



# **ORGANIC MATERIAL AND SEA-LEVEL CHANGE IN MANGROVE HABITAT**

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# Distributions and Compositions of Subaqueous Sediments around the Ca Mau Mangrove Habitats in Ca Mau Province, Viet Nam

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## Introduction

Dense mangrove habitats are widely distributed in the southern marginal part of Ca Mau Province, in the Mekong Delta region, Viet Nam (Fig. 1). However, no systematic sedimentological studies have been made in the area in spite of importance of understanding upon relationship between subaqueous sedimentary processes and mangrove habitat dynamics has been pointed out (*e. g.* Allen, 1965). As a part of the field research project "Organic Material and Sea-level Change in Mangrove Habitat", subaqueous sediments around the Ca Mau mangrove habitats were collected and investigated to comprehend present

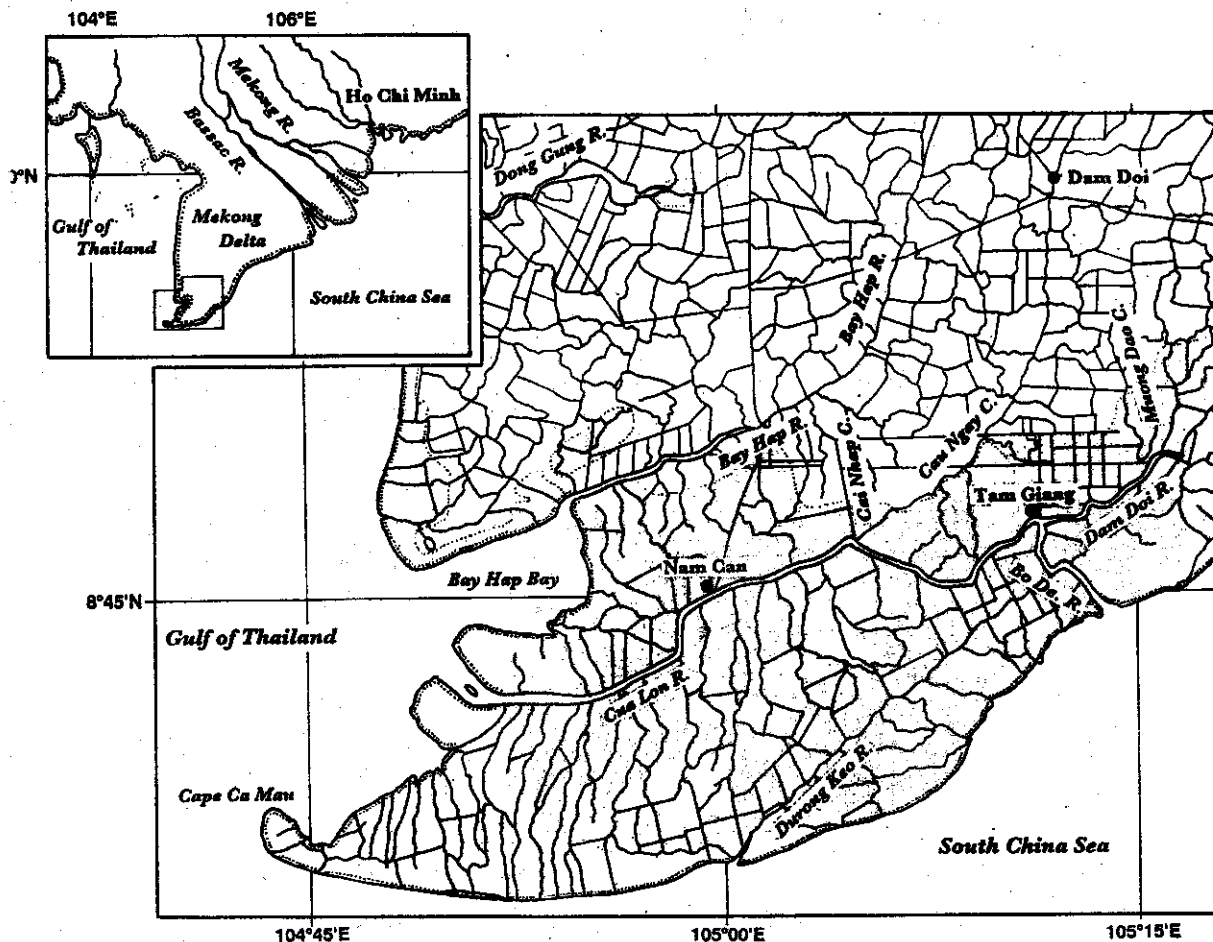


Fig. 1: Location of the studied area in the southern marginal part of the Mekong Delta region in Viet Nam (upper, left), and networks of estuaries, rivers and tidal channels, and distribution of the mangrove habitats in the studied area.

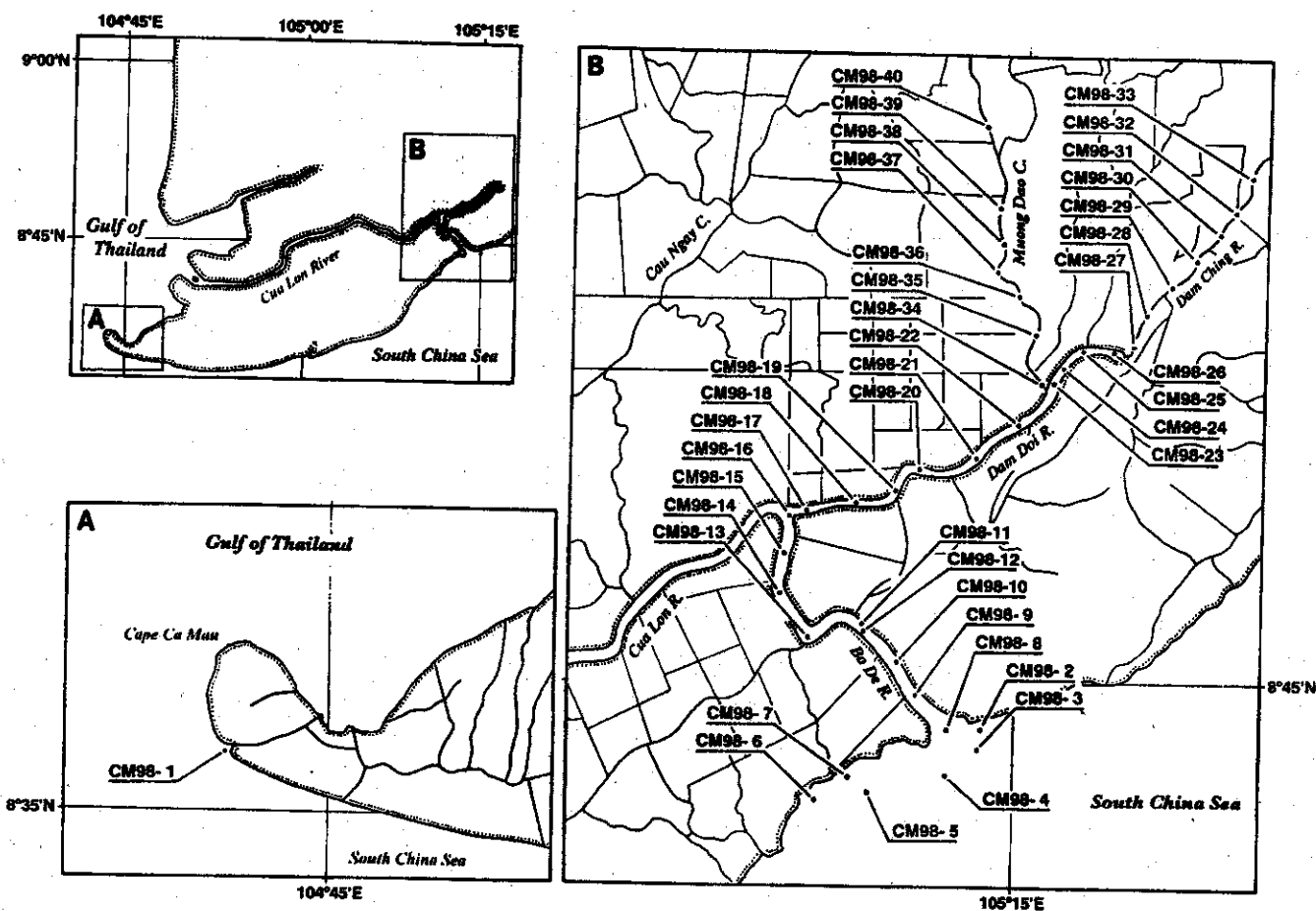


Fig. 2. Sites of subaqueous sediment samplings and measurements of chemical properties of surface waters in December, 1998.

subaqueous sedimentary processes. Further, measurements of water depths around the habitats and chemical properties of surface water were carried out in the area to grasp subaqueous topographies and salt-water/fresh-water mixing processes in the area.

