B-12.2 Study of modeling of the response and influence of sea-level rise on deltas and coastal lagoons (Final Report)

Contact Person Yoshiki Saito
Senior Research Scientist
Marine Sedimentology Section, Marine Geology Department
Geological Survey of Japan
Higashi 1-1-3, Tsukuba, Ibaraki 305-8567, Japan
Phone: +81-298-61-3772, Fax. +81-298-61-3533
E-mail : yoshi@gsj.go.jp

Total Budget for FY1997-FY1999 54,476,000 Yen (FY 1999; 17,184,000 Yen)

Abstract

To evaluate the influences of sea-level rise on deltas and coastal lagoon geological and geographical study were conducted in the Satun Lowland, Lake Songkhla and Chao Phraya Delta of Thailand and the Mekong Delta of Vietnam. Moreover multi-temporal analysis using SAR images of J-ERS-1 between 1992 and 1997 were applied for understanding of changes of land use and the shoreline in coastal areas of Thailand.

These results indicated that past sea-level rise of the order of 10s cm impacted seriously on coastal areas in Thailand. Particularly coastal erosion is one of key issues we must concern in the assessment of the future sea-level rise.

Key Words: human impact, Chao Phraya river, sea-level rise, coastal lagoon, delta.

Introduction

One of key issues related to global changes in coastal zones is impact and influence of future sea-level rise by global warming. The purpose of this study is to assess the impacts of sea-level rise on deltas and coastal lagoons in some Asian countries. Multi-disciplinary approaches were conducted in the Satun Lowland, Lake Songkhla and Chao Phraya Delta of Thailand and the Mekong Delta of Vietnam; geological and geographical field surveys, satellite image analysis, geochemical and biological analysis. These outlines and results are as follows.

Remote-sensing survey

Remote-sensing instruments view wide ranges repeatedly, and their images provide information on changes in the regional environment. Changes in the shoreline of the upper Gulf of Thailand, which was great before 1987 and is remarkable in the comparison of the remote sensing images with the old shoreline, continued till 1992. Three alternative explanations for the cause of the changes are (1) land subsidence, probably caused by

over-pumping of ground water, (2) the new artificial lakes along the upper streams of the Chao Phraya, and (3) the destruction of the mangrove forests. The Rayong area, 150km southeast of Bangkok, faced rapid coastal erosion. The images delineate recent artificial construction along the coast, suggesting that the construction was a cause of the erosion. The mangrove forests of Phuket Island and Phang Nga Bay in the "time-series SAR composite image" are marked by a gray color with a special texture. Remote sensing should be a powerful tool for mapping beach forests. The images of the Amphoe Khlung area suggest that the wetland has undergone a rapid change. A seasonal change in plant cover may account for that change. Since the coastal change was vulnerable to tides and waves, knowledge of the sea currents and their changes are crucial for the interpretation of coastal environments. The remote-sensing images show muddy flow from the river. Therefore, analysis of that flow could give information about currents.

Consequently, extensive analysis of remote-sensing images acquired at different periods can yield information about changes in coastal environments and their possible causes.

Geological and geographical study on the Chao Phraya delta

The Central Plain of Thailand, one of the largest deltaic and tidal plains in southeastern Asia, is located along the lower reaches of the Chao Phraya River in central Thailand. Landforms of the lower plain are classified as flood plain, deltaic plain, and tidal lowland. The elevation of the plain is mostly less than 5 meters in the central and southern region and 1-2 meters in the coastal region.

Holocene sediments in the central plain consist mainly of silt and clay with occasional organic matter. They are classified into four units: basal peat, marine, tidal, and fluvial, from bottom to top. The basal peat developed in places on top of Pleistocene sediments and was covered by the marine unit; it lay mainly at depths of about –5 to –10 m in the southwestern plain, and about –5 to 0 m in the eastern and northern parts of the plain. The marine unit, the so-called Bangkok clay, overlay the basal peat or Pleistocene sediments; it consisted of very soft, gray silty clay. The marine unit was more than 10 m thick in the central and southern plain, and decreased in thickness toward the margins of the plain. The tidal unit consisted of gray silt or silty clay with very thin organic-rich sandy layers; it was covered by the fluvial unit. The tidal unit was 2-3 m thick in the central plain and 3-5 m thick at the margins; its thickness decreased to the south.

