



ORGANIC MATERIAL AND SEA-LEVEL CHANGE IN MANGROVE HABITAT

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Preliminary Study on Subaqueous Sedimentation around the Khanom Mangrove Habitats in Nakhon Si Thammarat Province, South Thailand

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Introduction

Mangrove habitats are distributed limitedly in the Khanom area in the Nakhon Si Thammarat Province, South Thailand in the eastern coast of the central Malay Peninsula (Fig. 1, upper left). 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 mangrove habitats were collected and investigated to comprehend present subaqueous sedimentary processes. Further, measurements of water depth 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 sediments, and taking the results of measurements of water depth and chemical properties of surface water

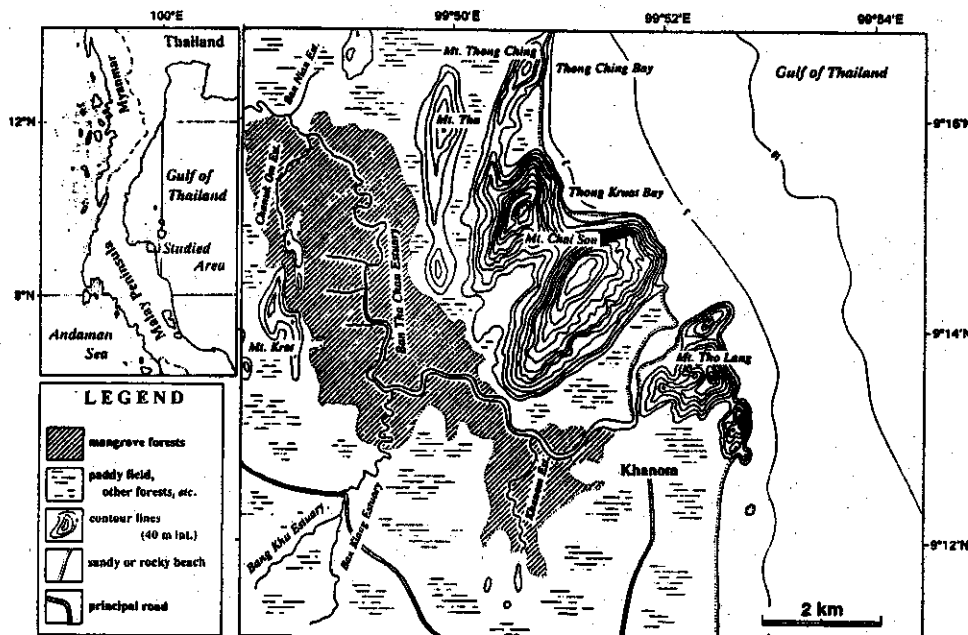


Fig. 1: Locations of the Khanom mangrove habitats in the eastern coast of the central Malay Peninsula, South Thailand (upper, left), and topographic features and distribution of mangrove habitats in the area.

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 present distribution of mangrove habitats in and around the studied area. The water areas can be divided geomorphologically into the areas of the Ban Tha Chan Estuary and the Gulf of Thailand. The narrow and long Ban Tha Chan Estuary, about 15 km long, starts about 10 km northwest of the town of Khanom and flows first southeastwards with meandering, then it turns the direction northeastwards on the west of the town, and flows into the Gulf of Thailand about 3 km north of the town. Several small and short estuaries such as the Ban Nian, Chanuk Om, Ban Klang and Khanom Estuaries flow into the Ban Tha Chan Estuary. Mangrove habitats are distributed around the Ban Tha Chan Estuary and the associated small estuaries. The Thong Ching, Tha, Chai Son and Tho Lang Mountains having N-S or NNE-SSW longitudinal axes and consisting mainly of the limestones, shales and sandstones of the Ordovician Thung Song Group (Department of Mineral Resources, 1987, 1992) shelter the habitat from the Gulf of Thailand. The Permo-Carboniferous sedimentary rocks of the Ratburi Group