Based on the results of both onboard observations and sedimentological analyses in the laboratory of the collected sediment samples, and taking the results of measurements of water depths and chemical properties of surface waters into account, this article describes mainly the spatial distribution and composition of the subaqueous sediments from the studied area, and illustrates preliminarily the subaqueous sedimentary processes in the area.

### Topography and Geology of the Studied Area

Figure 1 shows topographic features and distribution of mangrove habitats in and around the studied area situated in the southern marginal part of the Mekong Delta region. The water areas can be divided into the South China Sea, the Gulf of Thailand and the Bay Hap Bay, such main rivers as the Cua Lon, Bo De, Dam Doi, Durong Keo and Bay Hap Rivers, and tidal channel and artificial canal networks.

The South China Sea and the Gulf of Thailand are situated on the south and west of the studied area,

respectively. The Bo De River flows into the South China Sea. The Bay Hap Bay situated on the west of the area where the Cua Lon and Bay Hap Rivers flow in opens west-southwest to the Gulf of Thailand. A systematic directional transition of the main rivers can be recognized that the Bay Hap River and the Cau Ngay Canal judged to be the upper course of the Cua Lon River flow south-southwestwards in the northeast of the studied area, but they turn gradually the direction westwards and they have west-southwestward flow direction in the southwest of the area. Further, these main rivers flow almost parallel, and they keep roughly fixed distance among them. The mangrove habitats are widely distributed in the southern part of the studied area mainly between the Cua Lon River and the southern coast on the South China Sea. The habitats cut by numerous tidal channel and artificial canal networks.

### Sampling Methods and Analytical Procedures

The subaqueous sediment samples used for the present study were collected in December 1998 and August 1999. The samplings were carried out mainly around the village of Tam Giang III northwest of the town of Tam Giang where well known mangrove habitats are distributed in 1998 (Fig. 2) and uniformly in the southern marginal part of the Mekong Delta region in 1999 (Fig. 3). Sampling devices were a Seki-type grab surface sampler, about 500 ml in volume. Salinity for surface waters were measured using by a

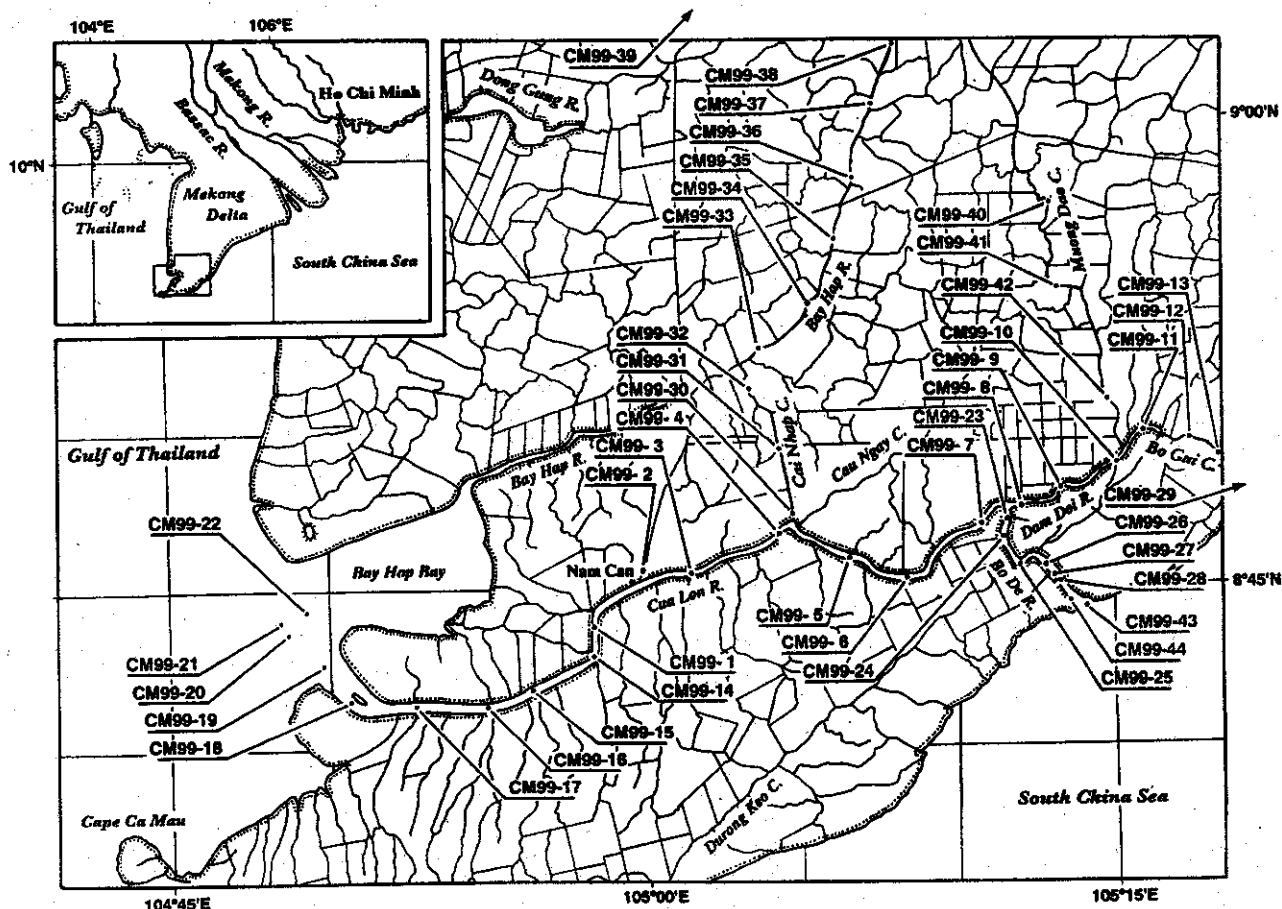


Fig. 3. Sites of subaqueous sediment samplings and measurements of chemical properties of surface waters in August, 1999.

**Table 1. Results of surface sediment samplings, and measurements of water depths and chemical properties of surface waters in December, 1998.**

