CHAPTER III

SEDIMENTS IN THE GULF OF THAILAND

Physiographic Setting of the Gulf

Thailand is situated in South East Asia between Latitude 6° and 20°N and between Longitude 95° and 105°E. The Gulf of Thailand extends from the shallow western part of the South China Sea over 750 km to the north-west between the Thai-Malaya Peninsula and Indo-China. The coast of the Central Plain of Thailand is its northern boundary.

The Thai-Malaya Peninsula is mountainous and has only narrow coastal plains, crossed by numerous small rivers. Through the vast Central Plain of Thailand the largest river, the Chao Phraya River, and its branch the Ta Chin River, enter the small square head of the Gulf which so-called the Upper Gulf of Thailand, flanked by the Mae Klong River on its western side and by the Bang Pakong River on its eastern side. These 4 main rivers transport sediments to fill the Gulf with variable ratios of bedrock and suspension load depending upon slope gradient and discharge condition, as indicated by prograding of delta averaging 4-5 m/yr (Brown, Buravas, Charaljavanaphet, Jalichandra, Johnson, Sresthapatra and Taylor, 1951; Achalabhuti, 1974). Along the western coasts of the Peninsula, rivers are short because of the proximity of the continental divide, hence sediment influx is low. Along the west coast of the Gulf, the Pattani River and the Tapi River carries considerable amount of silt, resulting in wide, flat coastal deposits, and delta formation at Surat

Thani and Pattani Provinces. The Phetchaburi River also gives rise to a wide deltaic plain. However, the previous four rivers are responsible for the major influx of sediment into the Gulf (Pitman, 1982). Windom, Paulsen, and Hungspreugs (1982) found most of the sediments in the Upper Gulf are land -derived in origin which deposit with the rates between 3.3-8.9 mm/yr. The sedimentation rate of the northern part of the Upper Gulf is about 3-9 times higher than the southern part.

The average depth of the Gulf over its total area of about 320,000 km^2 is 45 m, maximum depths in the central part are 70-86 m. Towards the coasts the depth gradually decreases.

The square (100x100 km^2) northernmost head of the Gulf has an average depth of 15 m. From the shallow northern coast the bottom slopes gradually downward to a mean depth of 24 m in its mouth between Sattahip and Hua-Hin. The eastern part, with its rocky offshore island, is slightly deeper than the western half. Generally, the eastern side is shallower and flatter than the rocky steep slopes of the western coast (Ichiye, 1966).

Geologically, the western part of the Gulf is a contamination of the syncline of the Central Plain of Thailand in which the Chao Phraya River and its tributaries have deposited their sediments in layers up to 3,000 m in thickness. Even at present the rivers build their delta southward into the Gulf with an average accretion of about 5 m/yr.

The mouth of the Gulf opening to the South China Sea is about 200 miles wide surface, but below 50 m there is only a 30-mile wide channel connecting with the inner deep basin of the South China Sea with the sill depth of 58 m. The channel cuts between a 30-m ridge on the north extending southwest from Cape Ca Mau and a 50-m ridge extending northeast from Kota Bharu (6.3°N, 103.2°E) (Ichiye, 1966). The sill considered to be an underwater continuation of the hills along the West Cambodian Coast. It is covered with a relatively thin layer of sediments.

Along the sides of the Gulf, the sea floor is interspersed with hills, many of which rise above the sea level as islands. Those Islands mainly of granite and/or meta-sediments of Mesozoic-Upper Paleozoic age with locally supply sand and rock fragments to the sea bottom (Achalabhuti, 1974). In general, the Gulf of Thailand is floored by modern detrital silts and clays (Achalabhuti, 1974).

The Gulf may be considered as a two-layers shallow water estuary. Low salinity water which has been diluted by heavy precipitation and river runoff out of the Gulf at the surface. Average surface salinity is 30.5-32.5 ppt in winter and 3.1-32.0 ppt in summer. There is an inflow of water from the South China Sea into the Gulf over 58-m sill through the entrance channel. This water has high salinity above 34.0 ppt and relatively low temperature below 27.0 °C, and it fills the deep central depression below a depth of approximately 50 m (Ichiye, 1966). The climate in the northern part of the Gulf is different from the southern part. In the northern part, the rainy season under the influence of southwest monsoon starts from May to October with highest precipitation in September. The lowest precipitation occurs during the dry season (northeast monsoon) in January with highest precipitation in November and lowest in April.

Wind-driven currents are generally less than half a knot, north to northeast at entrance, counterclock-wise inside during the summer, but southerly at the entrance and clockwise inside during rainy season and winter. However, neither the northeast nor the southwest monsoon during winter and summer , respectively, is constant in direction or velocity over the Gulf as a whole (Ichiye, 1966).

The combined effects of the variable winds, tidal current, freshwater runoff and excessive precipitation produce localized areas of divergence and convergence. In divegence area is upwelling from deep layer, and in convergence area is sinking from the upper layer. The strongest upwelling occurred along the western coast in August and on the northeastern coast in October and January, while slightly upwelling was detected in all seasons in a localized area south of 12°N and 101°E. Convergence and sinking occurred in the central part of the Gulf but were only occasionally observed along both the east and the west coasts. Productivity in the Gulf is higher than in the eastern side of the South China Sea and in the Philippines waters and the Celebes Sea. The rich productivity of the Gulf is attributed to vertical mixing and upwelling which bring the nutrients from the bottom (Ichiye, 1966).

Previous Investigations

There are few geological and geochemical studies on sediments of the Gulf of Thailand. Texture, colour, organic contents and minerals are of main interest e.g., Emery and Niino (1963), Aoki (1976), Kengkoom (1980), Kasemsupaya (1981), Kengkoom and Rodmanee (1982), Yamamoto and Yada (1982) and Umnuay (1984), etc..

