Margin Zone

This is divided into the North Belt and South Belt.

North Belt

This includes the Nansha Islands, the south shelf of the South China Sea, Nansha Trough and some parts of their neighbouring land regions. The Lower Cycle is of terrigenous flysch formation which comprises the rhythmic sediments of debris of the littoral-shelf sea. The Upper Cycle comprises terrigenous flysch formations which contain several regressive cycles and carbonatite, molasse formation, paralic coal-bearing formation, and carbonatite formation (Pubilli, 1973). It represents the sedimentation of the unstable type or early spreading-rifting basins and later fore-land basins.

South Belt

This includes the regions of Sabah, Sarawak and South Palawan. The Lower Cycle comprises

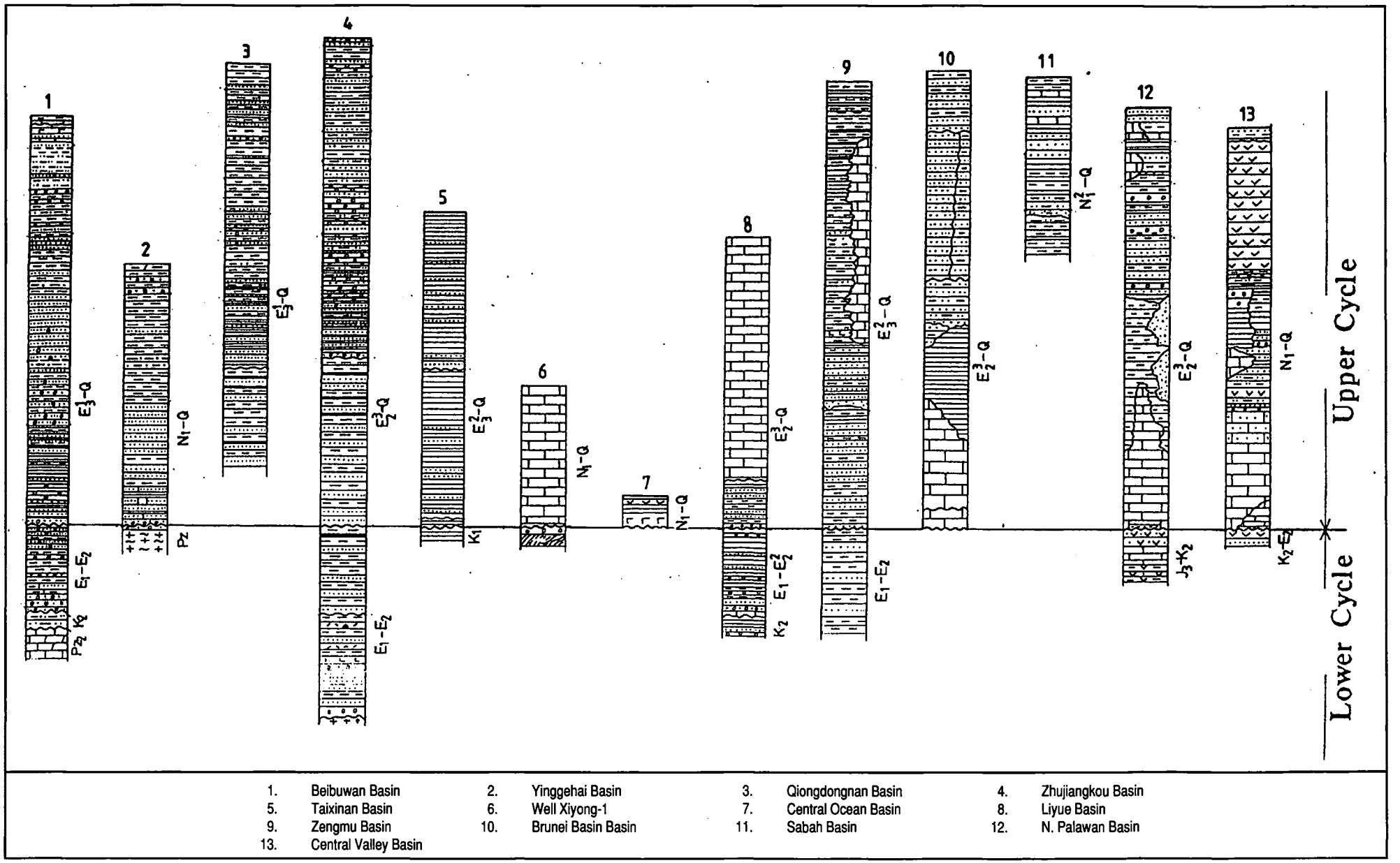


Figure 2. Some typical stratigraphic columns of Cenozoic basins in South China Sea and its neighbouring regions. Their locations are seen in Fig. 1 (after Miao *et al.*, 1989).