Station	Locality	Sampler	Date (DM/Y)	Time	Latitude (N)	Longitude (E)	Water Depth (m)	Water Temp (°C)	Water Salinity (‰)	Sediments	
CM98-1	Cap Ca Mau	Sed Grab	19/02/98	12:52	8° 38'08.3"	104° 43'43.9"	0.6	-	-	plant debris rich bluish grey homogeneous mud	
CM98-2	South China Sea	"	20/12/98	08:34	8° 44'40.0"	105° 14'30.0"	2.8	26.6	28.0	greenish grey homogeneous mud covered by plant debris bearing brownish grey soft mud	
CM98-3		"	"	08:44	8° 44'02.4"	105° 14'20.5"	8.2	28.4	29.0	dark grey homogeneous mud covered by plant debris rich brownish grey soft mud	
CM98-4		"	"	"	08:52	8° 43'47.8"	105° 12'48.7"	2.6	27.1	31.0	dark grey homogeneous mud covered by plant debris rich brownish grey soft mud
CM98-5		"	"	"	10:02	8° 43'38.9"	105° 12'42.7"	8.8	27.3	31.0	greenish grey homogeneous mud covered by shell fragment and plant debris bearing rich brownish grey mud
CM98-6		"	"	"	10:10	8° 43'18.0"	105° 12'01.1"	2.2	27.8	30.0	plant debris rich dark grey mud covered by brownish grey soft mud
CM98-7	Bo De River	"	"	10:20	8° 43'41.3"	105° 11'36.5"	1.1	27.5	31.0	plant debris rich, molluscan shell bearing grey sandy mud covered by brownish grey soupy mud	
CM98-8		"	"	10:32	8° 44'23.4"	105° 13'31.3"	2.4	28.1	34.0	plant debris rich, molluscan shell bearing greenish grey mud covered by reddish brown soft mud	
CM98-9		"	"	"	10:42	8° 44'56.0"	105° 13'31.5"	23.0	27.0	33.0	a little amount of plant debris bearing brownish grey sandy mud
CM98-10		"	"	"	10:58	8° 45'28.4"	105° 13'11.1"	23.0	26.8	33.0	a little amount of plant debris bearing shelly sand
CM98-11		"	"	"	11:05	8° 45'54.0"	105° 12'43.7"	30.0 <	-	-	no recovery
CM98-12	"	"	"	11:08	8° 45'46.9"	105° 12'43.9"	18.0	26.6	31.0	plant debris rich pale grey homogeneous mud	
CM98-13	"	"	"	11:25	"	"	30.0 <	-	-	no recovery	
CM98-14	"	"	"	11:31	8° 46'24.8"	105° 11'31.8"	7.2	27.6	32.0	plant debris rich, molluscan shell fragment bearing greenish grey sandy mud	
CM98-15	Dien Cai River	"	"	11:44	8° 46'56.1"	105° 11'38.5"	5.0	27.2	32.0	plant debris bearing light grey compact mud covered by reddish brown soupy mud	
CM98-16		"	"	15:03	8° 47'24.8"	105° 11'41.3"	1.8	26.6	28.0	plant debris rich light grey compact mud covered by brownish red soft mud	
CM98-17		"	"	"	15:15	8° 47'40.8"	105° 11'32.8"	11.8	26.4	28.0	plant debris rich brownish grey mud covered by brownish red soupy mud
CM98-18		"	"	"	15:28	8° 47'43.9"	105° 12'36.8"	15.0	26.4	21.0	plant debris rich brownish grey homogeneous mud covered by brownish red soupy mud
CM98-19		"	"	"	15:38	8° 47'53.8"	105° 13'10.8"	11.3	26.7	24.0	plant debris rich brownish grey homogeneous mud covered by brown soft mud
CM98-20	"	"	"	15:58	8° 48'14.9"	105° 13'32.9"	8.5	26.0	22.0	plant debris rich brown homogeneous mud covered by brownish red soupy mud	
CM98-21	"	"	"	16:28	8° 48'17.3"	105° 13'21.9"	7.8	26.7	22.0	plant debris rich brownish grey mud covered by plant debris bearing reddish brown soft mud	
CM98-22	"	"	"	16:12	8° 48'57.3"	105° 15'01.9"	8.4	26.9	21.0	plant debris rich dark grey homogeneous mud covered by reddish brown soft mud	
CM98-23	"	"	"	16:23	8° 49'25.9"	105° 15'28.5"	0.7	26.1	18.0	plant debris and shell fragment bearing light grey compact mud	
CM98-24	"	"	21/12/98	08:40	8° 49'38.4"	105° 15'35.8"	8.6	26.1	24.0	plant debris rich brownish grey homogeneous mud covered by brown soft mud	
CM98-25	"	"	"	08:46	8° 49'53.2"	105° 15'52.7"	0.8	27.2	29.0	plant debris rich brownish grey homogeneous mud covered by reddish brown soft mud	
CM98-26	Dam Chum River	"	"	08:56	8° 49'58.1"	105° 16'21.6"	2.7	27.3	28.0	dark greenish grey compact mud covered by plant debris rich reddish brown soft mud	
CM98-27		"	"	09:04	8° 50'01.1"	105° 16'43.9"	10.8	27.1	28.0	no recovery	
CM98-28		"	"	"	09:10	8° 49'58.8"	105° 16'41.1"	8.3	-	-	brownish grey compact mud covered by plant debris and molluscan shell fragment bearing reddish brown mud
CM98-29		"	"	"	09:25	8° 50'29.0"	105° 16'48.8"	8.0	27.7	28.0	plant debris rich dark brownish grey mud covered by plant debris rich reddish brown soft mud
CM98-30		"	"	"	09:36	8° 50'57.9"	105° 17'08.7"	6.4	27.6	27.0	plant debris rich brownish grey compact mud covered by reddish brown soft mud
CM98-31	Muong Dao Canal	"	"	09:45	8° 51'18.9"	105° 17'31.0"	8.3	27.8	28.0	plant debris rich brownish grey compact mud covered by plant debris bearing reddish brown soft mud	
CM98-32		"	"	10:03	8° 51'38.7"	105° 17'49.5"	8.4	27.8	25.0	plant debris rich dark brownish grey compact mud covered by reddish brown soupy mud	
CM98-33		"	"	"	10:21	8° 52'03.4"	105° 18'03.8"	8.8	27.5	19.0	brownish grey sandy mud covered by reddish brown soupy mud
CM98-34		"	"	"	10:40	8° 52'28.1"	105° 18'15.7"	8.5	27.4	24.0	plant debris rich, shell bearing brownish grey mud covered by reddish brown soft mud
CM98-35		"	"	"	13:12	8° 52'45.9"	105° 18'12.8"	10.4	28.3	18.0	plant debris rich greenish grey semi-consolidated mud
CM98-36	"	"	"	13:28	8° 53'13.3"	105° 18'12.8"	10.5	28.0	18.0	plant debris rich bluish grey semi-consolidated mud covered by brownish grey soft mud	
CM98-37	"	"	"	13:45	8° 53'06.2"	105° 18'13.4"	13.2	28.2	18.0	dark bluish grey semi-consolidated mud covered by brownish grey soft mud	
CM98-38	"	"	"	13:55	8° 51'30.7"	105° 14'45.9"	11.2	28.6	18.0	bluish grey semi-consolidated mud covered by reddish brown soft mud	
CM98-39	"	"	"	14:10	8° 52'04.2"	105° 14'43.7"	8.3	29.1	13.0	plant debris rich bluish grey semi-consolidated mud covered by reddish brown soft mud	
CM98-40	"	"	"	14:25	8° 53'17.8"	105° 14'27.4"	10.3	28.1	13.0	bluish grey semi-consolidated mud	

**Table 2. Results of surface sediment samplings, and measurements of water depths and chemical properties of surface waters in August, 1999.**

