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Evolution of holocene depositional environments in the coastal area from the Tien river to the Hau river mouths

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Abstract. The Holocene coastal zone of Mekong river plain is the result of prolonged marine-fluvial interaction. Lithofacies association in time and space is characterized by three depositional system tract belonged to the upper part of a sequence stratigraphy. Based on lithology should be divided 5 sedimentary types and 18 lithofacies distributed in stratigraphical column and in sea bottom varying from 25m water depth to mainland coastal area. According to sequence stratigraphy the transgressive systems tract at 5 Ky Bp, while from geochronology point of view the boundary between Middle Holocene and Late Holocene is 3 Ky Bp – a regressive stage.

During Early-Middle Holocene stage transgressive depositional system tract is characterized by two associated lithofacies upward section: delta front swamp mud rich in organic materials facies and marine shallow grey-greenish clay facies corresponded with marine flooding plain. And then Late Holocene regressive phase corresponding with Highstand systems tract composed of delta plain clayish silt facies in which there are different sandy ridges generations distributed younger seaward. Each sand ridge generation was mark by a coastal zone and associated lithofacies.

In circumstance of global climate change and sea-level rising, the Mekong river coastal zone will be changed much more in framework of modern tectonic subsidence. If the rate of sea-level rising is 2mm/year then sea bed will be subsided with a rate of 4mm/year. But recent rate of sediment accumulation is over 4mm/year, so the modern coastline continue to prograde seaward with a rate of 40m/year. The Mekong river mouths are migrating to East-North, and as a result geosystems and landscapes are changing.

1. Introduction

The study area is composed of Holocene deltaic coastal zone belonging to Mekong plain situated in South Vietnam (fig.1). Holocene deposits in coastal area and shallow sea in front of the Mekong river mouth were formed in relationship with sea-level change during the Flandrian transgression and the Late Holocene regression. Sedimentary composition, thickness and distribution of the Holocene deposits in the study area are related with two important factors: sea-level fluctuation and tectonic movement. A regression during the glaciation

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Wurm-2 had created a condition for Late Pleistocene alluvial deposits and weathering crust (Q_1^{3b}) to be formed. These deposits are spread from the land to -100m water depth on the shelf. The colorful clays contain a lot of laterites nodules likes texture of bread with graves. Waves and tides during the Flandrian transgression had destroyed a surface deposits, composed mainly of silty clay and laterite nodules and transported them into new depositional environments.