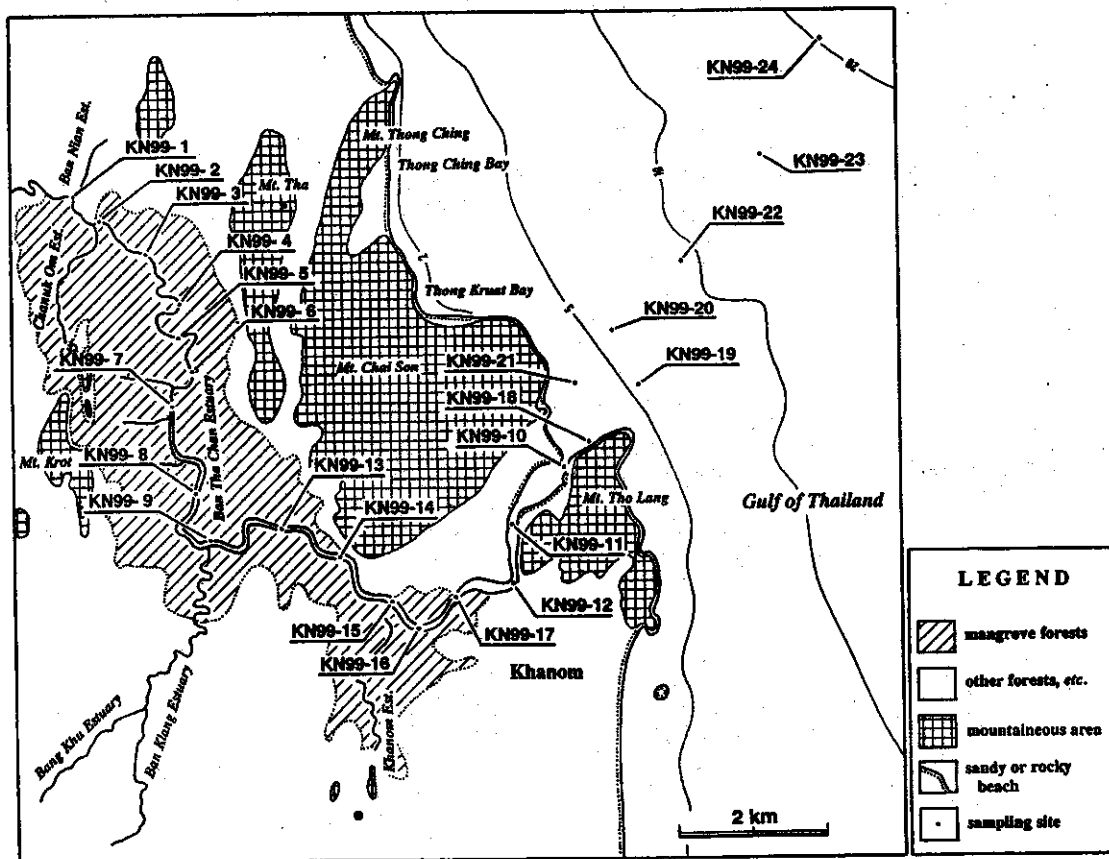


Fig. 2. Sites of subaqueous sediment samplings and measurements of chemical properties of surface waters in the Khanom area in August 1999.

Table 1. Results of surface sediment samplings, and measurements of water depths and chemical properties of surface waters in the Khanom area in August 1999.