Station	Locality	Sampler	Date (DM/Y)	Time	Latitude (N)	Longitude (E)	Water Depth (m)	Water Temp (°C)	Water Salinity (‰)	Water pH	Water DO (ppm)	Sediments	
CM99-1	Cua Lon River	Sed Grab	08/08/99	10:15	8° 42'44.2"	104° 58'16.7"	8.7	25.8	26.7	7.8	2.82	dark plant debris rich reddish brown homogeneous soft mud	
CM99-2	"	"	"	10:35	8° 42'25.8"	105° 02'18.9"	18.0	25.5	29.9	7.8	2.72	dark plant debris rich bluish grey consolidated mud	
CM99-3	"	"	"	11:35	"	"	18.0	-	-	-	-	consolidated mud ?	
CM99-4	"	"	"	11:36	8° 46'58.4"	105° 01'26.0"	18.0	25.8	29.8	7.7	2.73	a little amount of bluish grey semi-consolidated mud	
CM99-5	"	"	"	11:36	8° 46'58.4"	105° 01'22.4"	21.0	25.8	29.8	7.6	2.81	plant debris rich bluish grey semi-consolidated mud	
CM99-6	"	"	"	12:43	8° 46'58.4"	105° 01'22.4"	18.2	25.7	21.7	7.8	2.82	plant debris bearing bluish grey semi-consolidated mud	
CM99-7	"	"	"	13:09	8° 47'00.8"	105° 10'44.1"	23.0	26.0	22.5	7.7	2.82	plant debris and molluscan shell fragment bearing bluish grey semi-consolidated mud	
CM99-8	"	"	"	13:15	"	"	23.0	25.9	23.1	7.8	3.27	a little amount of yellowish grey semi-consolidated mud	
CM99-9	Dam Dai River	"	"	13:25	8° 47'30.0"	105° 12'08.5"	8.0	26.3	22.9	7.7	3.02	plant debris bearing light bluish grey semi-consolidated mud	
CM99-10		"	"	13:47	8° 48'13.1"	105° 12'23.7"	4.0	26.1	20.9	7.8	3.08	plant debris rich light brown homogeneous mud covered by reddish brown soupy mud	
CM99-11		"	"	"	14:07	8° 48'04.8"	105° 19'12.1"	8.0	26.8	18.9	7.6	2.86	plant debris bearing light brown homogeneous mud. slightly bluish in base
CM99-12		Bo Dai Canal	"	"	14:25	8° 49'53.0"	105° 19'54.4"	7.0	28.5	17.1	7.8	2.91	plant debris bearing greyish brown mud covered by reddish brown soft mud
CM99-13		"	"	"	15:15	8° 49'08.8"	105° 19'28.3"	14.0	28.2	21.4	7.8	3.01	molluscan shell fragment bearing moderate grey compact mud covered by reddish brown soft mud
CM99-14	Cua Lon River	"	08/08/99	10:36	8° 42'58.3"	104° 58'13.3"	3.8	25.4	21.5	7.8	4.05	molluscan shell and shell fragment bearing bluish grey semi-consolidated mud	
CM99-15		"	"	10:48	8° 41'58.3"	104° 58'13.0"	10.0	25.2	24.4	7.8	8.04	dark plant debris rich light / moderate brown mud	
CM99-16		"	"	"	11:19	8° 41'17.8"	104° 54'17.4"	11.0	25.7	24.4	8.0	6.48	dark plant debris rich light brown soft mud
CM99-17		"	"	"	11:55	8° 41'48.9"	104° 52'48.9"	11.0	25.7	25.7	8.0	6.40	dark plant debris rich light brown soft mud underlain by light grey mud
CM99-18		"	"	"	12:10	8° 41'28.5"	104° 52'48.9"	8.0	26.0	26.6	8.0	6.87	plant debris rich dark brownish grey mud covered by reddish brown soupy mud
CM99-19	Bay Hap Bay	"	"	12:38	"	"	7.5	26.3	28.5	8.0	8.71	plant debris bearing bluish grey compact mud covered by plant debris rich reddish brown soft mud	
CM99-20		"	"	13:15	8° 43'37.1"	104° 49'45.4"	1.5	26.1	28.0	8.0	7.40	plant debris rich light / moderate brown soft mud	
CM99-21		"	"	13:32	8° 43'39.8"	104° 48'32.2"	0.8	26.2	27.8	8.0	7.38	plant debris rich, shell fragment bearing dark greyish brown mud covered by yellowish brown soft mud	
CM99-22		"	"	13:45	8° 44'13.1"	104° 48'23.0"	3.8	26.3	26.7	8.0	6.88	plant debris bearing dark greyish brown mud covered by light brown soft mud	
CM99-23		Bo De River	"	07/08/99	09:19	8° 47'28.7"	105° 11'37.3"	20.0	25.9	21.1	8.0	6.01	a little amount of pale grey semi-consolidated mud
CM99-24	"	"	"	09:25	8° 48'41.4"	105° 11'28.9"	38.0	25.8	24.3	8.1	6.42	a little amount of pale grey semi-consolidated mud	
CM99-25	"	"	"	09:45	8° 48'53.8"	105° 12'08.3"	28.0	25.8	25.7	8.0	5.83	rounded granule- to pebble-gravel bearing pale grey semi-consolidated mud	
CM99-26	"	"	"	10:05	"	"	28.0	25.8	25.7	8.0	6.35	a little amount of moderate brown semi-consolidated sandy mud	
CM99-27	"	"	"	10:19	8° 49'52.4"	105° 12'40.9"	45.8 <	-	-	-	-	large plant debris rich moderate grey mud covered by reddish brown soupy mud	
CM99-28	"	"	"	10:22	"	"	18.0	-	-	-	-	no recovery	
CM99-29	"	"	"	10:35	8° 46'28.9"	105° 12'11.2"	22.0	25.7	28.8	8.1	7.32	shell fragment and plant debris bearing moderate grey compact mud covered by reddish brown mud	
CM99-30	"	"	"	10:52	8° 46'20.4"	105° 13'18.9"	8.0	25.9	29.9	8.2	6.03	rounded granule-gravel and shell fragment bearing bluish grey compact mud	
CM99-31	South China Sea	"	"	12:15	"	"	10.0	25.7	28.2	8.2	7.84	plant debris bearing bluish grey compact mud covered by reddish brown soft mud	
CM99-32	Cai Nhap River	"	"	09:45	8° 47'31.4"	105° 04'47.1"	16.0	26.1	21.1	8.1	6.43	plant debris rich reddish brown soft mud	
CM99-33	"	"	"	10:04	8° 47'27.4"	105° 04'24.4"	12.0	26.2	13.7	7.8	6.43	plant debris bearing light brown semi-consolidated mud, surface stained in brown	
CM99-34	"	"	"	10:24	8° 51'21.9"	105° 08'24.0"	11.0	26.9	10.1	7.7	4.70	bluish grey semi-consolidated and burrowed mud, surface stained in brown	
CM99-35	Bay Hap River	"	"	10:40	8° 52'40.9"	105° 0'43.5"	4.9	27.2	7.0	7.9	4.88	plant debris rich, molluscan shell bearing bluish grey semi-consolidated mud, surface stained in brown	
CM99-36	"	"	"	10:50	8° 54'08.0"	105° 09'22.0"	4.0	26.9	1.9	7.9	3.30	plant debris rich, calcareous material bearing moderate brown mud	
CM99-37	"	"	"	11:25	8° 53'08.5"	105° 08'11.1"	5.3	26.0	0.8	7.8	3.98	plant debris bearing light brown soft mud mottled with black sticky mud	
CM99-38	"	"	"	11:38	8° 53'58.3"	105° 08'36.2"	3.5	27.3	0.8	7.8	3.77	plant debris rich greyish brown soft mud intercalated with a thin plant debris layer	
CM99-39	"	"	"	11:52	8° 50'20.0"	105° 07'24.4"	5.0	27.4	0.8	7.8	3.97	molluscan shell fragment and plant debris bearing bluish grey semi-consolidated mud, surface stained in brown	
CM99-40	"	"	"	12:08	8° 50'43.8"	105° 08'15.9"	2.0	27.3	0.8	7.8	3.74	large plant debris rich greyish brown soft mud intercalated with a plant debris layer and covered by reddish brown mud	
CM99-41	Muong Dao Canal	"	"	12:24	8° 50'52.9"	105° 09'32.4"	5.0	27.3	0.8	7.8	3.40	plant debris bearing greyish brown soft mud	
CM99-42		"	"	13:40	8° 57'31.1"	105° 12'05.0"	10.0	27.5	4.2	7.8	3.28	plant debris bearing light greyish brown homogeneous mud, surface stained in brown	
CM99-43		"	"	14:10	8° 54'33.8"	105° 13'18.3"	14.0	27.5	8.2	7.8	3.64	light greyish brown compact mud, surface stained in brown	
CM99-44		"	"	14:19	8° 59'54.8"	105° 18'00.9"	12.0	27.4	13.7	7.8	3.87	large plant debris rich light greyish brown soft and sticky mud	
CM99-45	South China Sea	"	08/08/99	08:35	8° 44'38.9"	105° 14'00.2"	4.5	28.0	28.0	8.2	7.82	plant debris and molluscan shell fragment bearing light greyish brown soft mud	
CM99-46	Bo De River	"	"	10:04	8° 46'48.3"	105° 12'38.8"	5.0	-	27.1	8.1	-		

Sekisui type SS-31A salt-tester and an Atago digital salt-meter type ES-421 in 1998 and 1999, respectively. Further, hydrogen ion exponent value (pH), and temperature and dissolved oxygen amount (DO) measurements for surface waters were conducted using by a Horiba compact pH meter type B-212 and a Horiba handy DO meter type OM-12, respectively. The site survey was always carried out with a water depth measurement by using an about 45-metres-long nylon rope with an about two kilogrammes weight. Latitude and longitude of each sampling site were confirmed by using a Sony type IPS-360 GPS receiver. Thirty-eight and 44 subaqueous surface sediments were successfully obtained from the studied area in 1998 and 1999, respectively (Tables 1 and 2).

In the laboratory, smear slides were prepared first and examined under a microscope for compositional and textural description of muddy sediments. For sandy sediments, the entire sample was heated over 24 hours at about 50 °C, and its dry weight was measured. Then, it was washed over a screen with an opening of 63  $\mu$  m to remove muddy sediments, and dried and weigh again to obtain proportional mud contents. The remained sandy sediments were sieved over screens with openings of 90, 125, 180, 250, 355, 500, 710, 1,000, 1,400, 2,000, 2,800 and 4,000  $\mu$  m. Then, dry weights of remains on each screen were measured to obtain proportional grain-size distribution in weight for sandy sediments. Further, microscopic observations for each remain were conducted to the textural and compositional description for sandy sediments.