The sediments in the Gulf of Thailand can be classified genetically into 6 types: organic, authigenic, volcanic, residual, relict and modern detrital. The bulk of sediment (85-97%) is detrital in origin, therefore, it is chiefly recent deposits (Emery and Niino, 1963). Dubach (1968) reported that the bottom of the Gulf is principally mud, although irregular patches of mud-sand, sand, gravel, and rock occur near the coast, particularly on topographic elevations, while the bottom outside the Gulf consists mostly sand, but mud occurs off river mouths. Yamamoto and Yada (1982) concluded that grayish calcareous sandy mud and muddy sand were distributed throughout the Gulf. However, these works on colour and texture were done visually not systematically, thus making comparison difficult.

Yada, Takaki, Kanehara, Kuno and Yamamoto (1982) using Smith-McIntyre grab sampler to collect sediments from the Gulf of Thailand. They found that most of the top 10 cm sediment from the Gulf was blanketed with grayish calcareous sandy mud or muddy sand. In the central portion of the Gulf it was covered with reddish brown mud of only 1-2 cm thickness, which was suspected to be weathered products of the lateritic sand-stone gravel supplied from the adjacent slopes and the coastal region of the Malay Pennisula. In some places the sediment was comprised of grayish calareous silty clay which contained abundant nannofossils and forraminiferal remains. Suspended brownish silty clay is dispersed abundantly into the Upper Gulf from the Chao Phraya and associated rivers but not deposited in the Central Region of the Gulf bottom floor, judging from the lithology of bottom sediments.

The study of clay minerals distributions in the outer part of the Gulf was done by Aoki (1976) and Chen (1978), which are only 2 works taken in detail of clay mineral compositions in sediments of the outer part of Gulf of Thailand. Recently, clay mineral compositions of sediments from the inner part of the Gulf was studied by Dharmvanij and Sompongchaiyakul (1987) and in this study.

In term of pollution study, quite a number of works has been done in analyses of metals in sediment. Most of the works reported total metal contents in sediments on different basis i.e., correction carbonate or quartz, and size are not accounted for. Such the works of Polprasert, Vongvisessomjai, Lohani, Muttamara, Arbhabhirama, Traichaiyaporn, Khan and Wangsuphachart (1979), AIT (1980), Idthikasem, Bamrungrajhiran, Kaewpakdee and Chingchit (1981), who worked on total metals in sediments from the the Upper Gulf of Thailand. While Menasveta and Cheevaparanapiwat (1981) worked on sediments from the mouth of the four 4 rivers, Mae Klong, Ta Chin, Chao Phraya and Bang Pakong, and Chanpongsang (1982) studied the Chao Phraya estuarine sediments. Therefore, comparison is nearly impossible. In addition, results of total sediments analyses need to be interpreted correctly. Analytical results alone without considering partitioning effect will not yield any useful information for pollution study.

However, the works of Jaturanon (1983), Hungspreugs and Yuangthong (1983), Jindasombatjareon (1983) , Windom, Silpipat, Chanpongsang, Smith and Hungspreugs (1984), and Petpiroon (1988) are the first works taking into account partitioning effect. Partitioning study should be more meaningful for pollution study providing that contamination is kept to a minimum.

Those wokers concentrated their studies to the upper part of the Gulf of Thailand, very few works were done in the lower part. However, Kengkoom (1980) and Kengkoom and Rodmanee (1982) had studied sediments in the Lower Gulf in term of total metal contents.

It is obvious that sediment study in the Gulf of Thailand is still sketchy and inconclusive unless some basic, systematic groundwork is done.

The in depth studied in sediment sequential leaching was done by Jaturanon (1983). The content of Cd, Cr, Cu, Fe, Pb, Mn, Ni and Zn in various sediments from the Upper Gulf of Thailand were analyzed using 3 methods namely: leaching with dilute HCl, sequential leaching method and total digestion. He indicated that most of the metals are accumulated naturally except for Pb, Zn and Cu deposited in the northern part of the Upper Gulf were anthropogenic in origin. The metal contents in sediments from the sounthern part of the Gulf are similar to the natural level. The partitioning study showed that Pb, Zn, Mn and Fe were preferentially bound to oxyhydroxides, while Cd and Cu were bound to organic fraction.

<u>Grain Size Distribution of Sediment</u>

The percentage by weight of sand, silt and clay is plotted in a ternary diagram proposed by Gorsline (1960) (Figure 6) and the type of each sample is classified accordingly. Of the 73 samples, 7 types of sediments namely sandy clayey silt, silty sand, clayey silt, sand, sandy silt, silt and silty clayey sand are found in a decreasing order