Some radiocarbon ages for the Holocene sediments have been obtained from the sediments of the Central Plain. The ages of the basal peat collected by the authors and reported by Somboon (1990) were between ca 8000 to 5500 yr BP, and they show that a distinct mangrove forest had developed by the early to middle Holocene. The basal peat layers were distributed from –10 m to +2 m depth, and their ages indicate the period of the Holocene transgression. Radiocarbon ages obtained from the tidal unit ranged from ca.7000 to 4000 yrs BP. These ages are also indicative of past sea-level changes.

Based on the ages and heights of basal peat and tidal sediments, the maximum height of sea level was more than 2 meters above the present sea level, and occurred around 6000 yr BP. After the sea-level highstand, a slight regression occurred ca 4,500 yr BP. This sea-level change is similar to that shown by Sinsakul (1992). A former beach ridge is located in the southwestern part of the plain. The height of the ridge is 3-5 m a.s.l. and its age is 3420 yr BP. Late Holocene tidal sediments developed in the central and southern parts of the plain, and they show that the Central Plain expanded as the tidal plain retreated toward the south.

Late Holocene delta progradation of the Chao Phraya River delta, Thailand, is described based on delta-front sediments and radiocarbon dates from borehole and open-pit samples taken from the lower central plain in Thailand. Three borehole cores were taken from the central plain of Thailand in late 1998: Site 1 lat. 14°04'20"N, long 100°37'59"E; Site 2 lat. 13°40'03"N, long 100°13'20"E; Site 3 lat. 13°34'11"N, long 100°35'13"E. Holocene sediments at the borehole sites were 10-13 m thick, and they unconformably covered underlying Pleistocene marine or fluvial sediments. Radiocarbon dates from the basal part of the Holocene marine sediments were ca. 4.0 ka at Site 1, 7.0-7.5 ka at Site 2, and 2.5-3.0 ka at Site 3. Other radiocarbon dates on marine molluscan shells from the basal part of Holocene sediments in pits on the central plain were from 7.0-7.5 ka. As these molluscan shells with radiocarbon dates of 7.0-7.5 ka were recovered from sediments beneath the central plain and about 5 to 10 m below the present sea level, they are linked with the Holocene sea-level rise and inundation of the central plain. Accumulation curves from age-depth plots at borehole sites clearly show the time at which the delta front of the Chao Phraya delta passed each borehole site. This event occurred from 3.5-4.0 ka at Site 1 and ca. 1.0 ka at Site 3. These data and other radiocarbon dates on the delta-front facies provide continuous data on seaward delta progradation in the central plain for the last 6 ka.

Millennial change of the paleo Chao Phraya delta for the last 6 kys has been discussed based on of sediment data and radiocarbon dates of newly collected borehole samples from the central plain of Thailand. Estimated migration rate of delta front of the Chao Phraya delta for the last 4 ka is ca. 2 x 10^3 km^2 /ky in land increment. As the paleosediment discharge estimated from this value and sediment thickness is almost equal with the sum of present sediment discharges of both Chao Phraya and Maeklong rivers, rapid human influence on sediment discharge by soil erosion on time scales of 10^2-10^3 years is not obvious. For more precise estimate of paleosediment discharge in the late Holocene period, spatially distribution of paleo-delta front sediments with radiocarbon dates should be discussed.

Saltwater intrusion and coastal erosion in the Mekong delta

The Mekong River delta, one of the largest deltas in Asia, is a tide-dominated delta. Sediments dominated by silts, clays, and fine sands have been deposited in the South China Sea and the Gulf of Thailand. During the sea-level highstand and regression over last 5000 yr BP, delta progradation has produced a great flat plain of 62,500 km^2, the total shoreline of which is about 740 km long. A monsoon regime together with two different tidal patterns,

semi-diurnal and diurnal, on the South China Sea and Gulf of Thailand have played an important role in the coastal change of the Mekong River delta in recent years. Since 1885, large tidal ranges of 3-4 m have contributed considerably to coastal erosion and accretion on the coast of the South China Sea. The Bo De coast, 60 km long, a well-known eroding coast, is eroding at an average rate of 30-50 m/yr, and in places at a rate of over 80 m/yr. The remainder of the delta coast is eroding at about 10-25 m/yr, including the coastal segments of Go Cong, Ba Tri and Dong Hai of Tien Giang, Ben Tre and Tra Vinh provinces, respectively. The delta coast on the western side of Camau Cape is accreting with an average rate of 50-80 m/yr, and in places at a rate of over 100 m/yr.

