THE AGE OF THE SOUTH CHINA SEA TERRAINS RIFT-DEPARTING FROM SOUTH CHINA CONTINENT *

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ABSTRACT

The terrains in the South China Sea were a part of the Southeast China continent, and their rift-departing process dominated the formation and evolution of the South China Sea. The survey results of topography and paleoenvironment of the northern South China Sea during SO-49 cruise demonstrate that the terrains rift-departed from the South China continent before early Eocene.

INTRODUCTION

Some geologists considered that the Nansha Islands were a part of the Southeast China continent, but they held different viewpoints about the time of the terrains rift-departing from the South China continent. Jin (1989) considered that the basement of the Xisha, Zhongsha, Nansha terrains and the South China continent all consist of the Proterozoic formation. In Cretaceous the Nansha terrain was connected with the South China continent, and the South China Sea Basin was formed with the first sea-floor spreading from Late Cretaceous to Eocene.

During SO-49 cruise in 1987, topography data and manganese crust samples had been obtained from the northern slope of the South China Sea. Comparison of the depth of break points on the slope with net subsidence curve from wells in the Pearl River Mouth Basin and paleoenvironment information contained in manganese crust show that the terrains rift-departed from the South China continent before early Eocene.

THE FEATURES OF THE NORTHERN SLOPE OF THE SOUTH CHINA SEA

A topographic, geological and tectonic synthetical profile of the northern slope of the South China Sea is shown in Fig.1. This profile is located between the continental margin and the deep sea basin and perpendicular to isobath with the length of 198 km, height difference of 3555 m, average slope of 18 / 1000.

The sea-floor relief on this profile is gentle at upper and steep at lower and consists of 9 steps. The data of their steps are shown in Table 1. The seismic profile shows that the southeastward tilting basement was rifted and slid down along the faults and a series of skip basins were formed. The sediment layers in the basins slope southeastward indicate that the

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steps on the slope were formed by southeastward extension and depression while sediment was deposited. According to the paleomagnetic data, Emery (1983) considered that the East Asia has drifted about 400 km southward since Paleocene. Therefore, topographic features and tectonic structures on the northern slope of the South China Sea resulted from extension, thinning and depression of the South China continent induced by its southeastward creep diffusion. The break points on these steps, especially those with larger gradient, maybe recorded the crust depressional process. Comparing the topographic profile with the net subsidence curve from wells in the Pearl River Mouth Basin (Ru, 1987) (Fig.2), we