Station	Locality	Sampler	Date (DD/M/Y)	Time	Latitude (N)	Longitude (E)	Water Depth (m)	Water Temp (°C)	Water Salinity (‰)	Water pH	Water DO (ppm)	Sediments
KN99-1	Ban Tha Chan Estuary	Sekigrab	22/08/99	08:38	9° 18'39"	99° 48'21"	0.8	28.1	0.7	7.8	2.27	large plant debris rich moderate brown mud mottled with dark grey mud
KN99-2	"	"	"	08:50	9° 18'41"	99° 48'41"	1.1	25.5	1.8	7.7	1.89	plant debris rich and molluscan shell fragment bearing moderate brown/dark grey mottled mud
KN99-3	"	"	"	09:58	9° 18'38"	99° 49'00"	2.4	25.8	2.4	7.8	1.81	plant debris rich and molluscan shell fragment bearing moderate brown mud covered by black mud
KN99-4	"	"	"	10:15	9° 14'53"	99° 49'29"	2.1	26.1	4.2	7.8	1.46	calcareous fragment and plant debris rich moderate brown compact mud covered by pale brown soft mud
KN99-5	"	"	"	10:43	9° 14'59"	99° 49'17"	2.3	28.4	8.3	7.8	1.70	plant debris rich dark grey/black sandy soil mud
KN99-6	"	"	"	11:00	9° 14'49"	99° 49'16"	3.0	28.6	10.4	7.8	1.43	shell fragment bearing plant debris with a small amount of sand
KN99-7	"	"	"	11:12	9° 14'17"	99° 49'14"	3.1	28.7	13.7	7.8	1.01	calcareous fragment bearing black plant debris with a small amount of sand
KN99-8	"	"	"	11:29	9° 13'48"	99° 49'29"	4.4	27.2	16.1	7.8	1.99	calcareous fragment bearing black plant debris with a small amount of mud
KN99-9	"	"	"	11:45	9° 13'29"	99° 49'34"	3.5	27.9	4.2	7.9	1.35	plant debris, shell fragment and mud bearing gravelly medium- to coarse-grained sand
KN99-10	Estuary Mouth Area	"	"	12:40	9° 14'03"	99° 52'11"	5.6	29.8	34.0	8.4	6.44	calcareous fragment bearing bluish grey muddy fine-grained sand covered by yellowish brown mud
KN99-11	"	"	"	14:18	9° 13'58"	99° 51'49"	-	29.3	33.0	8.4	8.02	calcareous fragment rich, plant debris bearing dark bluish grey muddy sand covered by yellowish brown mud
KN99-12	Ban Tha Chan Estuary	"	"	14:26	9° 13'09"	99° 51'49"	-	28.9	27.5	8.1	4.38	calcareous fragment bearing black/dark grey soft mud
KN99-13	"	"	23/08/99	08:46	9° 13'09"	99° 50'03"	6.1	25.5	-	7.3	3.24	calcareous fragment and plant debris bearing moderate grey muddy sand covered by black soupy mud
KN99-14	"	"	"	10:01	9° 13'16"	99° 50'24"	3.2	28.9	-	7.8	4.88	calcareous fragment, plant debris and granite-gravel bearing moderate brownish grey mud covered by black mud
KN99-15	"	"	"	10:10	9° 13'09"	99° 50'55"	5.9	27.1	-	7.8	4.31	shell and shell fragment rich and granite gravel bearing moderate brown or greyish black sandy mud
KN99-16	"	"	"	10:18	9° 12'48"	99° 51'04"	8.8	28.9	-	7.4	2.35	plant debris, calcareous fragment and granite-gravel bearing moderate brown mud covered by black mud
KN99-17	"	"	"	10:40	9° 12'38"	99° 51'29"	6.0	27.3	24.6	7.4	2.18	plant debris and calcareous fragment bearing dark greyish brown soft mud mottled with black mud
KN99-18	Estuary Mouth Area	"	"	11:06	9° 14'11"	99° 52'19"	-	29.0	-	8.0	8.02	shell and shell fragment rich, granite gravel bearing yellowish olive green sandy mud
KN99-19	Gulf of Thailand	"	"	12:00	9° 14'38"	99° 52'49"	10.5	27.5	-	8.1	5.91	calcareous fragment rich bluish/greenish grey mud
KN99-20	"	"	"	12:12	9° 16'01"	99° 52'30"	8.2	27.5	-	8.1	6.02	calcareous fragment rich bluish/greenish grey mud mottled partly with black mud
KN99-21	Estuary Mouth Area	"	"	13:20	9° 16'13"	99° 52'14"	9.8	28.4	-	8.1	5.98	shell fragment rich, plant debris bearing bluish/greenish grey mud
KN99-22	Gulf of Thailand	"	24/08/99	08:45	9° 15'32"	99° 53'01"	10.0	27.3	-	8.1	5.42	molluscan shell bearing bluish/greenish grey soft mud covered by yellowish grey soupy mud
KN99-23	"	"	"	08:52	9° 18'18"	99° 53'39"	14.8	27.2	-	8.1	5.05	calcareous fragment bearing bluish/greenish grey soft mud covered by yellowish brown soupy mud
KN99-24	"	"	"	09:05	9° 17'18"	99° 54'03"	29.0	27.2	-	8.1	5.04	calcareous fragment bearing bluish/greenish grey soft mud covered by yellowish brown soupy mud

and the Precambrian metamorphic rocks of the Land Sang Gneiss Complex are distributed west and south of the habitats, respectively (Department of Mineral Resources, 1987, 1992).

Sampling Methods and Analytical Procedures

The subaqueous sediment samples used for the present study were collected in August 1999. The samplings were carried out uniformly in the areas of the Ban Tha Chan Estuary and the Gulf of Thailand (Fig. 2). Sampling devices were a Seki-type grab surface sampler, about 500 ml in volume. Salinity, hydrogen ion exponent value (pH), and temperature and dissolved oxygen amount (DO) measurements for surface waters were conducted using by an Atago digital salt-meter type ES-421, 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 20-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. Twenty-four subaqueous surface sediments were successfully obtained from the studied area (Table 1).