## Results

### *Water Depths and Chemical Properties of Surface Waters*

**Table 3. Summarized results of measurements of water depths and chemical properties of surface waters in December 1998.**

Area	Inner Parts of the Studied Area																	
	Muong Dao Canal							Dam Ching River					Dam Doi River					
Station (CM98-)	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23
Water Depth (m)	10.3	8.3	11.2	13.2	10.5	5.6	10.4	8.5	8.8	8.4	8.3	6.4	8.0	10.8	2.7	0.8	0.8	20.7
Salinity (‰)	13.0	13.0	15.0	16.0	18.0	19.0	18.0	24.0	19.0	25.0	28.0	27.0	28.0	28.0	29.0	29.0	24.0	16.0
Temperature (°C)	29.1	29.1	28.6	28.2	29.0	28.6	28.3	27.4	27.5	27.8	27.6	27.5	27.7	27.1	27.3	27.2	28.1	27.1

Area	Middle Parts of the Studied Area														
	Dam Doi River							Bo De River							
Station (CM98-)	22	21	20	19	18	17	16	15	14	13	11	12	10	9	8
Water Depth (m)	8.4	7.8	8.5	11.3	15.0	11.8	1.8	5.0	7.2	30<	30<	18.0	23.0	23.0	2.4
Salinity (‰)	21.0	22.0	22.0	24.0	21.0	28.0	28.0	32.0	32.0	-	-	31.0	33.0	33.0	34.0
Temperature (°C)	26.9	26.7	26.8	26.7	26.4	26.4	26.6	27.2	27.6	-	-	26.6	26.8	27.0	28.1

Area	Outer Parts of the Area							
	South China Sea							
Station (CM98-)	2	3	4	5	6	7	1	
Water Depth (m)	2.8	8.2	3.6	2.8	2.2	1.1	0.6	
Salinity (‰)	26.0	29.0	31.0	31.0	30.0	31.0	-	
Temperature (°C)	26.6	26.4	27.1	27.3	27.6	27.5	-	

**Table 4. Summarized results of measurements of water depths and chemical properties of surface waters in August 1999.**

Area	Inner Parts of the Studied Area												
	Bay Hap River							Cai Nhap C.			Muong Dao C.		
	39	38	37	36	35	34	33	32	31	30	40	41	42
Station (CM99-)	39	38	37	36	35	34	33	32	31	30	40	41	42
Water Depth (m)	5.0	2.0	1.5	3.5	5.3	4.0	4.9	11.0	12.0	16.0	10.0	14.0	12.0
Salinity (‰)	0.6	0.6	0.9	0.8	0.8	1.9	7.0	10.1	13.7	21.8	4.2	8.2	13.7
Temperature (°C)	27.3	27.3	27.4	27.0	26.0	26.9	27.2	26.9	26.8	26.1	27.5	27.5	27.4
pH	7.5	7.6	7.6	7.7	7.6	7.9	7.9	7.7	7.9	8.1	7.5	7.6	7.8
DO (ppm)	3.40	3.74	3.77	3.76	3.96	3.30	4.89	4.70	5.37	6.43	3.36	3.64	3.87

Area	Middle Parts of the Studied Area															
	Dam Doi River					Cua Lon River										
	11	10	9	8	7	6	5	4	3	2	1	14	15	16	17	18
Station (CM99-)	11	10	9	8	7	6	5	4	3	2	1	14	15	16	17	18
Water Depth (m)	7.0	6.0	4.0	6.0	25.6	23.0	19.2	21.0	18.0	18.0	8.7	3.0	10.0	11.0	11.0	8.0
Salinity (‰)	17.1	16.9	20.9	22.9	23.1	22.5	21.7	20.8	20.8	20.9	20.7	21.5	24.4	24.4	25.7	26.6
Temperature (°C)	26.5	25.8	26.1	26.3	25.9	26.0	25.7	25.8	25.8	25.5	25.6	25.4	25.2	25.7	25.7	26.0
pH	7.6	7.6	7.6	7.7	7.8	7.7	7.8	7.6	7.7	7.6	7.6	7.8	7.9	8.0	8.0	8.0
DO (ppm)	2.91	2.88	3.09	3.82	3.27	2.62	2.82	2.81	2.73	2.72	2.62	6.30	5.64	6.45	6.49	6.87

Area	Outer Parts of the Studied Area														
	Bo Gui C.			Bo De River							Bay Hap Bay				
	12	13	29	23	24	25	26	27	28	44	43	19	20	21	22
Station (CM99-)	12	13	29	23	24	25	26	27	28	44	43	19	20	21	22
Water Depth (m)	13.0	14.0	10.0	30.0	38.0	28.0	45.0	22.0	8.0	5.0	4.5	4.5	1.5	0.8	3.8
Salinity (‰)	21.4	26.3	28.2	21.1	24.3	25.7	22.7	28.8	29.9	27.1	28.0	28.5	28.0	27.5	28.7
Temperature (°C)	26.2	25.6	25.7	25.9	25.8	25.8	26.0	25.7	25.9	-	26.0	26.3	26.1	26.2	26.3
pH	7.8	7.9	8.2	8.0	8.1	8.0	8.0	8.1	8.2	8.1	8.2	8.0	8.1	8.0	8.0
DO (ppm)	3.51	4.05	7.84	6.01	6.42	5.83	6.35	7.32	6.03	-	7.62	6.71	7.40	7.38	6.69

Tables 3 and 4 show the summarized results of measurements of water depths and such chemical properties of surface waters as salinity, temperature, hydrogen ion exponent (pH) and dissolved oxygen amount (DO) in the studied area in 1998 and 1999, respectively. The results of them in each water area with the exception of them for water temperatures are as followings. For spatial distribution of surface water temperatures, they in the inner parts, 27 - 29 °C in 1998 and 26 - 28 °C in 1999, are generally higher than them in the outer parts, 26 - 28 °C in 1998 and around 26 °C in 1999.

**Bay Hap River:** The upper course of the river belonging to the innermost part of the studied area is shallow less than five metres deep in whole. Southward gradual increases of salinity from 0.6 to 7.0 ‰, pH from 7.6 to 7.9 and DO from 3.40 to 4.89 ppm are recognizable.

**Muong Dao Canal:** The water depths of the canal extending northward from the middle course of the Dam Doi River are 6 - 13 m. Southward increase of salinity from 4.2 to 13.7 ‰, pH from 7.5 to 7.8 and DO from 3.36 to 3.87 ppm are distinguished.

**Dam Chim River:** The water depths of the river are 6.4 - 8.8 m. Salinity decreases northward from 28.0 to 19.0 ‰, but it increase to 24.0 ‰ at the northernmost station.

**Cai Nhap Canal:** The water depths of the canal connecting the Bay Hap River with the Cua Lon River are 11 - 16 m. Marked southward increases of salinity from 10.1 to 21.8 ‰, pH from 7.7 to 8.1 and DO from

4.70 to 6.43 ppm are recognized within this comparatively short canal.

**Dam Doi River:** The river situating in the east of the studied area connects with the Cua Lon and Bo De Rivers on the west, and the Dan Ching River and the Bo Gui Canal in the east. Water depth of the river is extremely variable ranging less than one to over 20 m. Westward increases of salinity from 17.1 to 22.9 ‰ and DO from 2.91 to 3.82 ppm are recognizable, but pH is constant round 7.6.

**Cua Lon River:** The longest river, about 50 km long, in the studied area starts from the triple junction with the Bo De and Dam Doi Rivers in the east and flows into the Bay Hap Bay in the west. There is a westward decrease of the water depths from 25.6 to 8.0 m in the river with the shallow exceptions of the stations CM99-1 and 14 where the river turns southward in its direction. The lowest values of salinity (20.7 ‰), pH (7.6) and DO (2.62 ppm) are observed in the central part of the river, and they increase both westwards (26.6 ‰, 8.0, 6.87 ppm) and eastwards (22.5 ‰, 7.8, 3.27 ppm).

**Bo De River:** The short river, about 7 km long, starts from the triple junction with the Dam Doi and Cua Lon Rivers and flows into the South China Sea in the east of the studied area. The centre of the river is generally very deep more than 25 m, but it becomes shallower less than 10 m southwards. Marked southward increases of salinity from 21.1 to 28.0 ‰ are recognized. DO and pH are generally high 5.8 - 7.6 ppm and round 8.1, respectively.

**Bo Gui Canal:** The water depths of the short canal connecting the Dam Doi River with the South China Sea in the east of the studied area are 10 - 13 m. Seaward increases of salinity from 21.4 to 28.2 ‰, pH from 7.8 to 8.2 and DO from 3.51 to 7.84 ppm are clearly observed.

**Bay Hap Bay:** The bay situated in the west of the studied area opens to the Gulf of Thailand. All survey stations in 1999 are located in the bay mouth area. The bay mouth area is shallow less than five metres deep. Salinity, pH and DO of the surface waters are constant round 28.0 ‰, 8.0 and 6.7 - 7.6 ppm, respectively.

**Gulf of Thailand:** Only one station CM98-1 is located in the gulf area about one kilometre west off the Cap Ca Mau in the southwestern margin of the studied area. The water depth of the area is very shallow less than one metre.

**South China Sea:** All survey stations in the sea are located within a few kilometres south off the river mouth of the Bo De Rivers in 1998. The area are shallow less than a few metres deep in general. Salinity is comparatively high round 27 ‰.

#### *Subaqueous Sediments*

Onboard descriptions for subaqueous sediments obtained in 1998 and 1999 are summarized in Tables 1 and 2, respectively. Figures 4 and 5 indicate proportional grain-size distributions in weight for the selected subaqueous sediments obtained in 1998 and 1999, respectively. Further, Table 3 shows mud contents and sediment grain compositions of sandy sediments from selected sediments in both 1998 and 1999. Microscopic photographs of the sandy sediments from selected samples are shown in the Plate figures.

Muddy sediments mostly cover the bottom surface of the water area in the studied area (Figs. 4 and 5).