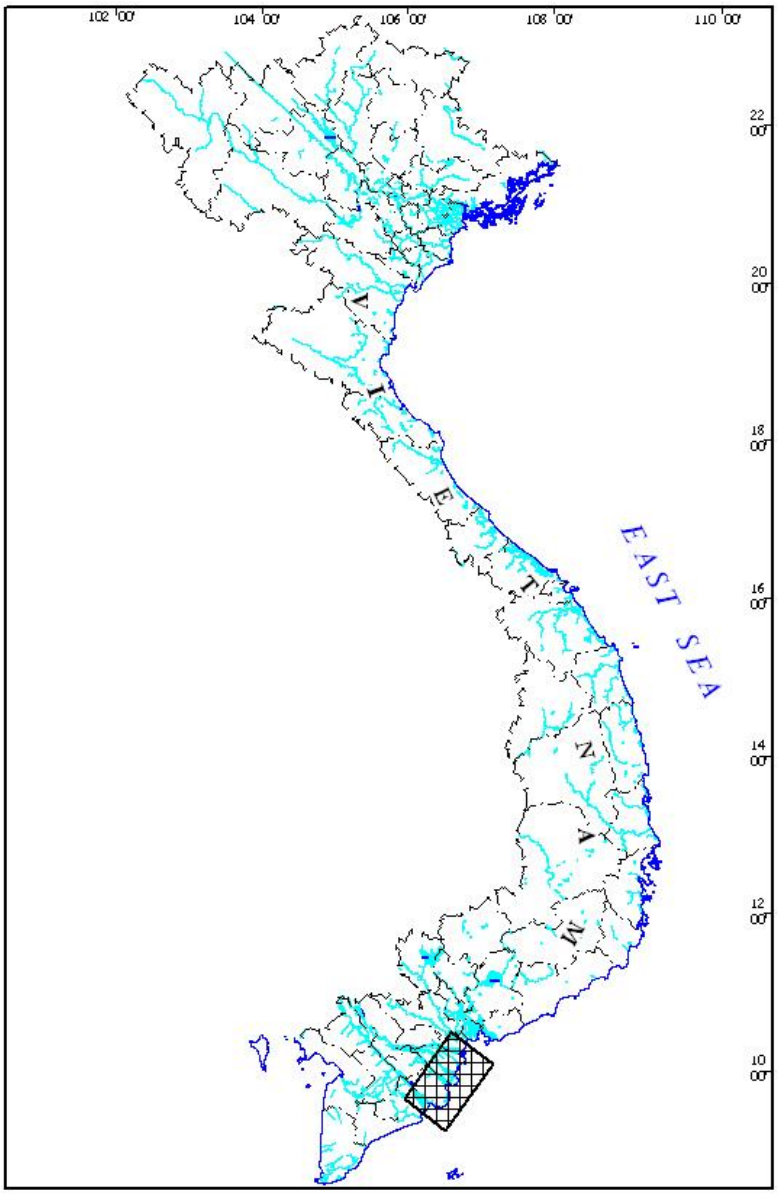


Fig.1. Position schema of study area.

Distribution of the Late Holocene deposits on the land as under the sea is following mechanic differentiation and facies association from the coast seaward by river flow and from North-East to South West by long-shore drift flows.

In coastal and shallow sea there are 5 sedimentary types and 18 depositional facies, which were formed from Early Holocene to present. On the map of the Late Holocene lithofacies muddy clays alternated with sands. Sands were formed mainly in river channels, river sand bars and river mouth bars. Muddy clays were formed in estuary, coastal swamps, tidal flat, river mouth lagoon and deltaic plain.

Data used for this paper coming from Project KC09.09/06-10. All results analyses of grain size, mineral and chemical composition, microfauna… from 5 deep boreholes of this project were collected and interpreted for facies analyze as well as for sequence stratigraphy to express all composition and evolution of the depositional environments in coastal and nearshore area from 12Ky Bp to present.

Study on facies changing in time and space helps to determine river mouth changes and paleocoasts during the Holocene. Based on this study we can predict a trend of river mouth changing with climate change and sea-level rising in the future for planning and coastal sustainable development.

2. Study methods

2.1. Methodology

Study sedimentary evolution of fast growing river delta such as the Mekong delta should based on two approaches: system approach and evolution approach. Sedimentary types and lithofacies systematically related. A big system is composed of smaller systems. For example, deltaic group is composed of delta plain, delta front and prodelta. Delta front is composed of river mouth sand bars facies, river mouth lagoon clay facies, sand of tidal flat facies…

From geological time point of view, evolution of deposits in river mouths of an aggradational deltas will follow a grainsize, lithofacies, mineral composition and sedimentary geochemistry periodicity

Holocene deposits of the Mekong river mouths belong to the upper part of a sequence, that consists of two depositional systems: transgressive system track (TST) and highstand system track (HST). Transgressive system track consists of 2 parasequences, corresponds to 2 depositional facies: organic transgressive deltaic muddy clay and lagoon grey-greenish clay facies. Highstand system track is composed of a group of regressive deltaic deposits.