In the laboratory, smear slides were prepared first and examined under a microscope for compositional 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 μm 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 μm. 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 2. Summarized results of measurements of water depths and chemical properties of surface waters.

Area	Ban Tha Chan Estuary															Gulf of Thailand								
	inner part					central part					outer part													
	1	2	3	4	5	6	7	8	9	13	14	15	16	17	12	11	10	18	21	19	20	22	23	24
Station (KN99-)																								
Water Depth (m)	0.8	1.1	2.4	2.1	2.3	3.0	3.1	4.4	3.5	6.1	3.2	5.8	6.8	5.0	-	5.6	-	9.6	10.5	8.2	10.0	14.8	20.0	
Salinity (‰)	0.7	1.8	2.4	4.2	8.3	10.4	13.7	15.1	4.2	-	-	-	-	24.6	27.5	33.0	34.0	-	-	-	-	-	-	
Temperature (°C)	25.1	25.5	25.8	26.1	26.4	26.8	26.7	27.2	27.0	25.5	26.9	27.1	26.9	27.3	28.9	29.3	29.8	29.0	28.4	27.5	27.5	27.3	27.2	27.2
pH	7.8	7.7	7.8	7.8	7.6	7.6	7.6	7.6	7.9	7.3	7.6	7.4	7.4	7.4	8.1	8.4	8.4	8.0	8.1	8.1	8.1	8.1	8.1	8.1
DO (ppm)	2.27	1.59	1.81	1.45	1.70	1.43	1.01	1.99	1.36	3.24	4.68	4.31	2.35	2.16	4.38	6.02	6.44	6.02	5.88	5.61	6.02	5.42	5.96	5.64

Table 2 shows the summarized results of measurements of water depths and chemical properties of surface waters in the studied area.

Water depths of the inner part of the Ban Tha Chan Estuary increase from 0.8 m at the innermost to 4.4 m at the confluence point of the Ban Klang Estuary, and in the central and outer parts of the Ban Tha Chan Estuary they fluctuate between 3.2 and 6.6 m. They show a clear offshoreward deepening in the area of the Gulf of Thailand from about 10 m near the estuarine mouth to 20 m at the furthest site KN99-24.

Salinity of the surface waters in the inner part of the Ban Tha Chan Estuary shows a clear increase from 0.7 ‰ at the innermost to 15.1 ‰ near the confluence point of the Ban Klang Estuary, but it drops to 4.2 ‰ at the point due to probably a certain amount of freshwater supply from the estuary. At the outer part of the Ban Tha Chan Estuary and the area of the Gulf of Thailand, salinity is high round 25 and over 30 ‰, respectively. A gradual increase of the surface water temperature can be recognized from 25 °C at the innermost part to 29 °C at the estuary mouth in the Ban Tha Chan Estuary. It is constant in the area of the Gulf of Thailand around 27 °C. Hydrogen ion exponent value (pH) is constant in the inner and central parts of the estuary about 7.3 - 7.9, but it increases to more than 8.0 in the outer part of the estuary and the area of the gulf. Dissolved oxygen amount (DO) is low less than 2.5 ppm in the inner part and between 2.2 - 4.7 in the central part of the estuary, on the other hand it is rather high more than 6.0 ppm and 5.4 - 6.0 ppm in the outer part and the gulf area, respectively.

Subaqueous Sediments

The subaqueous sediments from the studied area can be classified into three types distributed in the Ban Tha Chan Estuary area, the estuarine mouth area and the area of the Gulf of Thailand, based mainly upon their textural and compositional features. Table 3 and Fig. 3 show mud contents and sediment grain compositions for sandy sediments, and proportional grain-size distribution in weight for selected samples from the studied area, respectively. Microscopic photographs of the sandy sediments from selected samples are shown in the Plate figures.