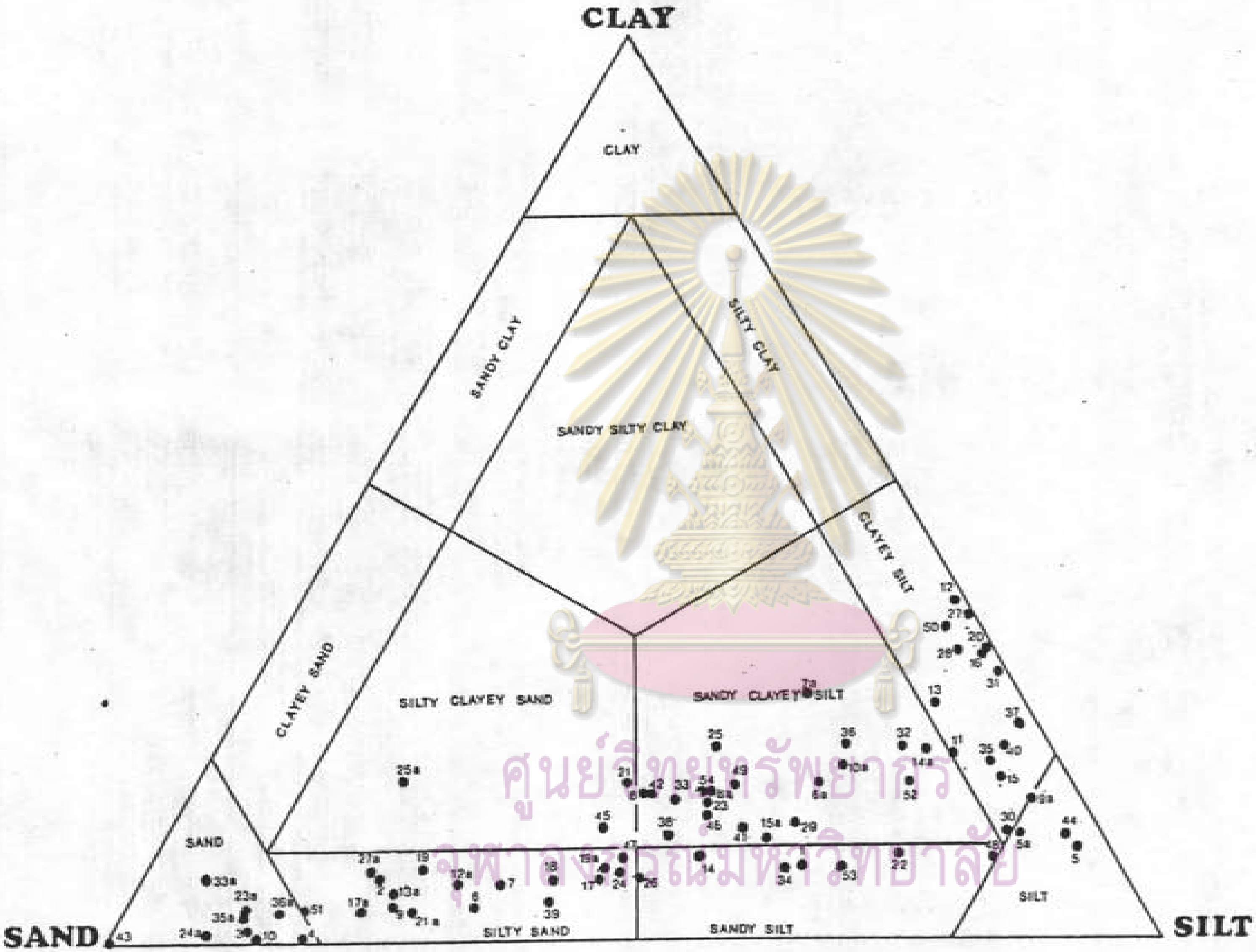

Figure 6 Ternary plot of sand-silt-clay component according to the categories of Gorsline (1960).

of abundance.

In the Upper Gulf percentage of silt tends to be highest around the river mouths and decrease gradually southward with the increase in percentage of sand (Figure 7). In the Lower Gulf percentage of sand tends to be relatively high in sediments along the northern and northeastern boundary. Silt is the most abundance fraction in the middle and the Lower part of the Lower Gulf (Figure 8).

It is amazing that the result of this study is still quite comparable to th works done over the last two decades (Emery and Niino, 1963; Dubach, 1968; Dheeradilok, 1980; Yamamoto and Yada, 1982; Umnuay, 1984). The distribution pattern of grain size still remains relatively the same (Figure 9, 10, 11, 12). It may be concluded that the Upper Gulf in under the direct influences of the 5 rivers discharging into it while the Lower Gulf sediments are likely to be transported from and deposited under the influence of South China Sea.

<u>Clay Mineralogy of Bottom Sediment</u>

Clay mineralogy of bottom sediment from the Gulf of Thailand has never been studied in detailed until Dharmvanij and Sompongchaiyakul (1987) and this study has carried out a comprehensive study. Previous works by Emery and Niino (1963), Aoki (1976) and Chen (1978) have only studied mineralogy of sediments collected from the parts that should be rathet called South China Sea than the Gulf of Thailand.