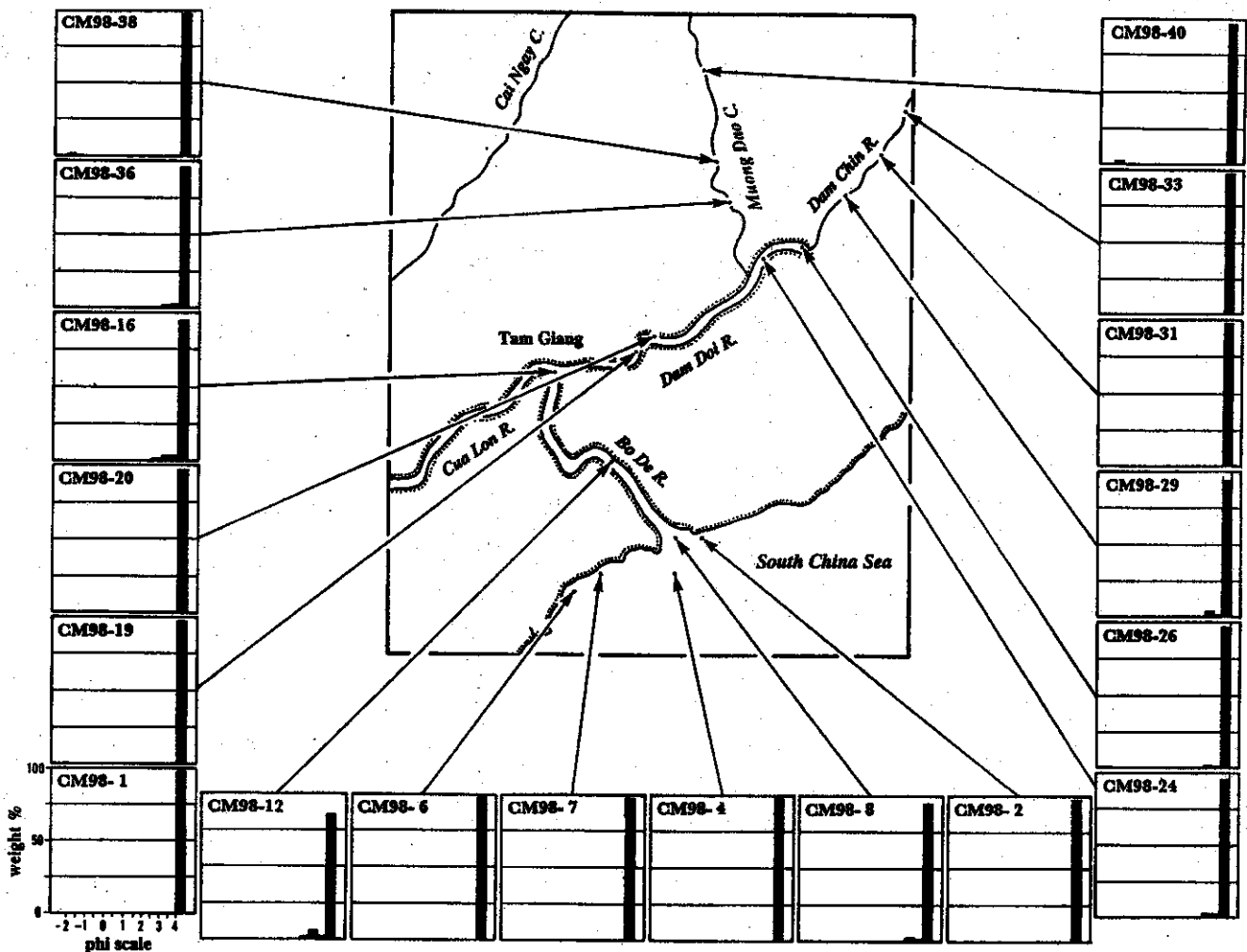


Fig. 4. Proportional grain-size distributions in weight of the selected subaqueous sediments obtained in December, 1998.

However, reliable differences on the textural and compositional features of the subaqueous sediments, particularly on the biogenic sediments, are recognized in each water area. Brief description of the sediments in each area as follows:

**Bay Hap River:** Plant debris rich light brown soft or soupy mud covers the bottom surface of the river with the exception of the station CM99-33 where bluish grey semi-consolidated burrowed mud crops out. Proportional mud contents of them are more than 90 %. Muddy sediments are composed mainly of clay minerals and very fine plant debris. Diatoms and pollens are frequently recognized in the muddy sediments. Sandy sediments consist mainly of such terrigenous sediments as quartz, feldspar, biotite and muscovite. Authigenic pyrites are frequently, and such biogenic sediments as molluscan shell fragments, benthic foraminifers and sponge spicules are rarely distinguished in the sediments.

**Muong Dao Canal:** Bluish grey or light grey semi-consolidated burrowed mud crops out in the most part of the bottom surface of the canal. The mud is covered by plant debris rich greyish brown soft mud in part. Proportional mud contents of the semi-consolidated mud are high more than 95 %. Muddy sediments are

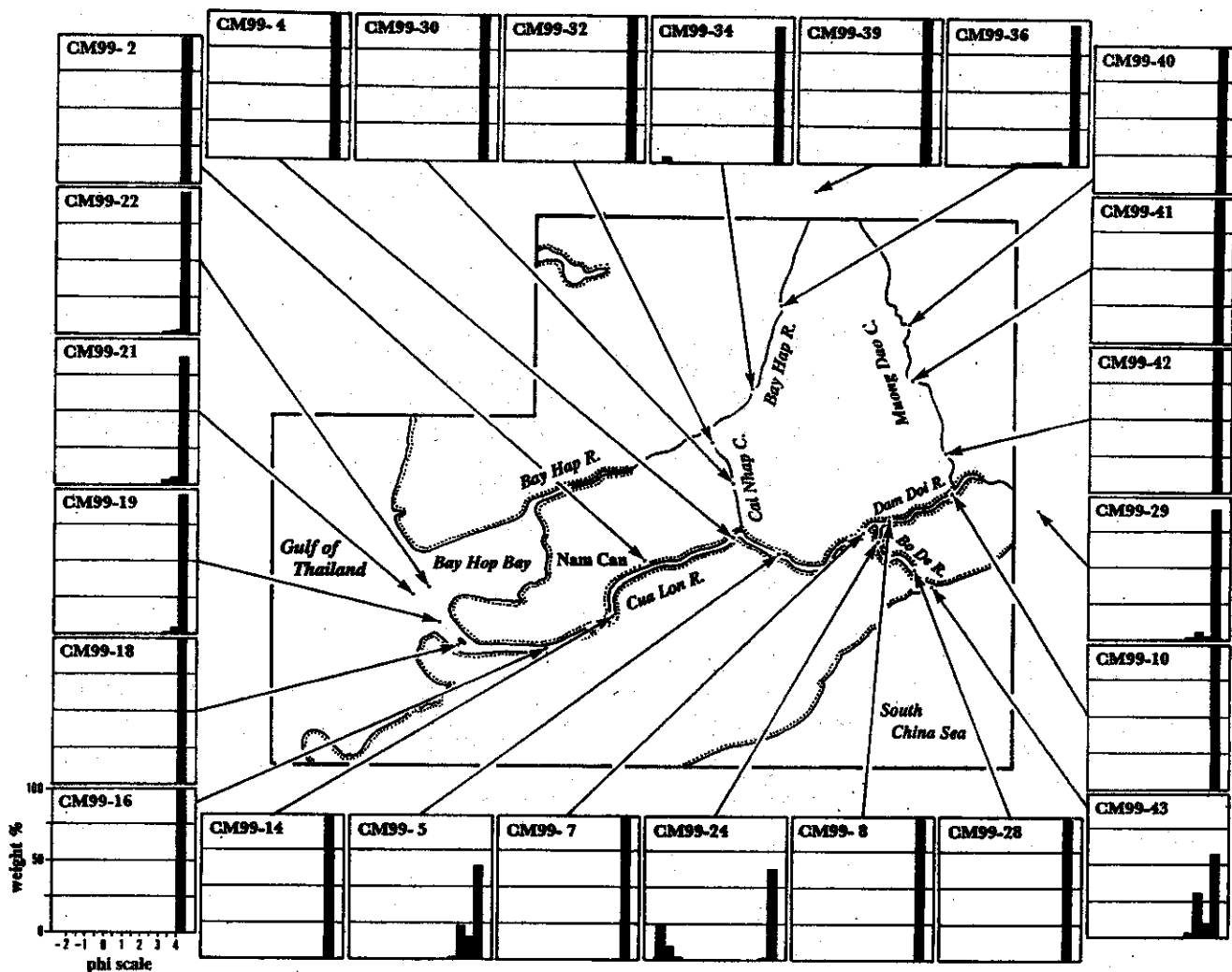


Fig. 5. Proportional grain-size distributions in weight of the selected subaqueous sediments obtained in December, 1999.

composed mainly of clay minerals. Coccolith is frequently recognized in the muddy sediments. Sandy terrigenous sediments are composed mainly of quartz, feldspar, lithic fragments and biotites. Molluscan shells, shell fragments and benthic foraminifers are commonly, and planktonic foraminifers, radiolarians and sponge spicules are occasionally recognized in the sediments. Authigenic pyrites are distinguished in the sandy sediments.