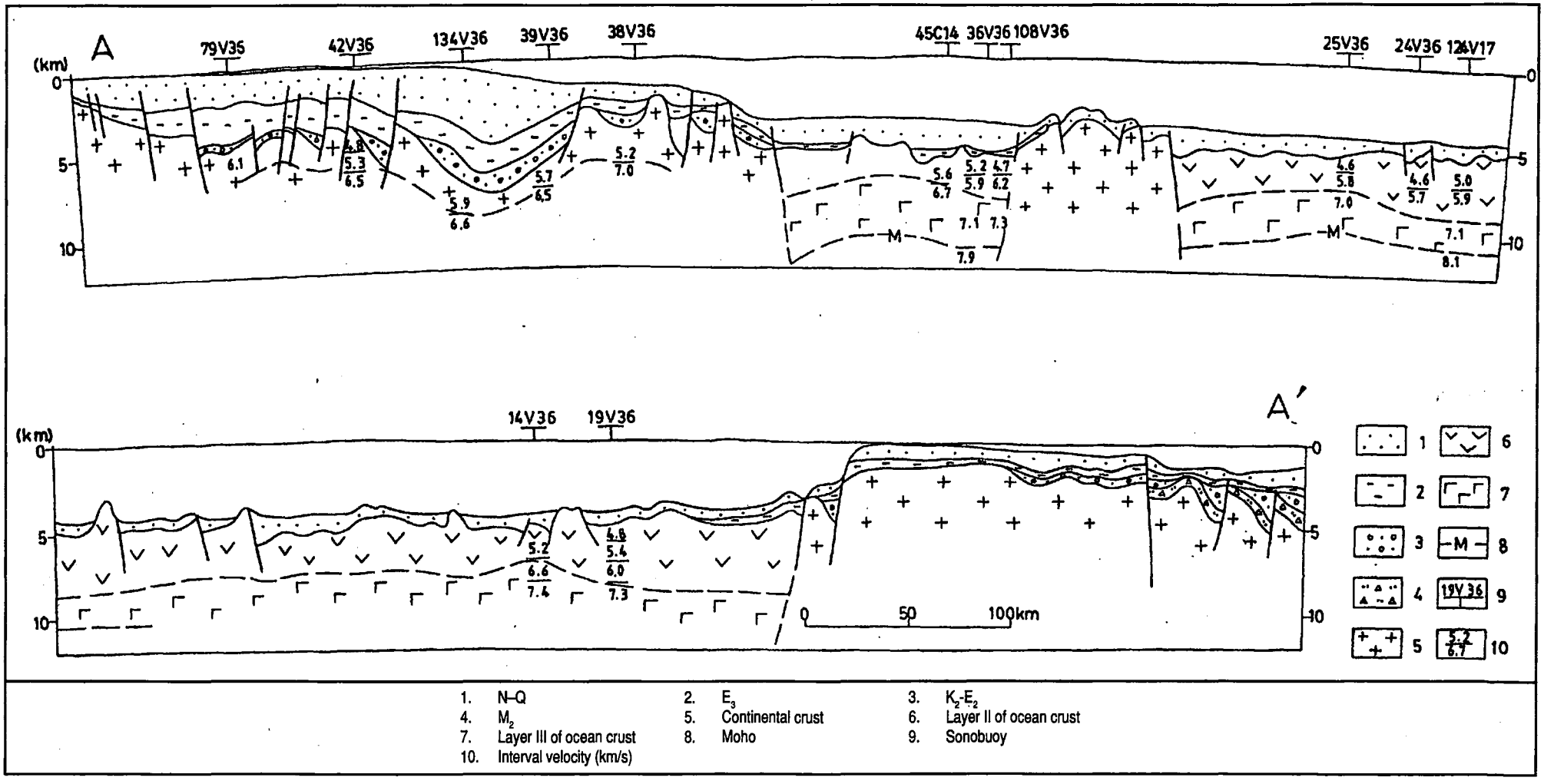


Figure 3. Section AA', its location is seen in Fig. 1 (after Jin, 1984; Zhou *et al.*, 1994).

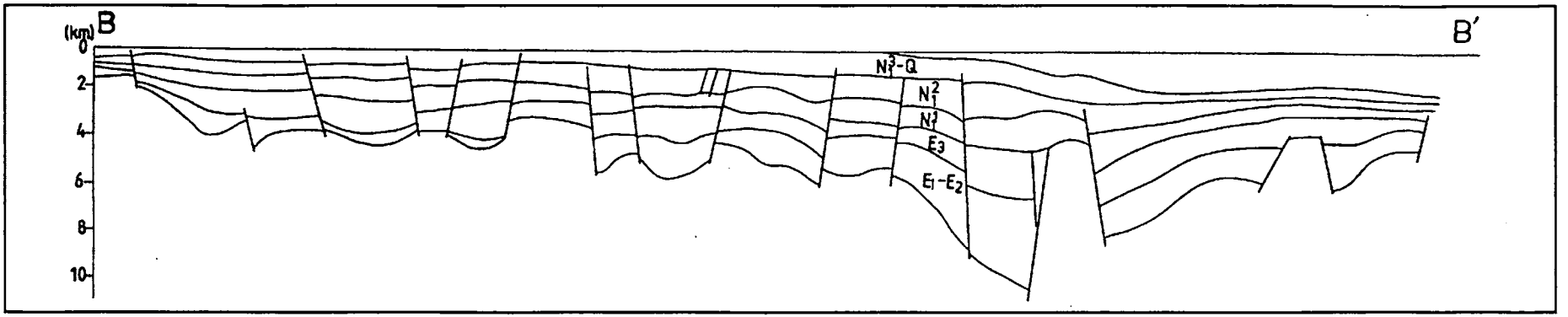