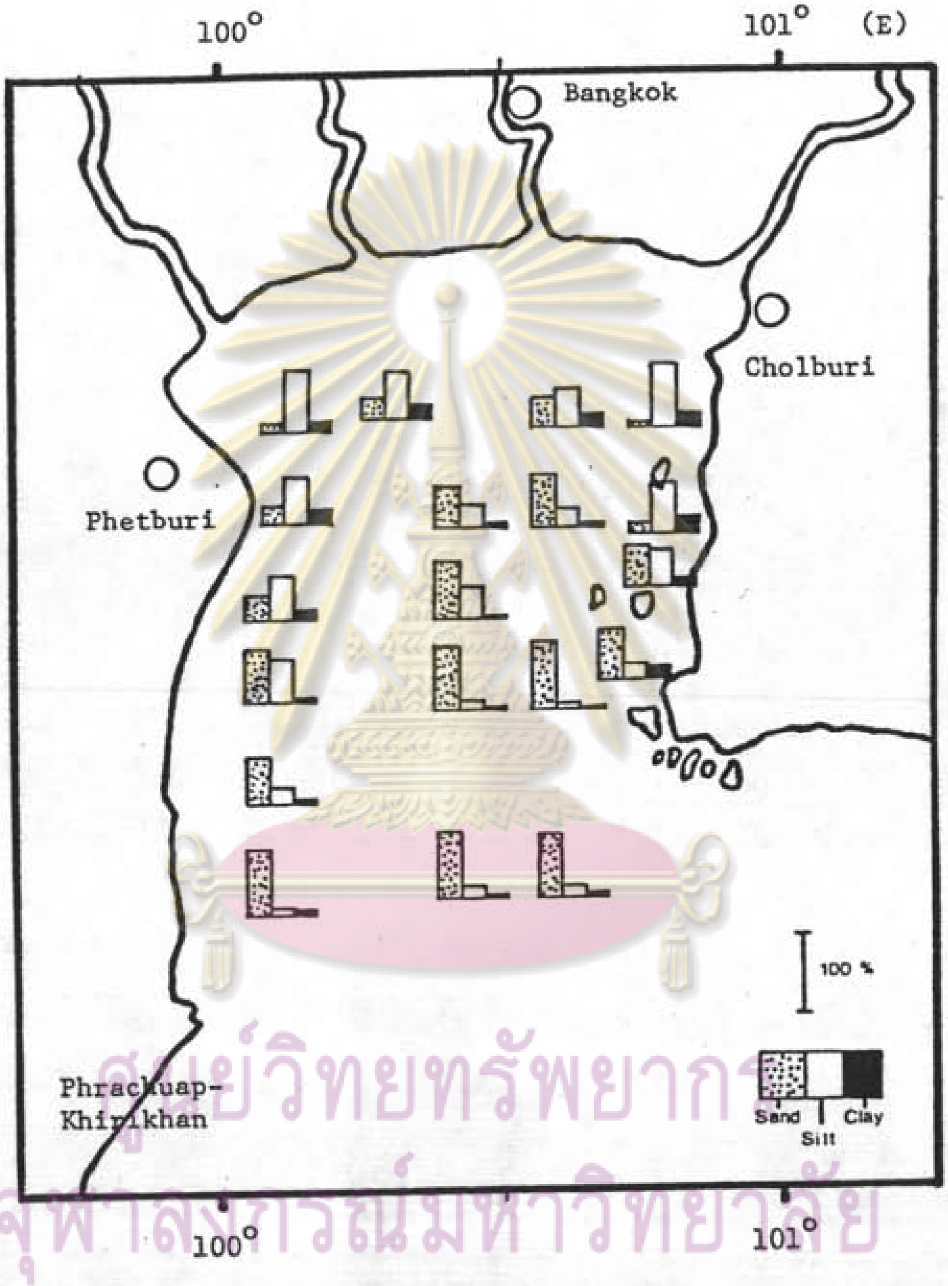

Figure 7 Distribution of grain size along the Upper Gulf of Thailand, represented by histograms.

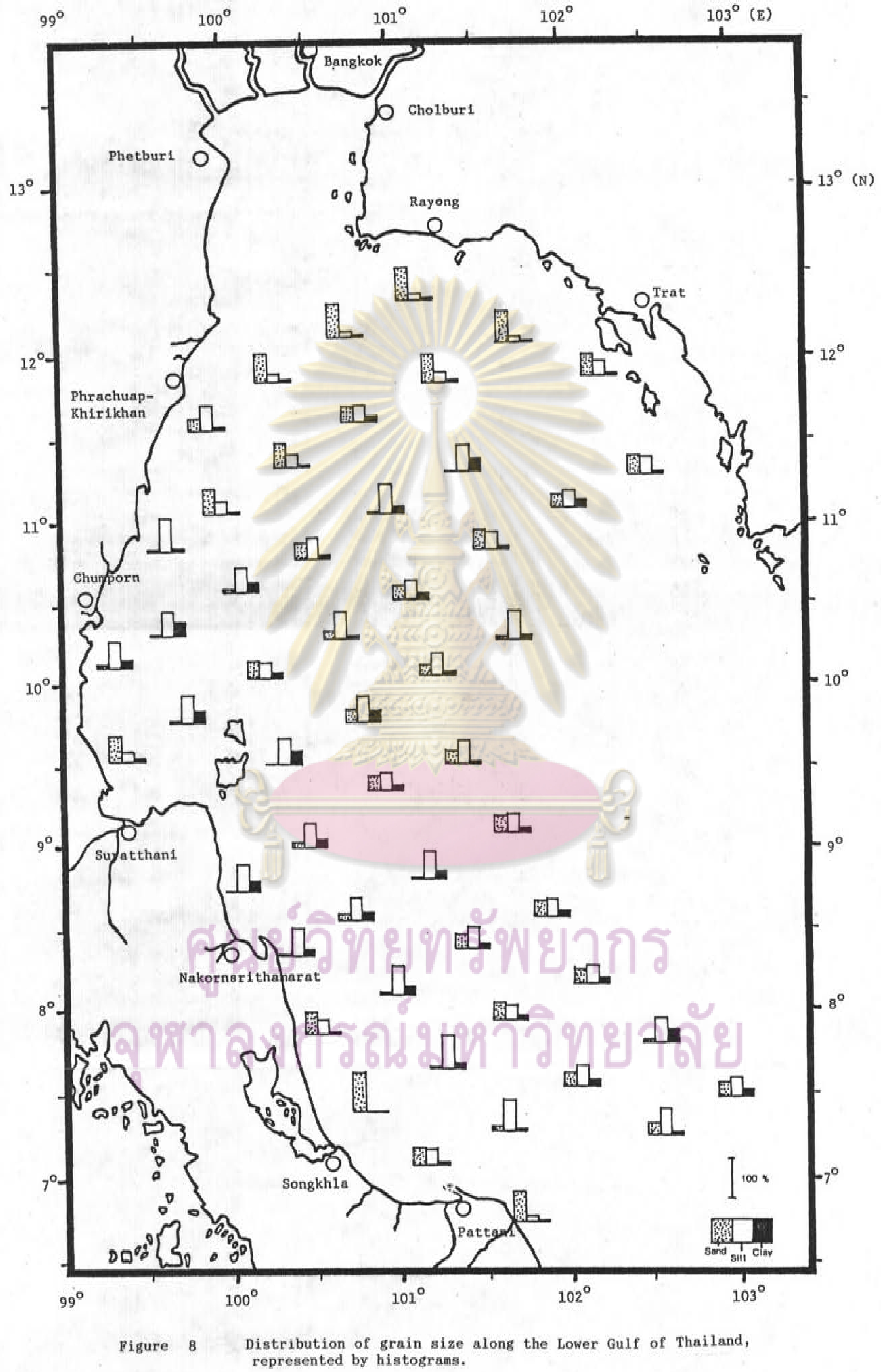

Figure 8 Distribution of grain size along the Lower Gulf of Thailand, represented by histograms.