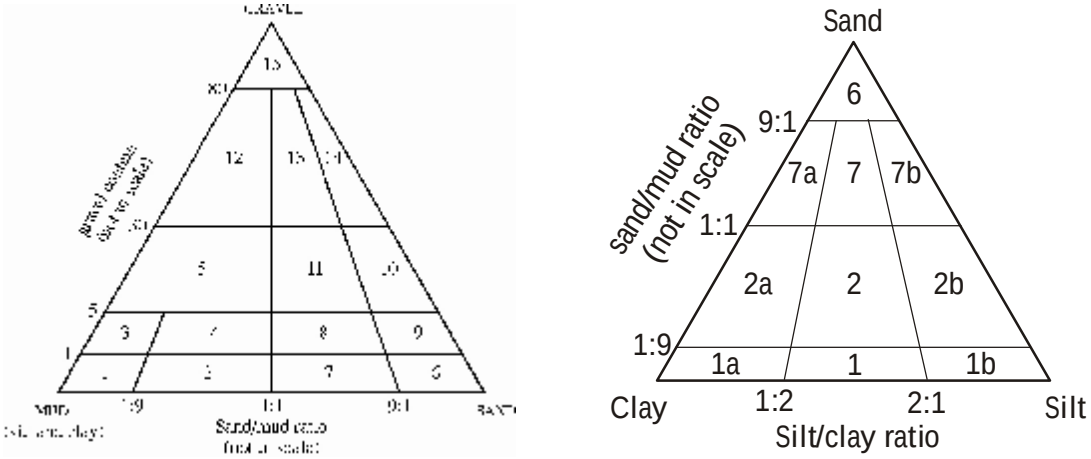
2.2. Study methods.

- Grain size analysis and data processing

A results of grain size analysis will be processed following a formula: $\Phi = -\log_2 d$ in which d is a diameter of grain (mm). An accumulative curve of grain size allows calculate grain size parameters: Md, So and Sk. A grain size analysed results will be plotted on the schema of sedimentary classification of the Royal British Geological Survey (fig.2).

- Petro-mineralogical method analysis

This method includes study of thin section under polarized microscope of non-cemented sediments and analyze of minerals under stereoscope microscope. An analyze result of clastic minerals and molluscs will help in classification of rocks according Petijhon (1973) classification when apply for sandstones. Analyze under stereoscope microscope will be useful for determining a composition (Q, F, R) and morphology of clastic grains (Ro, Sf).



(1) (2)

Fig.2. Schema of sedimentary classification (After Royal British Geological Survey, 1979).

(1)-Deposits contain gravels. Schema has 3 parts: gravels, sand and mud (silt + clay)

1. Mud
2. Sandy mud
3. Slightly gravelly mud
4. Slightly gravelly sandy mud
5. Gravelly mud
6. Sand
7. Muddy sand
8. Slightly gravelly muddy sand
9. Slightly gravelly sand
10. Gravelly sand
11. Slightly muddy sand
12. Muddy gravel
13. Muddy sandy gravel
14. Sandy gravel
15. Gravel

(2)-Deposits do not contain gravels. Schema has 3 parts: sand, silt and clay

1- Mud	2- Sandy mud	3- Muddy sand
a - Clay	a - Sandy clay	a - Clayish sand
b - Silt	b - Sandy silt	b - Silty sand

- Lithofacies and sequence stratigraphy analysis

Lithofacies analysis is determination of different facies names and association of lithofacies in space and time, based on geochemical, environmental and depositional parameters as well as on texture and structure of sediments. In this paper following geochemical environmental and depositional parameters are used: pH, Eh, Kt, So, Ro, Q, Cl/S.

Depositional environments have been determined using different structures of deposits:

- River channel deposits have a cross stratification

- Flood plain deposits have a ragged parallel stratification

- River mouth deltaic tidal flat deposits have a cross stratification.

- Nearshore deposits have a wave stratification

- Delta front deposits have a progradational sigma structure

Lithofacies analysis results are backgrounds for sequence stratigraphy analysis in circumstance of Early-Middle Holocene transgression, Late Holocene regression and recent transgression.