**Dam Chim River:** Plant debris bearing light brown compact burrowed mud and plant debris rich dark brown soft mud are distributed in the bottom of the river. Proportional mud contents of both are more than 90 %. Muddy sediments of both are composed mainly of clay minerals and very fine plant debris, but coccolith is commonly recognized in the former. Sandy sediments of the compact mud consist mainly of quartz and biotite with a small amount of authigenic pyrite, benthic and planktonic foraminifers, ostracodes, sponge spicules and molluscan shell fragments.

**Cai Nhap Canal:** Molluscan shell fragments and plant debris bearing bluish grey semi-consolidated

burrowed mud crops out in the bottom of the canal. Proportional mud contents are almost 100 %. Surface of the mud is stained in reddish brown in colour. Muddy sediments consist mainly of clay minerals. Coccolith and diatoms are commonly recognized in the muddy sediments. Sandy sediments are composed mainly of such terrigenous sediments as quartz, biotite, muscovite and feldspar with a small amount of lithic fragments. Biogenic sediments such as molluscan shell fragments, benthic and planktonic foraminifers, ostracodes and echinoid fragments are occasionally distinguished in the sandy sediments. Authigenic pyrites are common in the sandy sediments.

**Dam Doi River:** Plant debris rich brownish grey homogeneous mud is distributed in the bottom surface of the river. Proportional mud contents are high more than 94 %. Muddy sediments are composed mainly of clay minerals and fine plant debris. Sandy sediments consist chiefly of quartz, feldspar, biotite, lithic fragments and a little amount of muscovite and authigenic pyrite. Molluscan shell fragments and benthic foraminifers are commonly distinguished in the sandy sediments.

**Cua Lon River:** Plant debris rich brownish grey homogeneous mud is distributed in the bottom surface of the river. Proportional mud contents are generally high more than 90 %, but 62 % at the station of CM99-5. A little amount of sands were recovered at the site CM99-4 where the content is 0 %. Muddy sediments are composed mainly of clay minerals and fine plant debris. Sandy sediments consist chiefly of quartz, feldspar, biotite, lithic fragments and a little amount of muscovite and authigenic pyrite. Molluscan shell fragments and benthic foraminifers are rarely distinguished in the sandy sediments.

**Bo De River:** A wide variety of sediments were recovered from the bottom surface of the river. Molluscan shell fragment and plant debris bearing medium- to coarse-grained sandy mud are distributed in the southernmost part of the river. Proportional mud contents are high more than 90 %. Muddy sediments are composed of clay minerals. Coccolith is commonly recognized in the muddy sediments. Sandy sediments consist chiefly of quartz with a small amount of lithic fragments, biotite and authigenic pyrite. Benthic foraminifers, ostracodes and sponges are frequently recognized in the sandy sediments. In contrast to this, plant debris bearing bluish grey compact mud crops out in the central part of the river. Proportional mud contents are high round 99 %. Muddy sediments are composed chiefly of clay minerals. Coccolith is commonly recognized in the muddy sediments. Sandy terrigenous sediments consist mainly of quartz, feldspar, biotite and lithic fragments. Benthic foraminifers and molluscan shell fragments are rarely detected in the sandy sediments. Authigenic pyrites are commonly observed in the sediments. A little amount of pale grey semi-consolidated muds were recovered from the bottom surface of the northern part of the river. Proportional mud contents are round 60 %. Muddy sediments are composed mainly of clay minerals. Sandy sediments consists chiefly of quartz, feldspar and lithic fragments with a small amount of benthic foraminifers and molluscan shell fragments. Plant debris rich brownish grey homogeneous soft mud is distributed in the coastal shallow areas of the river. Proportional mud contents of them are more than 90 %. Muddy sediments are composed mainly of clay minerals and fine plant debris. Sandy sediments consist chiefly of quartz, feldspar, biotite, lithic fragments and a little amount of muscovite and authigenic pyrite. Molluscan shell fragments and benthic foraminifers are rarely distinguished in the sandy sediments.

**Table 5. Proportional mud contents and compositions of sandy sediments of the selected samples (+++: dominant, ++: common, +: present, \*: hornblende and zircon, \*\*: lateritic rocks).**

Station	Locality	Mud Content (%)	Terrigenous Sediments							Biogenic Sediments							Artificial Sediments		
			quartz	feldspar	biotite	muscovite	heavy min.	pyrite	lithic frag.	benth. foram.	plank. foram.	ostracods	radiolaria	diatom	sponge spiculae	sponge micros.		echinoide	plant debris
CM99-33	Dam Chim River	99	+++		+			++		+							+++		+++
CM99-31	"	99	+++		+			++		+							+++		+++
CM99-29	"	94	+++		++			+		+							+++		+
CM99-20	Muong Dao Canal	97	++		+			+	+++	++							+++	++	
CM99-38	"	96	++	+	+			+	+++	++							+++	++	
CM99-36	"	96	+		+			+	+	++							+++	++	
CM99-28	Dam Doi River	97	+++		++			+	+	+							+++	+	+
CM99-24	"	94	+++	+	++			+	++	+							+++	+	+
CM99-20	"	98	+++		+			+	+	+							+++	+	++
CM99-19	"	99	+++	+	++			+	+	+							+++	+	++
CM99-16	"	94	+++	+	++			+	+	+							+++	+	+
CM99-12	Bo Dai River	97	+++	+	++			+	+	++							+++	+	+
CM99-8	"	94	+++		++			+	++	++							+++	++	+
CM99-2	South China Sea	96	+		+++			+	+	+							+++	++	+
CM99-4	"	97	+		+++			+	+	+							+++	+	+
CM99-7	"	99	++	+	++			+	++	+							+++	++	+
CM99-6	"	100	+		++			+	++	++							+++	++	+
CM99-1	Cape Ca Mau	98	+		++			+	+	++							+++	+	+
CM99-40	Muong Dao Canal	100	+	+	+	+		+	+	+							+++	+	++
CM99-41	"	99	+	+	+	+		+	+	+							+++	+	++
CM99-42	"	97	+	+	+	+		+	+	+							+++	+	++
CM99-39	Bay Hap River	100	+	+	+	+		++	+	+							+++	+	++
CM99-36	"	93	+	+	++	+		+	+	+							+++	+	++
CM99-34	"	92	+	+	++	+		++	+	+							+++	+	++
CM99-32	Cal Nhap Canal	100	++	+	+	+		+	+	+							+++	+	++
CM99-31	"	99	+	+	+	+		+	++	+							+++	+	++
CM99-10	Dam Doi River	100	++	+	++	+		+	++	+							+++	+	++
CM99-8	"	99	++	+	++	+		+	++	+							+++	+	++
CM99-7	Cua Lon River	92	+	+	+			+	+	+							+++	+	++
CM99-5	"	82	+++	+++	+			+	++	+							+++	+	++
CM99-4	"	0																	
CM99-2	"	86	++	++	++	+		+	+	+							+++	+	++
CM99-14	"	91	++	+	++	+		+	+	+							+++	+	++
CM99-16	"	99	+	+	+			+	++	+							+++	+	++
CM99-18	"	100	+	+	+			+	+++	+							+++	+	++
CM99-19	Bay Hap Bay	97	+++	+	++	++		+	++	++							+++	++	+
CM99-21	"	88	++	++	++	++		+	++	++							+++	++	+
CM99-22	"	86	++	+++	++	+++		+	++	++							+++	++	+
CM99-24	Bo Dai River	95	++	++	++	++		+	+++	+							+++	++	+
CM99-26	"	99	++	+	+			++	++	++							+++	++	+
CM99-43	"	86	++	+++	+	+++		++	++	+++							+++	++	+
CM99-28	South China Sea	91	+++	+++	++	++		+	+	+							+++	+	+

**Bo Gui Canal:** Molluscan shell and shell fragment bearing bluish grey semi-consolidated burrowed mud are distributed in the bottom of the canal. Proportional mud contents are high more than 95 %. Muddy sediments consist mainly of clay minerals. Coccolith and diatoms are generally recognized in the muddy sediments. Sandy sediments are composed mainly of such terrigenous sediments as quartz, biotite, muscovite and feldspar with a small amount of lithic fragments. Biogenic sediments such as molluscan shell fragments, benthic and planktonic foraminifers, ostracodes and echinoide fragments are occasionally distinguished in the sandy sediments. Authigenic pyrites are common in the sandy sediments.