Figure 4. Section BB', its location is seen in Fig. 1.

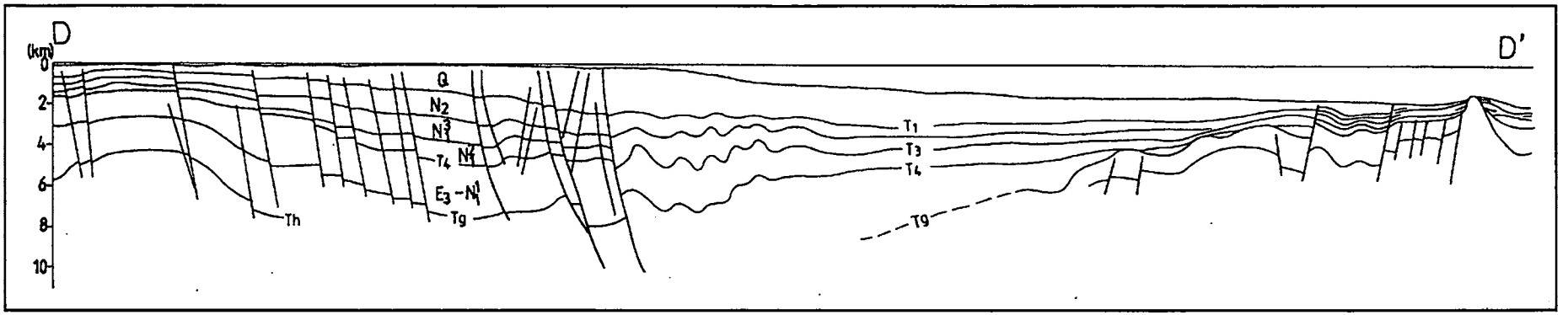


Figure 5. Section DD', its location is seen in Fig. 1.