3. Characteristics of lithofacies

3.1. Characteristics of the Early Holocene lithofacies (Q_2^1)

Tidal flat sand and supretidal mud appear in deep boreholes BT3, BT2 and BT1 from 39m to 59 m (fig.9). Tidal flat sands are well to intermediate sorted but supretidal mud is weakly sorted because of different grainsize composition. These tidal flat deposits are transitional so they have almost the same geochemical parameters (pH=7-7.8; Kt= 0,8-1,6) (Tab.2).

Many coastal lithofacies associated each other in space and time. In space can be observed a transition from coastal swamp mud to river mouth channel sand, sand ridges and lagoon mud facies. In cross section, upward can be observed a facies replacement from river mouth sand bar by tidal flat muddy clays and by coastal swamp muddy clay facies at the end.

A group of submarine Middle-Early Holocene marine facies composed of two facies: a shallow marine sands and gravelly sands are spread from 25 m water depth shallow sea. They are a product of denudational and redepositional processes of the Flandrian transgression. The boundary between these sediments and the underneath Late Pleistocene deposits is transgressive ravinement surface as a result of wave and tide action. Therefore, a certain quantity of laterites, coming from motley coloured clays always is available in these sands (fig.3,4,5). The Holocene deposits distributed in coastal zone of Mekong delta consist of 18 facies which are expressed on the map of the Holocene depositional environments (fig.7). However, in this paper ones important of them were only described in detail the lithological, environmental characteristics and distributed regulation in space and time.

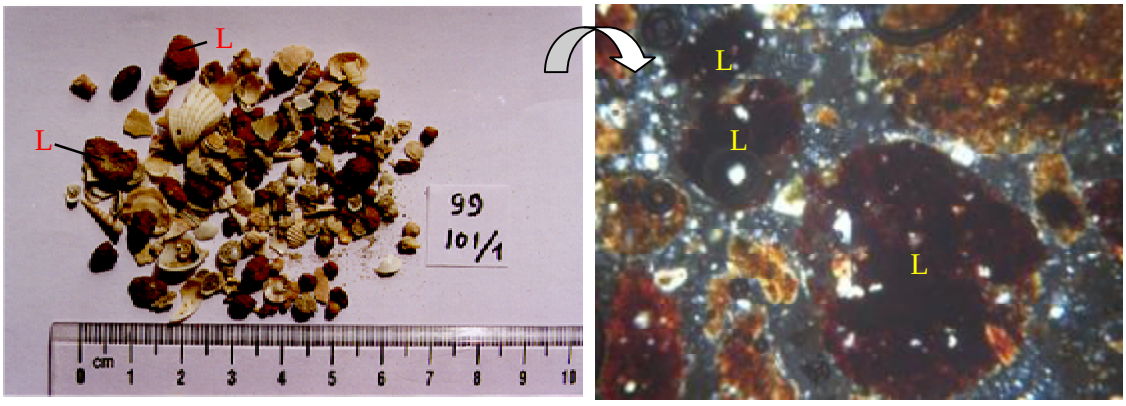


Fig.3. Well rounded laterite gravels (L) in shallow marine zone (lithofacies 16 showing in fig.7) (Q_2^1) – N^+ x60.

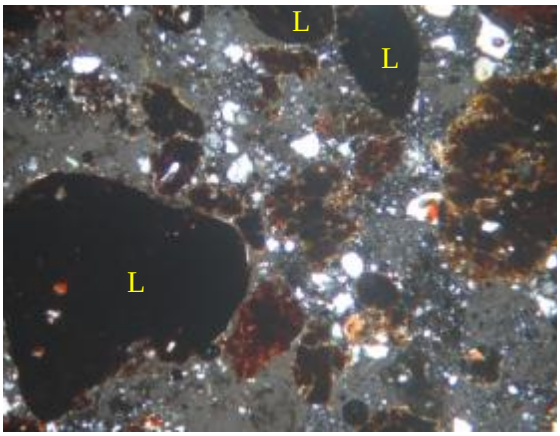


Fig.4. Reb-brown color laterite grains (L) was redeposited from Late Pleistocene Laterited clay layer (Q_2^1-N^+ x 60).