The low-lying Holocene coastal plains supporting freshwater wetlands are often close to or below the level reached by the highest tides. Together with the large tidal range and the wave and northeast monsoon actions, saltwater intrusion has clearly occurred for the last several decades. Saltwater intrusion has extended more than 20 km inland in more than 20 years, and saltwater has invaded the low-lying fresh-water wetlands through a combination of inland extension along main channels, tidal creeks, incompletely infilled paleochannels, and artificial canals. Moreover, the extension of salt marsh and mangrove marsh environments inland along most tidal creeks has been considerable because of increasing pressures from shrimp farms along the landward fringes of the salt and mangrove marshes. Since the price of shrimp has increased rapidly in recent years, large areas of mangrove forest and rice fields in the Camau Peninsula have been destroyed in order to set up shrimp farms. The area devoted to shrimp farms has increased rapidly from 82,300 ha in 1991 to 147,000 ha in 1997. The expansion has not been managed well, and it aggravates the ongoing processes of coastal erosion and saltwater intrusion.

The main concern of this study is the rate of coastal change, especially emphasizing coastal erosion as documented during the past 100 years and saltwater intrusion during the last 20 years. Further coastal erosion and saltwater intrusion in the Mekong River delta will probably be induced by the sea-level rise as a consequence of global warming.

Impacts on coastal lagoons

According to the characteristics of both natural and socioeconomic systems in the lacustrine lowlands of the Songkhla Lake, lowlands can be divided into five distinctive geographical zones and the development factors of each zone are identified. Taken these factors into consideration, some serious impacts will be estimated when the sea level rises about 1 m in future as follows.

(1) In the beach ridge plain coastal erosion will become more severely, where large-scale shrimp farming developed along the present coast will be affected critically by the retreat of the shoreline. And the increase in salinity of the lake water will be serious problem particularly in the double-cropping area of the northern part of the plain.

(2) The area of Songkhla City should be protected by higher or stronger seawall if the coastal erosion would become more severe. On the other hand the channel linked the lake and Gulf of

Thailand will become twice or three times as wide as present one because of the erosion of the north end of the spit. Then the groundwater at the littoral lowlands will be affected by the increase in salinity of the lake water.

(3) Both in the western part of Thale Luang and in the deltaic lowland of Thale Songkhla, wide littoral area will be inundated with lake water about 1 to 3 km in width from the present lake shoreline. Lacustrine lowlands covered with new types of land use, such as a littoral resort area, rubber plantation, shrimp or fish ponds and built-up area with urban facilities, should be protected from severe floods or long-term inundation.

Discussion & Conclusion

Severe coastal erosion has occurred at the river mouth area of the Chaophraya for the last 30 years. However our satellite image study showed active erosion was not clear since 1992 It was mainly occurred in 1970s and 1980s. The Maeklong River is a similar river with the Chao Phraya in sediment discharge, damming, and dredging sand in rivers. However the Maeklong delta has a well-developed natural mangrove forests. Coastal erosion is not occurred at its delta. The major difference of both deltas is subsidence. In relation to subsidence in Bangkok area, subsidence was occurred at the river mouth and nearshore areas in 1970s-1980s. Total subsidence amount is estimated to be around 50 cm. One of characteristic features in the nearshore area of the Chaophraya delta is a very gentle deltafront with gradient of 1m/km. Deepening nearshore area by local subsidence must induce increase of wave energy. As the coastal erosion is observed in the early 1970s, subsidence had an effect on coastal erosion so quickly. Relative sea-level rise and ground subsidence are the same phenomena in relative change in sea level. So this result of coastal erosion in the Chao Phraya, Thailand indicates the importance of coastal erosion in the influences of the future sea-level rise.

These results indicated that past sea-level rise of the order of 10s cm impacted seriously on coastal areas in Thailand. Particularly coastal erosion is one of key issues we must concern in the assessment of the future sea-level rise. Other important factor is saltwater intrusion in the deltaic area, where is the main part in rice product in SE Asia.

References

Somboon, J.R.P. Geomorphology of the Chao Phraya delta, Thailand. Ph.D Thesis, Kyoto Univ., 86p. 1990.

Sinsakul, S., Evidence of Quaternary sea level changes in the coastal areas of Thailand: a review. Journal of Asian earth Science, 7: 23-37. 1992.