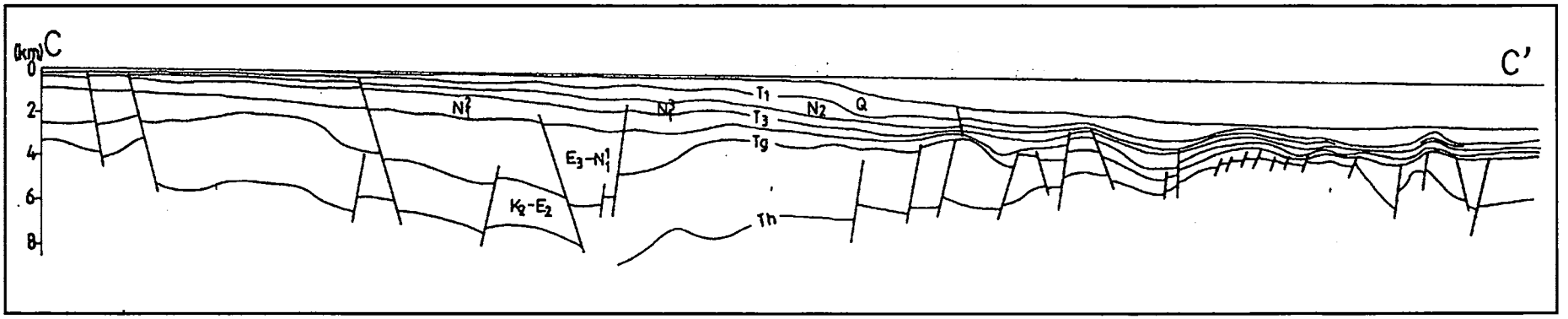


Figure 6. Seismic interpretation of section CC', its location is seen in Fig. 1 (after Jiang *et al.*, 1989).

the formations of deep-sea flysch and ophiolite. It represents sedimentation of the unstable type of slope and oceanic crust. Sibu Movement occurring in Late Eocene, resulted in the collision-orogeny between the Nansha Block and the Continental Nucleaus of Kalimantan, and the strong fold-nappe structure and light metamorphism of the Lower Cycle, and the omission of most parts of the Upper Cycle.

East Sedimentary Zone

This includes the Philippine Islands-East Coast Mountain of Taiwan and its vicinities. The Lower Cycle has already been folded and metamorphised. The Upper Cycle is made up of formations of volcanic sediments and volcanic flysch. This represents sedimentation of the unstable type and island-arc, fore-arc, and inter-arc basins.

West Sedimentary Zone

This includes Yinggehai Basin, Zhongjianxi Basin, Wananxi Basin, and comprises flysch formation. It represents sedimentation of the substable type and shearing-spreading basins.

SEDIMENTARY ENVIRONMENT AND TECTONIC EVOLUTION

From the earlier mention characteristics, Cenozoic sedimentary environments in South China Sea can be divided into two sedimentation cycles E_2^2-E_1 (or partly includes K_2, Fig. 7) and Q-E_3 (or partly includes E_2^3, Fig. 8) by the boundary of the E_2^2 unconformity, which showes characteristics of fill sedimentation in the Lower Cycle, and onlap sedimentation in the Upper Cycle. The North