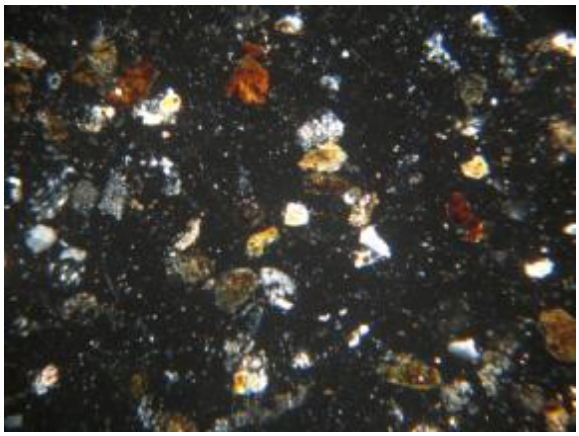


Fig.5. Paleo shallow marine, well rounded, monomineral, fine sand richen in volcanic fragments of rocks (Ro >0,6) (m/SQ_2^{1-2}) – N^+ x30.

3.2. Late Holocene lithofacies

3.2.1. Sand ridge facies ($amSQ_2^{3a}$)

Sand ridge has a sickle, kidney or bow-shape, simple or branched of with a back seaward. This sand ridge is composed mainly of sand (60-80%), silty clay and mollusc, therefore its colour is brownish yellow-typical colour of oxidized environment [11,12]. The elevation of these sand ridges is about 2-7m, their width varies from 100 to 3000m. They distributed parallel to the shore in the form of bows with a distance from each other about 3-10km. They are evidences of paleocoast existence during delta progradation from delta front into delta plain. Due to these sand ridges delta plain in study area has a typical wave relief with the ages younger seaward. Sands in these sand ridges always are well sorted (So≤ 1,5), their roundness is from average to good (Ro>0,5) (Fig.6) [10].

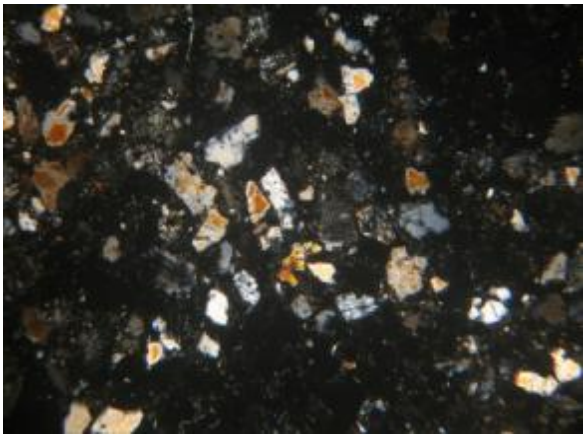


Fig.6. Ancient river mouth sand ridge. Feldspar Quartz sand, average to well rounded, well sorted (am/SQ_2^{3a}) – N^+ x60.

3.2.2. Delta plain sandy mud facies (amf/MQ_2^{3a})

This lithofacies is well spread on the land of the study area. This facies alternated with a sand ridges and old swamp mud facies. It composed mainly of silty clays (50-70%) and fine sand (30-50%). Its colour is grayish brown to blackish gray. They were formed mainly by sedimentation of suspended materials during flooding of delta plain area. Therefore this deposits are bad sorted (So>3) and always contains a lot of leaves and steams, sometime brackish molluscs also available. The pH value of clays varies from 6,9 to 7,5, Eh from -20mv to +150mv and Kt from 0,7 to 1,4. These environment indicators proved a brackish transitional environment from river to the sea (Tab.2)

3.2.3. Coastal swamp mud facies (amb/MQ_2^{3a})

This lithofacies is distributed in narrow area between delta plain mud and river mouth sand ridges, created a low-lying relief parallel to the ancient coast. Their colour is black or blackish grey. They are composed mainly of silty clays (50-80%) and fine sands with an organic matters. Somewhere a peat is available at the depth of 0,5 to 2,0m [11,12]. The value of pH and Eh in deposits vary according to their colour and grain size composition. Where black mud is dominated a value of Eh always less than 0 and pH varies from 4 to 7,5.