Plant debris dominated dark grey or moderate brown muddy sand or sandy mud mostly covers the bottom surface of the inner and central parts of the Ban Tha Chan Estuary (Plate, figs. 1 and 2). Size and relative quantity of the plant debris decrease downstreamwards. A certain amount of granule- to

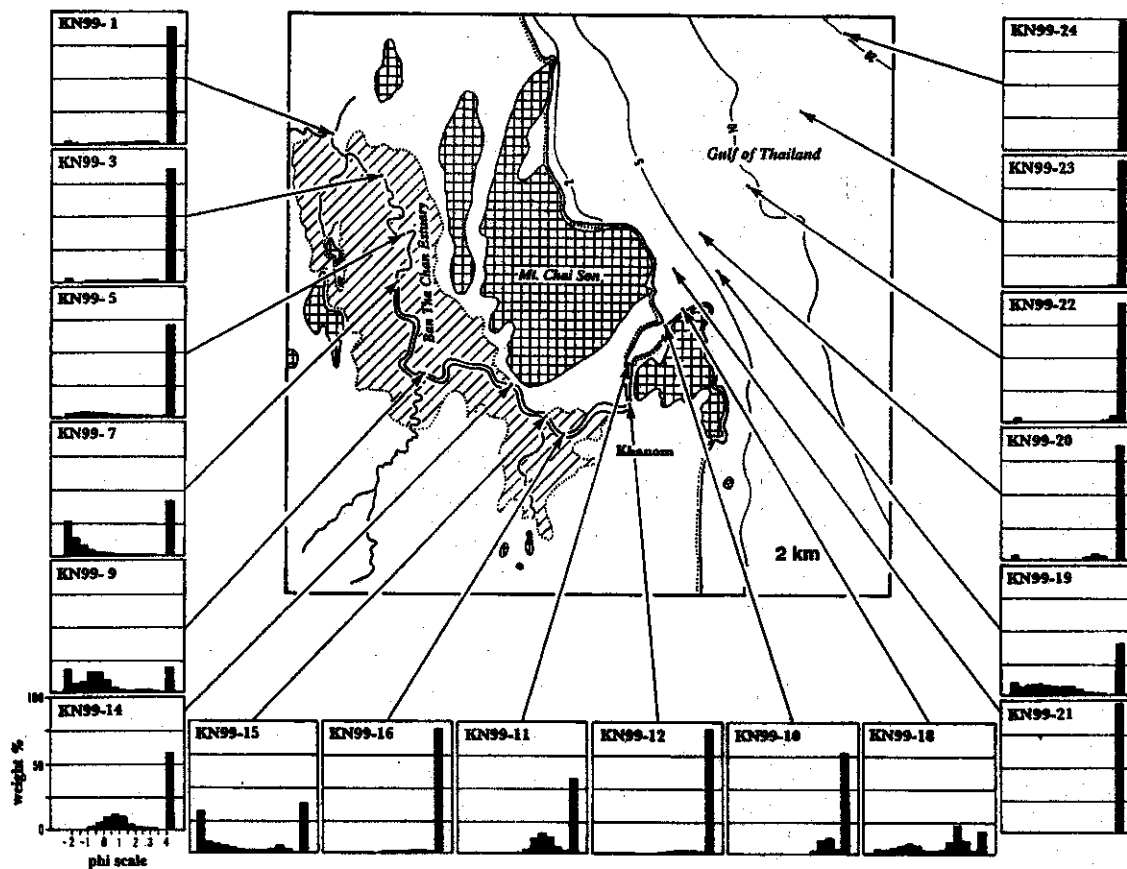


Fig. 3. Proportional grain-size distributions of sandy sediments from the selected subaqueous sediments.

pebble-gravels consisting mainly of limestones are contained in the sediments obtained in the central to outer part of the estuary (Plate, fig. 3). Proportional mud contents of them are generally high more than 70 % with some exceptions which contain a large amount of above mentioned gravels and/or large wood fragments. Sandy terrigenous sediments are composed mainly of very fine- to very coarse-grained quartz and fine-grained feldspar with a small amount of biotite, muscovite, pyroxenes and lithic fragments (Plate, figs. 5 and 6). Muddy sediments consist mainly of clay minerals and organic materials in probable. Molluscan shells and shell fragments are commonly, and agglutinated and calcareous benthic foraminiferal tests and their fragments are rarely recognized in the sediments.