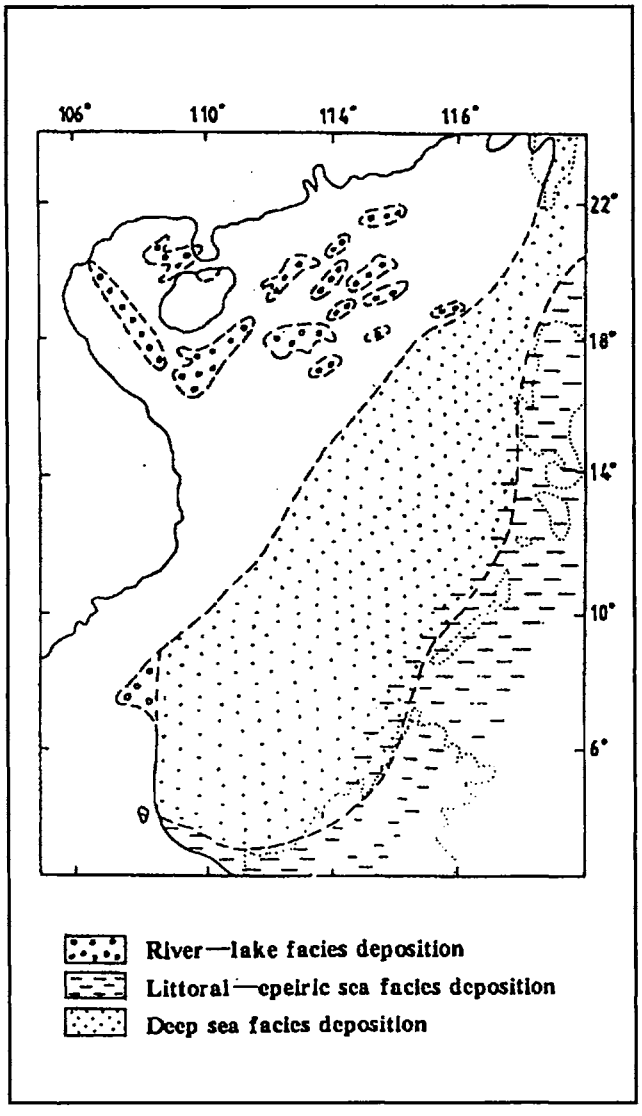


Figure 7. Sedimentary environment of Lower Cycle of the South China Sea in Cenozoic.

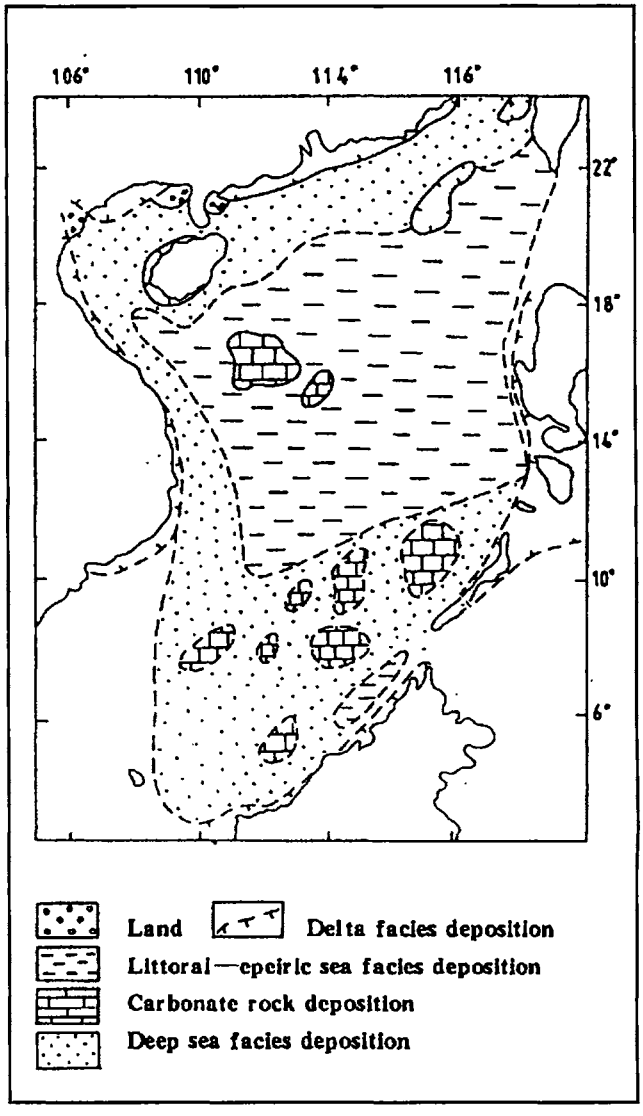


Figure 8. Sedimentary environment of Upper Cycle of the South China Sea in Cenozoic.