3.2.4. Relict river channel muddy sand facies (amc/mSQ_2^{3a})

On the map, this facies formed a straight body parallel to the recent river flow. The sediments have a brownish grey, blackish grey colour and composed mainly of sands (50-70%) and silty clays with some a little amount of not well preserved plant remains. Their very bad sorting coefficient (So >3,5) and grain size accumulative curves always have 2 picks are evidences of complicated hydrodynamic regime during river migration and degradation.

3.2.5. Recent river channel muddy sand facies (amc/mSQ_2^{3b})

This deposits are distributed in river mouths Dinh An, Tran De and Ham Luong. Deposits of this facies are composed mainly of muddy sands, but as a result of continuous changes of hydrodynamic regime so grainsize composition also changed depending on time and their places in river beds. Sand content is 50-75%, 25-50% are silty clays and fragments of mollusc came from the sea during high tide. Their bad sorting coefficient (So >2,8), pH of bottom sediments is 7 and Kt= 0,9 at low tide and pH=7,8, Kt =1,5 at high tide and the value of Eh always positive are evidences of sedimentary environment changing continuously in river mouth.

3.2.6. Tidal sand ridge facies (amc/SQ_2^{3b})

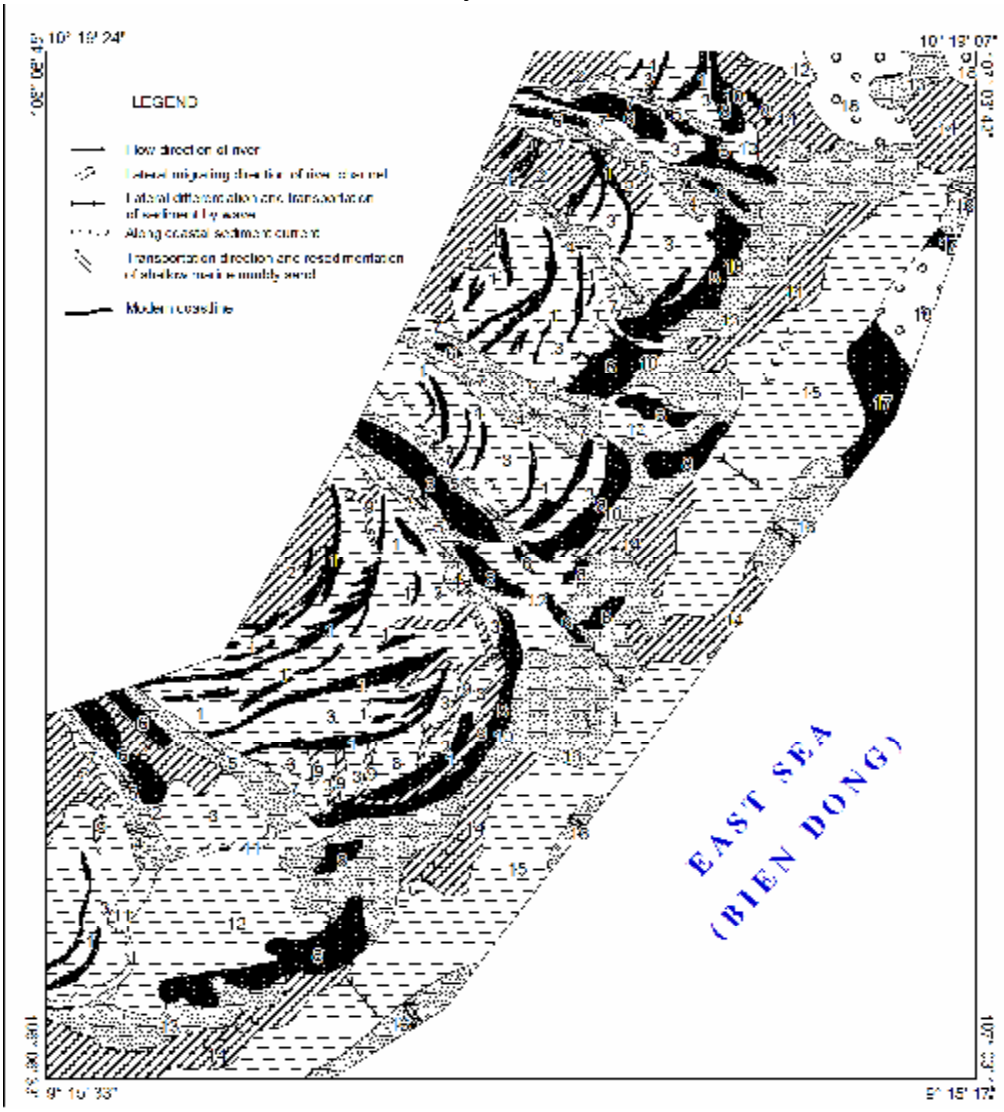
This facies is distributed in all river mouths and they are parallel to the recent river bed. Deposits of river sand ridges are intermediate to well sorted and were formed under river dynamic in relationship with changing tide regime. Their size depends on river discharge and supplied suspended materials. Changing of these sand ridges occurred at the same time of migration of river bed from west-south to east-north.