**Bay Hap Bay:** Plant debris rich and molluscan shell fragment bearing dark greyish brown homogeneous soft or soupy mud covers the bottom surface of the bay. Proportional mud contents of the sediments are 88 - 95 %. Muddy sediments are composed mainly of clay minerals. Coccolith and diatoms are distinguished in the muddy sediments. Sandy terrigenous sediments consist chiefly of quartz, lithic fragments, feldspar, biotite, muscovite. Such biogenic sediments as benthic foraminifers and echinoide fragments are commonly observed in the sandy sediments.

**Gulf of Thailand:** Plant debris rich and molluscan shell fragment bearing brownish grey homogeneous mud is distributed in the bottom surface of the gulf off the Cape Ca Mau at a water depth of 0.8 m. The proportional mud content is 99 %. Muddy sediments are composed of clay minerals. A little amount of quartz, biotite and lithic fragments are distinguished as sandy terrigenous sediments.

**South China Sea:** Plant debris rich and molluscan shell fragment bearing brownish grey homogeneous mud is distributed in the bottom surface of the South China Sea south off the Bo De River. Proportional mud contents are high more than 97 %. Muddy sediments consist chiefly of clay minerals. Sandy terrigenous sediments are composed mainly of biotite, lithic fragments and quartz with a small amount of muscovite and feldspar. Benthic and planktonic foraminifers, ostracodes and sponge spicules are commonly recognized in the sandy sediments as biogenic sediments. Authigenic pyrite is detected in the sandy sediments.

### **Discussion: Depositional Settings of the Water Areas around the Mangrove Habitats**

For understanding the subaqueous sedimentary processes in the studied area, the first thing to be considered is the depositional settings in the water areas around the Ca Mau mangrove habitats. The depositional setting of the main water areas such as Dam Doi, Bo De and Cua Lon Rivers around the habitats should be defined as estuarine environments rather than tidal channel or fluvial environments, in spite of they are called as "*song* (= rivers)" by local people. As is well-known, water and sediment dynamics in estuaries are closely dependent upon the relative magnitude of tidal, river and wave processes (Prentice *et al.*, 1968; Prichard and Carter, 1971; Allen *et al.*, 1976; Leeder, 1982; Elliott, 1986). Prichard and Carter (1971) divided the water and sediment dynamics in estuaries into four such end members as; *Type A*: river-dominated estuaries where tidal and wave mixing processes are at a minimum, *Type B*: 'partially mixed' because of the effects of tidal turbulence which destroy the upper salt wedge interface and produce a more gradual salinity gradient from bed to surface water by both advective and diffusional mechanisms, *Type C*: vertically homogeneous because strong tidal currents completely destroy the salt-water/fresh-water interface over the entire estuarine cross section, and *Type D*: theoretical end members of the estuarine continuum and they show both lateral and vertical homogeneity of salinity.

The Ca Mau mangrove habitats are located in the southern marginal part of the Mekong Delta where very flat and low land areas are widely developed. The river mouths of the Mekong and Bassac Rivers that seem to be the major terrigenous sediment sources are situated far off about 400 km northeast of the area. Accordingly, it is inferred that freshwater supply into the water areas in the studied area is rather small due to undeveloped real fluvial system around the areas. On the other hand, since the southern margin of the studied area opens to the South China Sea and the Gulf of Thailand on the south and west, respectively where marked wave processes take place due to seasonal generation of typhoons in the South China Sea, sedimentary processes in the coastal areas are under the influence of such strong wave activity. However, the wave activity is not effective to the depositional processes in such main water areas as estuarine and tidal channel systems where most of the Ca Mau mangrove habitats are located, because each river or estuarine mouth is very narrow less than one kilometre wide as well as shallow less than 10 m deep. Thus, it can be stated that river and wave processes are inferior in the main water areas around the mangrove habitats. It is known that tidal ranges of the southern coastal part of the Mekong Delta are wide three to four metres in maximum. Strong tidal currents at the maximum stages in both flooding and ebbing tides

were observed during the sediment samplings in the present study even in the inner parts of the area. Thus, it is concluded that tidal process gives the dominant effect to the water and sediment dynamics in water areas around the Ca Mau mangrove habitats.

As already described in the present article, such chemical properties of surface waters as salinity, hydrogen ion exponent and dissolved oxygen amount show clear decreases from the outer parts to the inner parts though the middle parts. Excepting the distribution of bluish grey semi-consolidated mud that seems to be basement strata (Pleistocene ?) in the area, plant debris bearing muddy sediments mostly cover the bottom surface of the water areas. Such marine benthic micro-organisms as ostracodes and calcareous benthic foraminifers which are principal biogenic sediments in the offshore area are common or abundant in the samples obtained closely to the open sea. Their appearance in the sediments is traceable into the inner parts through the middle parts, and they are frequently recognized in the sediments even the sample obtained in the innermost parts of the area such as the upper course of the Bay Hap River. Since salinity of the surface water is below 2 ‰ in the innermost parts, it is inferred that these biogenic sediments are transported from the outer parts by strong flooding tidal currents. Taking all these factors into consideration, it is concluded that the sedimentary environments around the mangrove habitats in the studied area defined as 'Type C' estuary of Prichard and Carter (1971) that is tidal current dominated estuaries where active sedimentary processes take place by strong flooding and ebbing tidal currents.

## Conclusion

The principal findings of this study can be summarized as follows.

### 1. Water depths and chemical properties of surface waters.

- a. Water depths in the such water system as the Cua Lon and Dam Doi Rivers are generally 5 - 20 m, but they are more than 40 m in the centre of the Bo De River. They in the areas of the South China Sea and the Bay Hap Bay are shallow less than 5 m in general.
- b. Gradual decreases of such chemical properties of surface waters as salinity, hydrogen ion exponent and dissolved oxygen amount are recognized clearly from the outer parts to the inner parts in the water areas.

### 2. Subaqueous sediments around the mangrove habitats

- a. Plant debris dominated brownish grey mud mostly covers the bottom surface of water areas around the Ca Mau mangrove habitats. Muddy sediments are composed mainly of clay minerals and very fine plant debris. Sandy terrigenous sediments consist chiefly of quartz, feldspar, biotite, muscovite and lithic fragments. Such biogenic sediments as benthic foraminifers, marine ostracodes, sponge spicules and molluscan shell fragments are frequently recognized in most of sediments. Marked tendency of compositional and spatial distributions of these sediments is undistinguished
- b. Bluish grey semi-consolidated mud are distributed in the bottom surface of the Muong Dao Canal and the Cai Nhap River. Lithology and compositions of biogenic materials suggest that the mud is pre-Holocene basement strata in presumable.

3. The sedimentary environments around the mangrove habitats in the studied area defined as 'Type C' estuary of Prichard and Carter (1971) that is tidal current dominated estuaries where active sedimentary processes take place by strong flooding and ebbing tidal currents.

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## Explanation of Plate

Microscopic photographs of sandy sediments of the subaqueous sediments around the Ca Mau mangrove habitats in the southern marginal part of the Mekong Delta region, Viet Nam.

**Fig. 1:** Plant debris with a small amount of fine-grained quartz and calcareous fragments from the site CM98-17 in the lower course of the Dam Doi River.

**Fig. 2:** Plant debris with a small amount of fine-grained quartz and calcareous fragments from the site CM99-2 in the middle course of the Cua Lon River.

**Fig. 3:** Plant debris with a small amount of fine-grained quartz and calcareous fragments from the site CM99-8 in the lower course of the Dam Doi River near the triple junction with the Cua Lon and Bo De Rivers.

**Fig. 4:** Plant debris and fine-grained quartz and feldspars with a small amount of calcareous materials from the site CM99-21 in the bay mouth area of the Bay Hap Bay.

**Fig. 5:** Plant debris and fine-grained quartz and feldspars with a small amount of calcareous materials from the site CM99-29 in the river mouth area of the Bo Gui Canal near the South China Sea.

**Fig. 6:** Calcareous materials and plant debris bearing fine-grained quartz and feldspars contained in the semi-consolidated mud cropping out at the site CM99-31 in the central part of the Cai Nhap Canal.

**Fig. 7:** Plant debris with a small amount of very fine-grained quartz from the site CM99-36 from the upper course of the Bay Hap River. Calcareous materials are very rare.

**Fig. 8:** Large plant debris with a small amount of very fine-grained quartz from the site CM99-41 from the middle course of the Muong Dao Canal. Calcareous materials are rare.