Continental Margin developed fluvial-lacustrine facies while the South Continental Margin developed coastal and shallow marine facies. All data showed that when the Lower Cycle was formed, the North and South Continental Margins were connected to each other, and were located at the Indo-China-South China Continental edge, and a Paleo-South China Sea existed in southern Liyuetan. Its sedimentary environment turned from continental to marine sedimentation from north to south of the areas. Source material came from the north. Sea depths got deeper from north to south. The Central Ocean Basin only developed after Mid-Oligocene. That is, the northern area of Zhongyue-Yunqun-Wanan was continental region in Eocene while the southern area of Liyuetan was the region of the Paleo-South China Sea. The Nansha Islands and their southern shelf were epeiric sea. Sabah-Sarawak and their southern areas were regions of the ocean-slope of the Paleo-South China Sea. On the other side of the Paleo-South China Sea was the Paleo-Continental Nucleus of Kalimantan.

After Mid-Oligocene, the North and South Continental Margins were isolated by the Central Ocean Basin which was formed by sea-floor spreading. The Sibu Tectonic Event of Late Mid-Eocene, the Mili Tectonic Event of Mid-Miocene, the counterclockwise rotation of Kalimantan, and the nappe and obduction of NNW direction of the Philippine Islands towards the South China Continent in Late Cenozoic, resulted in the formation of the Sibu Orogenic Belt and fore-land basins in its northern region, and the gradual closing of the Paleo-South China Sea from southwest to northeast.

REFERENCES

HINZ, K. AND SCHLUTER, H.U., 1985. Geology of the Dangerous Grounds, South China Sea, and the continental margin of southwest Palawan: Results of Sonne cruises SO-23 and SO-27, Geology and hydrocarbon potential of the South China Sea and possibilities of joint development. *Energy, 10(3/4)*, 297-315.

HO KIAM FUI, 1978. Stratigraphic framework for oil exploration in Sarawak. *Bull. Geol. Soc. Malaysia, 10*, 1–13.

JIANG SHAOREN, HUANG CILIU, ZHOU XIAOZHONG ET AL., 1989. Interpretation of seismic information and structure features of Zengmu Basin. *In: Comprehensive Investigation and Research Report of Nansha Islands and its Surrounding Sea Areas, Vol. 1.* Science Press, Beijing, 180-199 (in Chinese).

JIN QINGHUAN, 1989. Geology and Oil-gas Resource of South China Sea. *Geology Press*, Beijing, 197–199, 248–291, 374–401 (in Chinese).

MIAO XIANGQING, HUANG CILIU, WANG QILING, 1983. A study of basement structure of Zhujiangkou Basin. *Rep. of South China Sea Inst. of Oceanology, Academia Sinica; and the Nanhai West Oil Corp.*, 1–16 (in Chinese).

PUBILLI, M., 1973. Geological evolution of South China Sea area: Tentative reconstruction from borderland geology and well data. *In: Proceedings of the 2nd Annual Convention, IPA*, 223–241.

TAYOR, B. AND HAYES, D.E., 1980. The tectonic evolution of the South China Sea Basin. The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands. *Geophys. Monograph, 23*, 89–104.

ZHOU XIAOZHONG AND JIANG SHAOREN, 1994. Interpretation and comparison of tectonic stratum of seismic profiles from Liyuetan to Pearl River Mouth. *In: Studied theses of geology-geophysics and island-reef in Nansha Islands and their neighboring region, 2.* Science Press, Beijing, 9–15 (in Chinese).

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