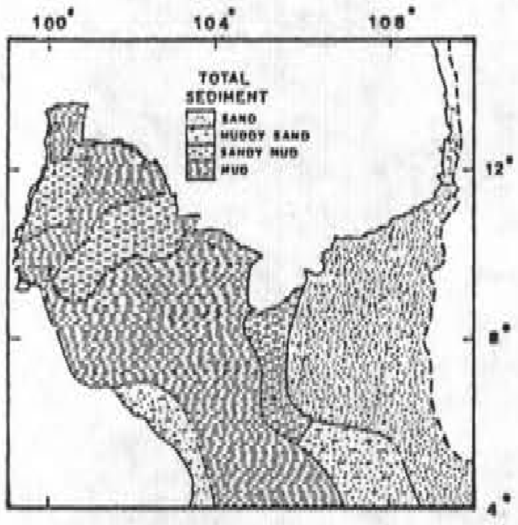

Figure 9 General descriptions of total sediment and median diameters of the Gulf of Thailand and adjacent continental shelf (Emery and Niino, 1963).

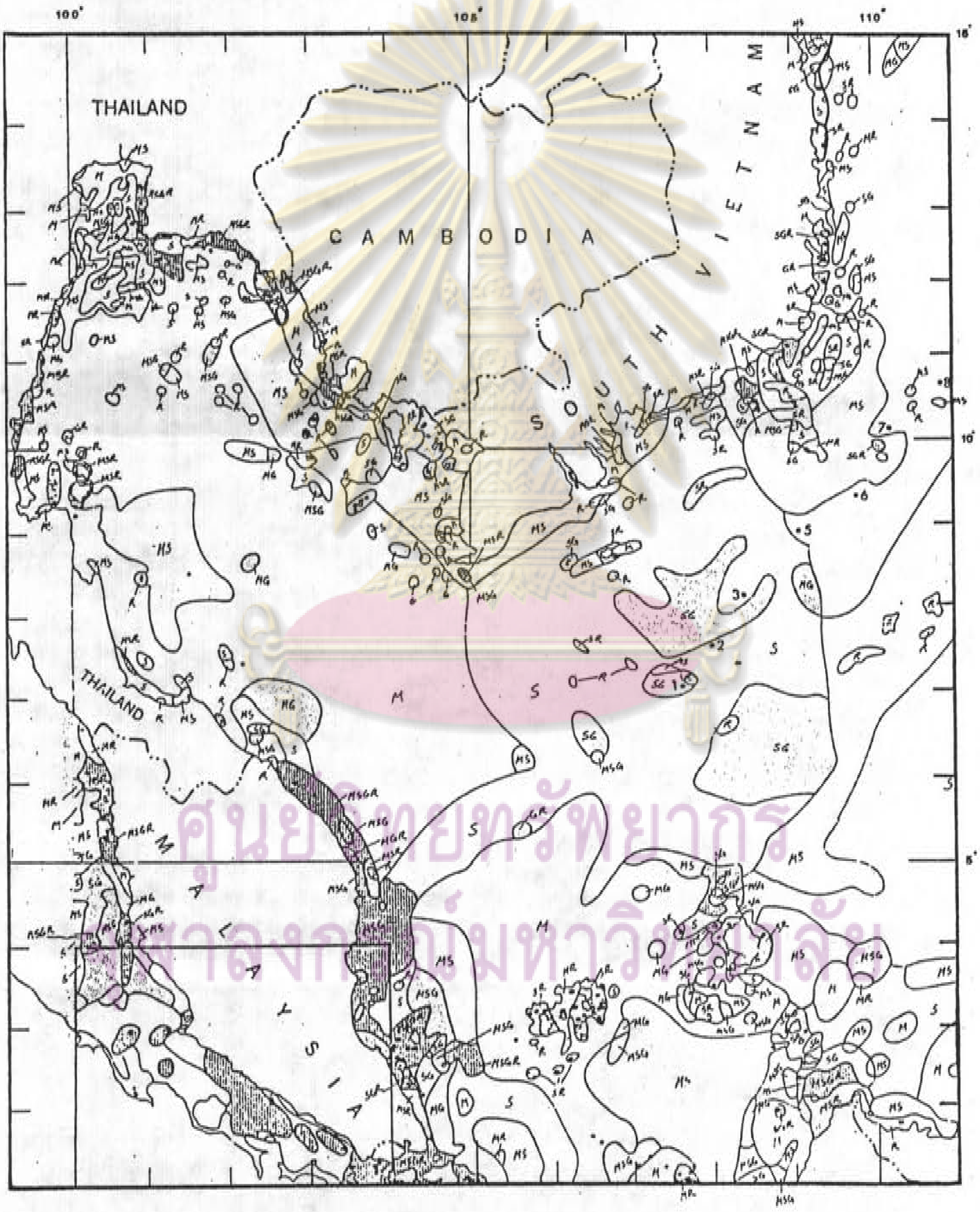

Figure 10 Grain size distribution pattern of the Gulf of Thailand and adjacent continental shelf (Dubach, 1968).