On the other hand, calcareous materials consisting mainly of molluscan shells and shell fragments bearing bluish grey very fine-grained sandy mud is the dominated surface sediments in the area of the Gulf of Thailand (Plate, figs. 7 and 8). Proportional mud contents of them are very high over 80 % with an exception of the sample from the site KN99-19 that contains a large amount of granule- to pebble-gravels derived probably from the strata cropping out on the coastal cliff. Calcareous benthic foraminifers, marine ostracodes and coccolith are dominant in whole sediments. Echinoide spines and fragments are commonly recognized in the sediments. Radiolarians, planktonic foraminifers, sponge spicules and microscleres are detected in the sample from the offshoremost site KN99-24. Plant debris is less common. Sandy terrigenous sediments are composed mainly of fine-grained quartz and feldspars with a small amount of

Table 3. Proportional mud contents and compositions of sandy sediments from the Khanom area (+++: dominant, ++: common, +: present, *: pyroxenes, hornblende and zircon, **: limestones and metamorphic rocks).

Station	Locality	Mud Content (%)	Terrigenous Sediments							Biogenic Sediments										Artificial Sediments
			quartz	feldspars	biotite	muscovite	heavy min.	pyrite	lithic frag.**	benth. foram.	plant. foram.	ostracode	radiolarian	diatom	sponge spicule	sponge microc.	echinoids	plant debris	mollus. shell	charcoal grain
KN99-1	Ban Tha Chan Estuary	85	++	++					++	*							+++	++	*	
KN99-3	"	85	++	++					+	*							+++	+	*	
KN99-5	"	70	+	+					+	*							+++	+	*	
KN99-7	"	41	++	++				+	++								+++	+	*	
KN99-9	"	18	+++	+++			*	+	+								+++	+	*	
KN99-14	"	57	++	+++	+		*	+	+	*							+++	+	*	
KN99-15	"	34	+++	+++	+		*	+	+	*							++	++	*	
KN99-16	"	81	+++	++	+		*	+	++								++	++	*	
KN99-12	"	93	+++	++	+			+	+								++	++	*	
KN99-11	Estuary Mouth Area	58	+++	+++	++		++	++	+	*							++	++	*	
KN99-10	"	73	+++	++	+		+	+	+	*							+++	++	*	
KN99-18	"	18	+++	++	+		+	++	+	*							++	++	*	
KN99-21	"	97	++	++	++		+	++	+	*							+	++	*	
KN99-19	Gulf of Thailand	38	+++	+++	+		+	++	+	*							++	++	*	
KN99-20	"	83	+++	+++	+		+	++	++	*							+	+++	*	
KN99-22	"	87	+++	+++	+		+	++	++	*							+	+++	*	
KN99-23	"	97	+++	+++	++		+	+	++	*							+	+++	*	
KN99-24	"	99	+++	++			+	++	++	*							+	+++	*	

biotite, muscovite, pyroxenes and lithic fragments. Muddy sediments consist chiefly of clay minerals and quartz.

The sediments from the estuarine mouth area are defined as mixtures of the sediments from the Ban Tha Chan Estuary area and the area of the Gulf of Thailand that stated above. All sediments from the estuarine mouth area are contained a certain amount of plant debris, molluscan shells and shell fragments, calcareous benthic foraminifers, marine ostracodes and echinoide fragments. Sandy terrigenous sediments are composed of fine- to medium-grained quartz and feldspars with a small amount of biotite, muscovite, pyroxenes and lithic fragments. Muddy sediments consist mainly of plant debris and clay minerals. The sample at the site KN99-18 contains a large amount of granule- to pebble-gravels consisting of limestones derived from the starata cropping out around the mouth area. The sediments at the site KN99-12 located closely to the fishing port of Khanom are black coloured sticky mud with an offensive smell.

Discussion: Subaqueous Sedimentary Processes around the Khanom Mangrove Habitats

For understanding the subaqueous sedimentary processes in the studied area, the first thing to be considered is the depositional setting in the water areas around the Khanom mangrove habitats. The depositional setting of the Ban Tha Chan Estuary around where the habitats are distributed is defined undoubtedly as either the estuarine or lagoonal environment. As is well-known, water and sediment dynamics in estuaries and lagoons 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).

The Ban Tha Chan Estuary are situated in the eastern coast of the central Malay Peninsula where tidal range is small less than one metre in maximum and freshwater supply from surrounding rivers is also small due to undeveloped fluvial system around the estuary. Thus, it can be stated that tidal and river processes are inferior in the estuarine area. Further, although the estuary opens to the Gulf of Thailand where wave processes are dominant, it is inferred that the wave does not exert influence upon water and sediment dynamics in the estuarine area because the estuary is mostly sheltered from the gulf due to the very narrow,

less than 100 m in width, estuarine mouth.