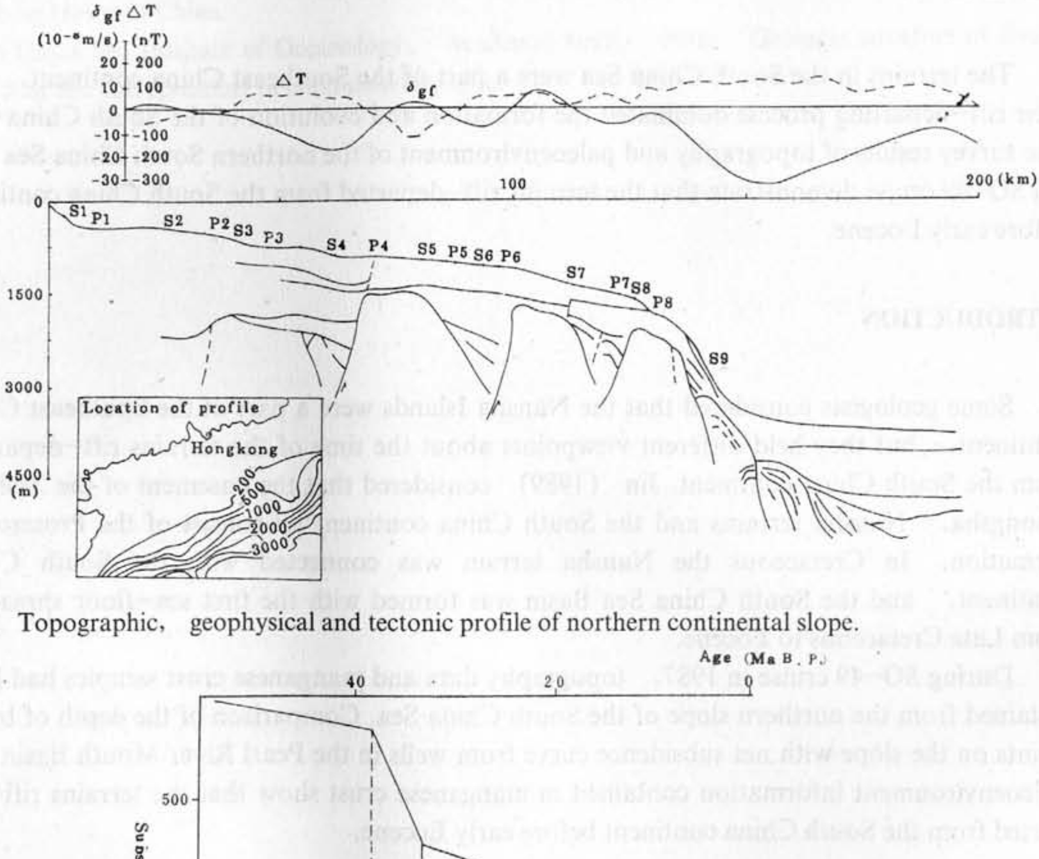

Fig.1 Topographic, geophysical and tectonic profile of northern continental slope.

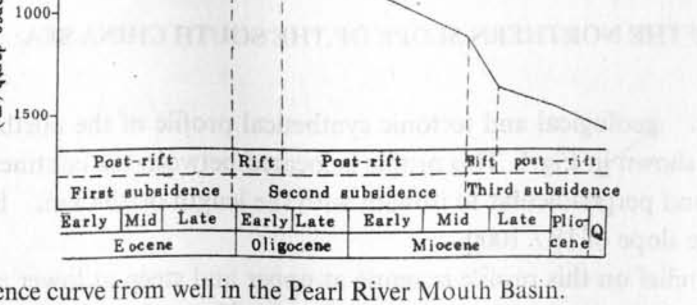

Fig.2 Net subsidence curve from well in the Pearl River Mouth Basin.

discover that depth of turning points on the subsidence curve corresponds to that of break points S1, S4, S7 and S8, respectively. In view of the well data, these turning points indicate the post−rift and rift stage of the first subsidence, the post−rift stage of the second subsidence and the post−rift stage of the third subsidence, respectively. These subsidences occurred in Eocene, from Oligocene to middle Miocene and after middle Miocene. Thus these times are also the forming ages of the northern slope of the South Chian Sea.

Table 1 The data of topographic profile of northern slope of the South China Sea

Features		Location Lat.	Location Long.	Depth (m)	Distance (km)	Depth range (m)	Gradient
Shelf	Break						
		20°03.03′	114°02.56′	170			
Step	Steep 1				5.36	250	2°40.35′
		20°00.34′	114°03.69′	420			
1	Flat 1				15.37	5	1°12′
		19°52.62′	114°06.95′	425			
Step	Steep 2				13.16	100	26.12′
		19°46.01′	114°09.73′	525			
2	Flat 2				3.17	2	2.17′
		19°44.42′	114°10.40′	527			
Step	Steep 3				4.82	183	2°10.46′
		19°43.00′	114°11.42′	710			
3	Flat 3				12.05	10	2.85′
		19°35.95′	114°13.97′	720			
Step	Steep 4				7.37	180	1°10.46′
		19°32.25′	114°15.53′	900			
4	Flat 4				17.12	80	16.06′
		19°23.66′	114°19.15′	980			
Step	Steep 5				6.99	58	28.52′
		19°20.15′	114°20.62′	1038			
5	Flat 5				1.63	9	18.98′
		19°19.34′	114°20.97′	1047			
Step	Steep 6				8.34	71	29.27′
		19°15.15′	114°22.73′	1118			
6	Flat 6				1.10	2	6.25′
		19°14.60′	114°22.96′	1120			
Step	Steep 7				27.11	407	57.57′
		19°01.00′	114°28.69′	1527			
7	Flat 7				1.95	5	8.81′
		19°00.02′	114°29.10′	1532			
Step	Steep 8				4.85	288	3°26.02′
		18°57.62′	114°30.12′	1820			
8	Flat 8				1.56	20	44.07′
		18°56.84′	114°30.45′	1840			
Step	Steep 9				51.43	1790	1°59.60′
9		18°31.04′	114°41.31′	3630			

PALEOENVIRONMENTAL INFORMATION CONTAINED IN MANGANESE CRUST FROM THE LOWER SLOPE

At the seamount located on the northern slope with a water depth of 2470 m, the manganese crust with thickness up to 8.5 cm was sampled. It grew on the surface of submarine rock. The material content variation of its every layer maybe reflects the evolution of its paleoenvironment. For this reason, according to its growth bedding, we divided it into 10 layers from surface to interiority and analysed samples from its every layer. The element content and trace element content are shown in Table 2.