M = mud
G = gravel
S = sand
R = rock
MS = mud, sand
MG = mud, gravel

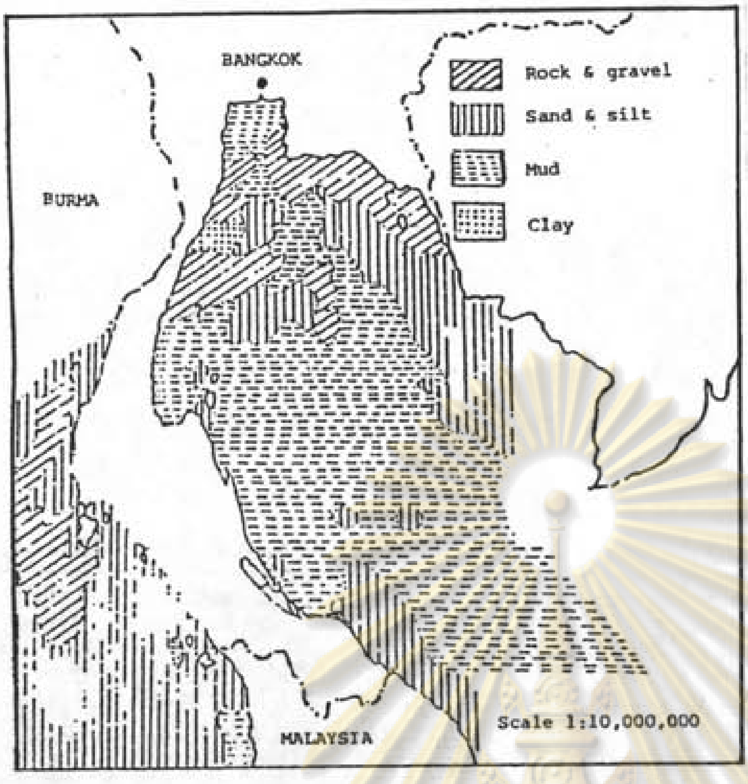

Figure 11
Distribution of sediments in the Gulf of Thailand (Dheeradilok, 1980).

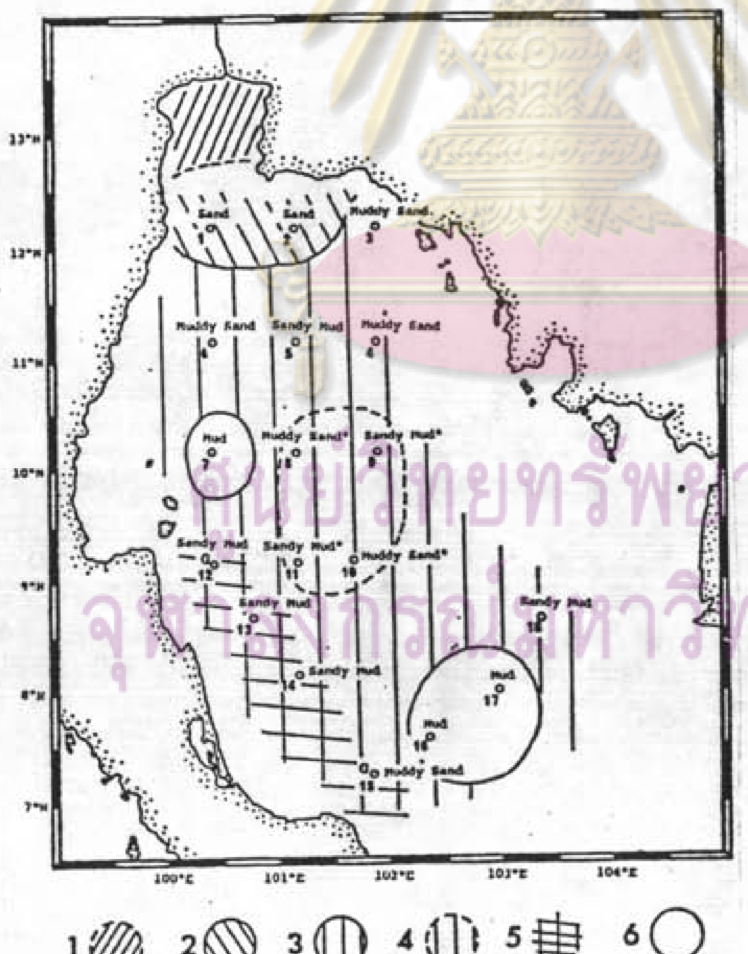

Figure 12
Distribution map of bottom sediment types in the Gulf of Thailand (Yamamoto and Yada, 1982.

* bottom sediment which is coverred by thin brown mud on surface.
G gravels (pebbles and granule) in bottom sediment.
1 Brown mud (suspected to be deposited).
2 calcareous medium to coarse sand.
3 Sandy mud and muddy sand.
4 Sandy mud or muddy sand with thin (1 or 2 cm thick) brown mud on surface.
5 Non-calcareous(quartz and lithic fragment rich) sandy mud or muddy sand.
6 Grayish calcareous mud.

The factors controlling clay mineral distribution in marine sediment vary greatly from place to place. Rateev, Gorbunova, Lisitzyn and Nosov (1968) has proposed that there factors are sedimentation conditions, the nature of the catchment basins of the continents, hydrodynamics of the oceans, the influence of volcanism and sediment formation process. Therefore, the finding of Dharmvanij and Sompongchaiyakul (1987) and this study will greatly enhance the understanding of the processes occurring in the Gulf of Thailand.

Illite is the most abundant clay mineral in the Gulf of Thailand sediments and the amount of other clay minerals is found to be decreasing in the order of montmorillonite-mixed layer clays, chlorite an dkaolinite respectively (Dharmvanij and Sompongchaiyakul, 1987; Appendix M) (Figure 13, 14). The content of illite and chlorite tend to be higher and is relative more abundant than montmorillonite in the Upper Gulf. Montmorillonite and chlorite are equally abundant in the Lower Gulf. Kaolinite is uniformly distributed throughout the Gulf. Selected diffractograms showing characteristic peaks of each clay minerals are shown in Appendix M.

It is obvious that distribution pattern of clay minerals in the Gulf of Thailand is different from the general distribution in oceans and appears to have been strongly influenced by regional geology and soil formation of the bordering land areas. However, the Gulf itself is not really diversed and can be divided into 4 provinces according to the diffrerent in clay mineral composition of the sedimentary found in each province (Figure 15).