As already described in the present article, such marine benthic micro-organisms as ostracodes and calcareous benthic foraminifers which are principal biogenic sediments in the offshore area are very rare or absent in the sediments from the central to inner part of the Ban Tha Chan Estuary. In contrast to this, plant debris derived from the mangrove habitats and other forests distributed around the inner and middle parts of the estuary are rare in the sediments from the area of the Gulf of Thailand. Further, the values of such chemical properties of surface waters as salinity, hydrogen ion exponent value, temperature and dissolved oxygen amount in the estuarine area are clearly distinguished from them of the gulf area. These facts support the idea that the subaqueous sediment and surface water exchanging processes between the areas of the estuary and the gulf are inactive in the studied area.

On the basis of the distribution and composition of the subaqueous sediments in the Khlong Thom and Satun areas in the western coast of the central Malay Peninsula where tidal range is wide three to four metres in maximum, Tsukawaki and Kamiya (1998), Tsukawaki and Asano (1999) and Tsukawaki *et al.* (1999) demonstrated the active subaqueous sediment exchanging processes in and around these mangrove habitats in both areas. Within the water areas of both, such marine biogenic sediments as calcareous benthic foraminifers and marine ostracodes are detected in most of sediments from the innermost parts of the estuaries. On the other hand, plant debris and charcoal grains originated in the mangrove habitats and local villages located in the habitats in the inner parts of the estuaries are traceable into almost all sediments from the offshore areas.

Taking all above stated things into consideration, it is concluded that the subaqueous sedimentary processes as well as water and sediments dynamics around the Khanom mangrove habitats are markedly inactive in comparison with that of the water areas around the mangrove habitats distributed in the western coast of the central Malay Peninsula.

Conclusion

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

1. Water depths and chemical properties of surface waters.
 - a. A gradual deepening is recognized from the innermost to the central part of the Ban Tha Chan Estuary.
 - b. Chemical properties of surface waters in the estuarine area are clearly distinguished from them in the area of the Gulf of Thailand.
2. Subaqueous sediments around the mangrove habitats
 - a. Plant debris dominated muddy sand or sandy mud, and muddy very fine- to very coarse-grained sand are distributed in the estuary area. Some of them contain a large amount of limestone gravels derived from strata around the estuary.
 - b. Subaqueous sediments distributed in the estuarine mouth area are mixtures of them in the estuarine area and the area of the Gulf of Thailand. Black sticky mud with offensive smell covers the bottom

surface near the fishing port of Khanom.

- c. Calcareous fragments rich bluish grey very fine-grained sandy mud is the dominated subaqueous sediments in the area of the Gulf of Thailand. Calcareous benthic foraminifers and marine ostracodes are frequently recognized in them.
3. Subaqueous sedimentary processes, water and sediments exchanging processes in other word, are inactive around the Khanom mangrove habitats.

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Explanation of Plate

Microscopic photographs of sandy sediments of the subaqueous sediments around the Khanom mangrove habitats, South Thailand

Fig. 1: Plant debris with a small amount of quartz and calcareous fragments from the site KN99-1 in the innermost part of the Ban Tha Chan Estuary.

Fig. 2: Plant debris with a small amount of quartz and calcareous fragments from the site KN99-5 in the inner part of the Ban Tha Chan Estuary.

Fig. 3: Poorly sorted quartz and feldspar from the site KN99-9 in the central part of the Ban Tha Chan Estuary in where the Ban Klang Estuary flows.

Fig. 4: Fine-grained quartz and feldspars with a small amount of calcareous materials from the site KN99-11 in the outer part of the Ban Tha Chan Estuary near the town of Khanom.

Fig. 5: Plant debris bearing fine- to medium-grained quartz and feldspars from the site KN99-14 in the central part of the Ban Tha Chan Estuary located closely to the Mt. Chai Son.

Fig. 6: Plant debris bearing fine- to medium-grained quartz and feldspars from the site KN99-16 in the central part of the Ban Tha Chan Estuary.

Fig. 7: Calcareous materials rich very fine-grained quartz from the site KN99-22 in the Gulf of Thailand. Calcareous benthic foraminifers and marine ostracodes are recognizable.

Fig. 8: Calcareous materials rich very fine-grained quartz from the site KN99-24 in the area of the Gulf of Thailand. Calcareous benthic foraminifers and marine ostracodes are recognizable.