In order to discuss the sedimentary environment, it is necessary to determine the growth rate of manganese crust. Because the manganese crust has undergone such a long growth process, it is difficult to determine the earliest time by using direct dating methods. The calculated result based on the empirical formula by Huh and Ku (1984) corresponds to the dating data of manganese nodules sampled from Pacific Ocean and the South China Sea (Mangini and Kudrass *et al.*, 1986). So we Calculated the growth rate of manganese crust using the following empirical formula by Huh and Ku (1984):

$$S\ (\mathrm{mm/ma}) = 13.39 \times (\mathrm{Mn/Fe^2}) + 0.75$$

and obtained the growth rate ranging from 1.5 to 1.2 mm / ma. If the growth discontinuance can be neglected, it is possible that the earliest manganese crust was formed 52 Ma B.P., i.e. early Eocene.

In order to verify the growth age of manganese crust, we have drawn the growth rate and age, chlorine content, Fe^{3+}/Fe^{2+} δO^{18}, P_2O_5 and CaO in Fig.3.

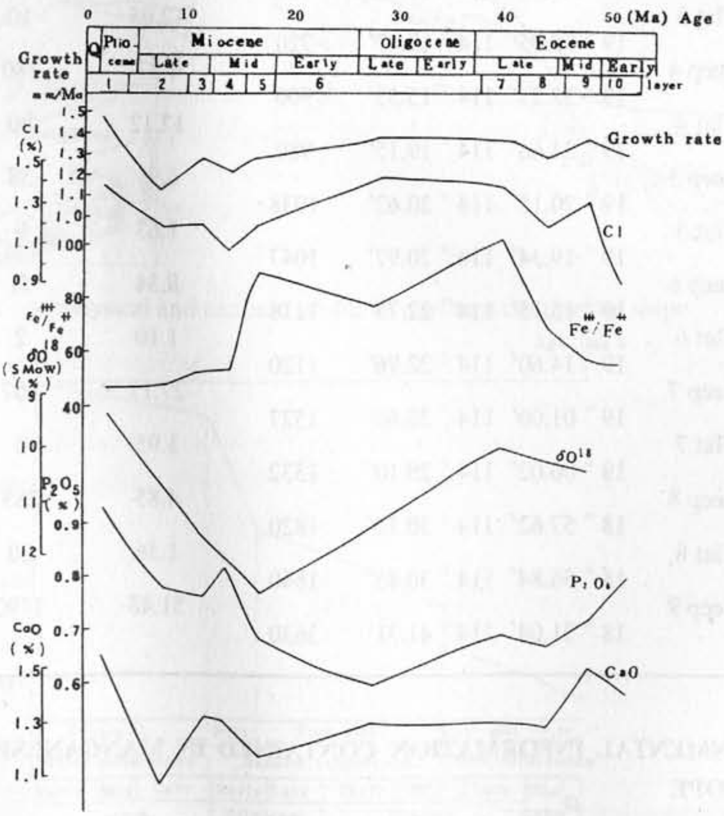

Fig.3 Variation of growth rate, chlorine, Fe^{3+}/Fe^{2+}, δO^{18}, P_2O_5 and CaO content in manganese crust.

The variation of chlorine content in manganese crust may reflect the variation of salinity in sea water. In early Eocene, the sea basin may be at its initial stage; and the chlorine content was only 0.907%. From late Eocene to early Miocene, the chlorine content increased up

Table 2–1 The element content of manganese crust (%)

Layer	MnO_2	Fe_2O_3	SiO_2	Al_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	P_2O_5	Ni	Cu	SrO	Combus–tible	∑	H_2O	Cl	SO_3
1	25.968	25.557	10.309	2.981	0.704	1.567	1.420	2.042	0.314	0.922	0.259	0.331	0.339	27.26	99.973	12.55	1.396	0.540
2	16.579	25.553	24.005	4.007	0.491	1.074	1.434	1.710	0.445	0.776	0.113	0.344	0.140	23.43	100.101	10.27	1.171	0.420
3	25.367	28.403	9.605	3.041	0.574	1.337	1.200	1.857	0.290	0.753	0.074	0.084	0.152	26.57	99.307	11.33	1.194	0.385
4	20.554	29.747	15.463	3.352	0.575	1.317	1.344	1.684	0.265	0.815	0.285	0.434	0.109	25.42	101.364	13.18	1.080	0.472
5	23.108	30.826	12.135	2.850	0.547	1.174	1.161	1.514	0.223	0.685	0.182	0.608	0.339	25.58	100.932	11.42	1.184	0.385
6	18.992	25.109	23.354	3.608	0.505	1.315	1.269	1.849	0.313	0.596	0.258	0.090	0.292	21.72	99.270	9.22	1.1407	0.1435
7	25.304	28.737	10.490	2.349	0.441	1.294	1.331	1.461	0.020	0.698	0.162	0.163	0.356	26.68	99.486	12.13	1.387	0.425
8	22.988	28.362	12.813	1.932	0.401	1.281	1.320	1.629	0.214	0.664	0.179	0.216	0.409	26.03	98.438	10.73	1.119	0.437
9	24.894	28.524	12.718	1.222	0.421	1.504	1.235	1.620	0.210	0.701	0.117	0.130	0.315	25.71	99.321	10.60	1.323	0.588
10	23.769	24.162	8.598	2.224	0.436	1.410	1.261	1.522	0.211	0.774	0.143	0.084	0.315	25.50	100.41	10.96	0.907	0.510