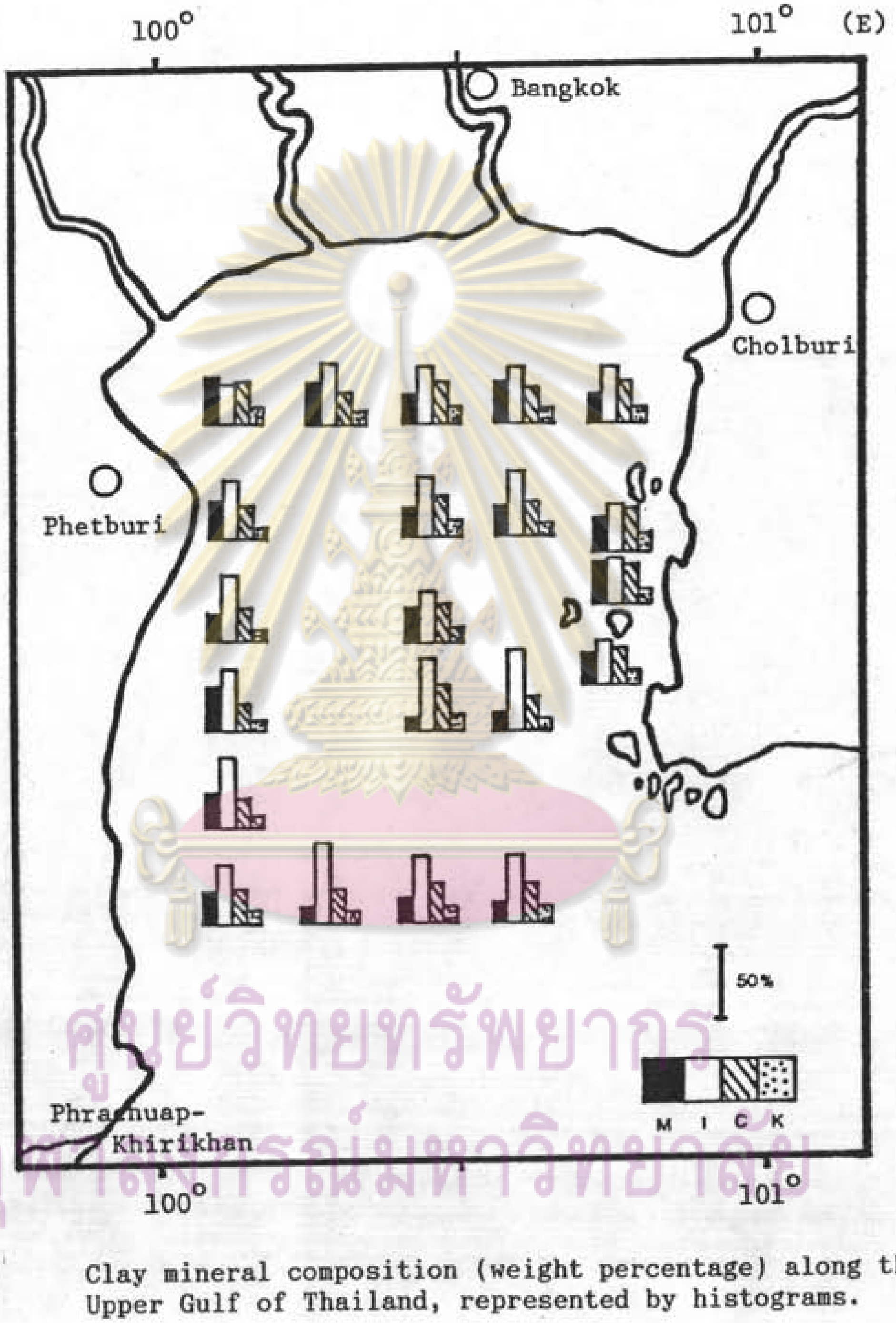

Figure 13 Clay mineral composition (weight percentage) along the Upper Gulf of Thailand, represented by histograms.

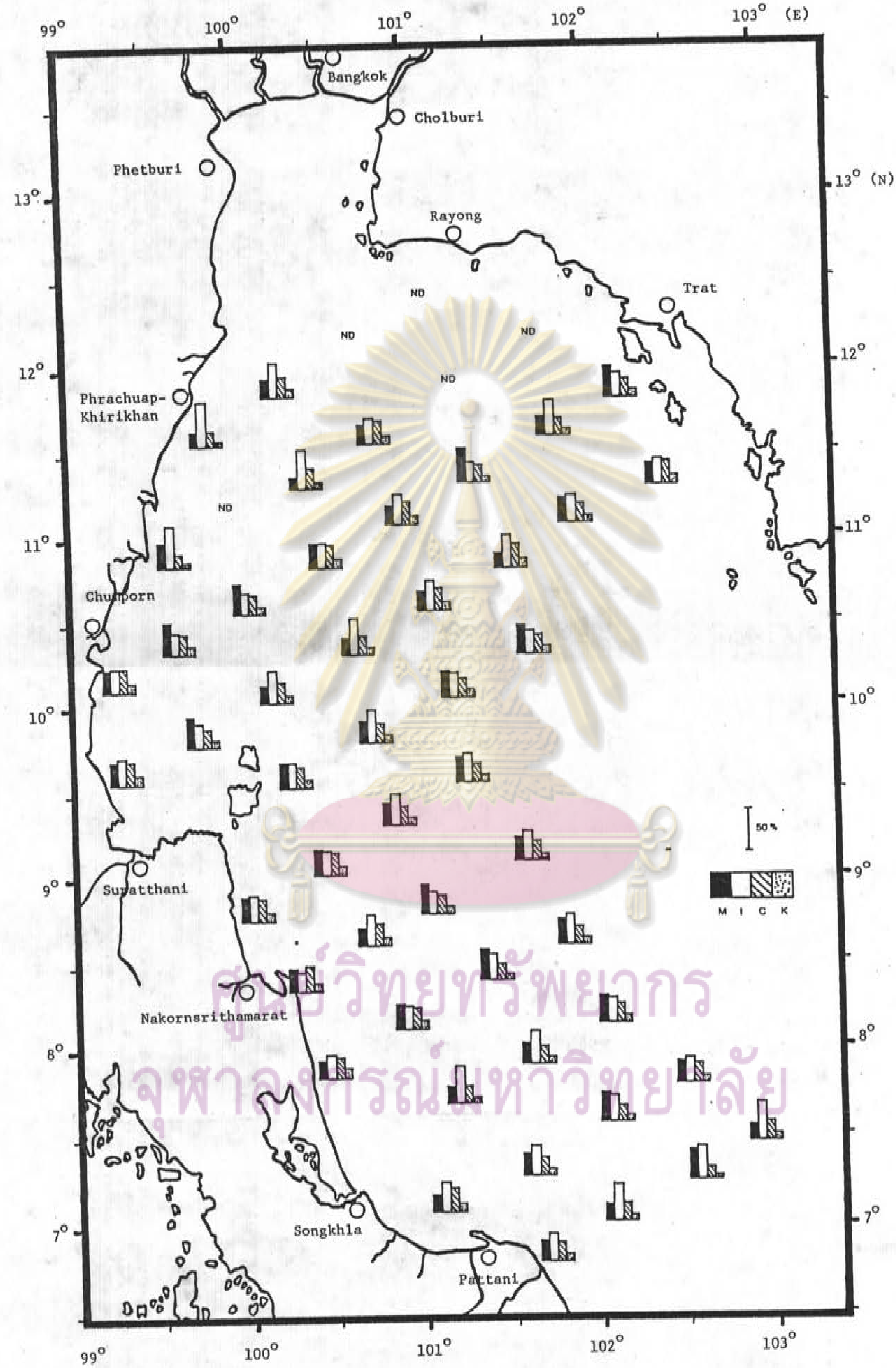

Figure 14 Clay mineral composition (weight percentage) along the Lower Gulf of Thailand, represented by histograms.

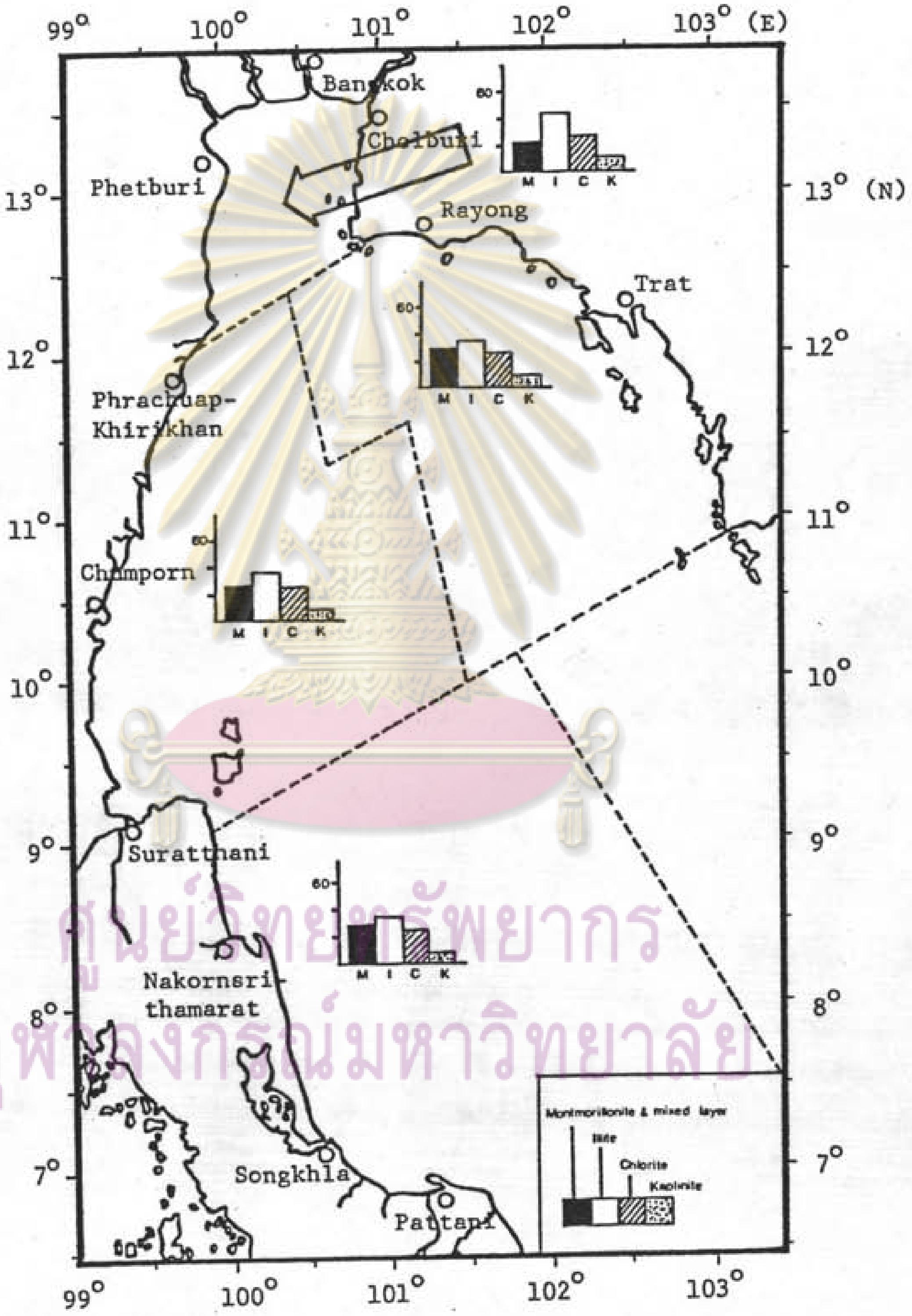

Figure 15 Average clay mineral composition (weight percentage) in various provinces of the Gulf of Thailand, represented by histograms.