Table 2–2 The trace–element content of manganese crust (ppm)

Layer	Cd	Sr	Bi	Pb	Ba	Co	Be	Cr	V	B	Ga	In	Zn	Sn	W	As	Mo	Ag	Rb_2O (%)
1	<1	1419	34	2100	1207	2500	<1	19	441	95	4	<1	132	3	52	<30	320	<1	0.0025
2	<1	1118	24	1800	907	1500	<1	20	500	140	2	<1	185	3	44	<30	400	<1	0.0020
3	<1	1462	30	2050	1354	1550	<1	15	519	113	<2	<1	153	3	57	<30	380	<1	0.0020
4	<1	1376	35	2100	1251	1280	<1	15	456	126	2	<1	187	3	56	<30	360	<1	0.0025
5	<1	1500	34	2000	1402	1400	<1	18	475	112	<2	<1	125	3	500	<30	460	<1	0.0025
6	<1	1200	28	1250	1112	1100	<1	27	429	103	4	<1	117	3	52	<30	500	<1	0.0025
7	<1	1634	39	1700	1382	980	<1	12	472	108	4	<1	195	3	62	<30	500	<1	0.0020
8	<1	1677	26	1650	1569	900	<1	12	551	138	3	<1	210	3	68	<30	500	<1	0.0020
9	<1	1750	32	1700	1337	950	<1	11	573	173	4	<1	415	3	72	<30	500	<1	0.0020
10	<1	1634	35	1700	1489	1000	<1	12	604	120	2	<1	260	3	68	<30	500	<1	0.0025

to 1.407% ; in middle Miocene it was 1.080% ; after late Miocene it increased to 1.217%.The variation of salinity may be related to the basin evolution. Karig (1973) considered that there was a transform fault connecting trench with trench between the Luson Arc and Taiwan in early Tertiary when the South China Sea was opened as an extensional marginal sea. During 32–17 Ma B.P., the South China Sea Basin was enlarged and its salinity increased with the sea–floor spreading (Taylor and Hayes, 1980). In mid–late Miocene and early Pliocene, because the northern extended part of the Luson volcanic arc collided with Taiwan, the Huo–Shao Tao island and the Babuyan ridge were formed, which impeded water exchange between the Philippine Sea and the South China Sea and made the salinity decrease. Since Pliocene, the central water of the Northwest Pacific Ocean has ever passed through the Bashi Channel and filled into the bottom of the South China Sea Basin (about 1500–4000 m deep), therefore, the chlorine content in the manganese crust was up to 1.396%.

The variation of δO^{18} content in the manganese crust may reflect paleotemperature variation. From late Eocene to middle Miocene, an increase of δO^{18} content indicates a drop in water temperature. It is identical with the variation of paleotemperature in the northern Pacific Ocean.

The Fe^{3+} / Fe^{2+} ratio reflects the oxidizing milieu of sea water. From late Eocene to early Miocene, Fe^{3+} / Fe^{2+} ratio was up to 91–104, indicating that the basin was opened and the water was renewed continuously. After middle Miocene, the oxidizing milieu became weak because the Bashi Channel was formed. However, the South China Sea Basin keeps on opening and is in the stronger oxidizing milieu.

CONCLUSION

The growth rate calculated from the manganese crust and the paleooceanographic variation contained in the manganese crust conforms to tectonic evolution and paleooceanographic variation from the surrounding area, which indicates that calculated age is desirable. Well No.1 in Sampaguita shows that the Read Bank was marginal sea facies in late Cretaceous, deltaic facies in Paleocene, bythyal facies in late Oligocene, bathyal facies in mid–Miocene and marginal facies after mid–Miocene. The coincidence between the paleooceanographic variation contained in the manganese crust and the variation of surrounding tectonics maybe indicates the evolution between northern and southern margins of the South China Sea Basin has internal connection. Along with evolution of slope topography, these conclusions suggest that the terrains rift–departed from South China continent before Eocene. The paleogeographical chart by Jin (1989) expresses the same opinion.

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