3.2.7. Delta front and prodelta facies group

Depends on coastal hydrodynamic regime, tidal flat mud and tidal flat sand are alternately distributed in front of river mouths Dinh An, Tran De, Ham Luong. Where the coast is open, wave is active and sandy tidal flat facies will be formed, which composed of over 80% of sand and 20% of silty clay and badly preserved fragments of molluscs and plants. Deposits of sandy tidal flat facies have a average to good sorting coefficient, depending on its silty clay percentage. Normally, width of sandy tidal flat is much narrow than muddy tidal flat. Their altitude and slope are also different. The sandy tidal flat has higher altitude and steeper. Their formation is closely related with river mouth

sand ridges. Muddy tidal flat is related with low-lying plain in front of river mouth or tidal channel inside islands.

The late Holocene lithofacies distributed from 0 to -20 m water depth in the area of delta front and prodelta. Seaward, with increasing water depth their grain size is declined and follows mechanical differentiation, which is expressed facies distribution from muddy sand to sandy mud of delta front and finally prodelta mud [11,12]. Recent coast is a boundary between group of delta plain facies and delta front, while line -20m water depth is boundary between group of delta front facies and prodelta facies. In this direction a grainsize and mineralogical composition also changed, depending on following factors: material supply, material composition, transportation and depositional process in relationship with direct hydrodynamic factors such as wave, horizontal flows by wave, river flows, coastal drift, tide and flow by tide…



I. Late Holocene lithofacies in delta plain of Mekong river

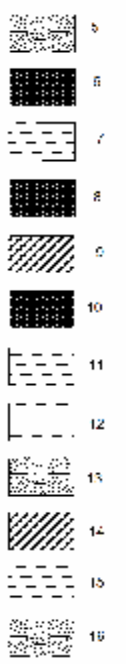
Sand Ridge sand facies

Delta plain sandy mud facies

Coastal swamp mud facies

Ancient river channel muddy sand facies

II. Late Holocene lithofacies in submarine delta of Mekong river



Modern river mouth channel muddy sand facies

Modern river mouth islet sand facies

Modern river bank swamp mud facies

Modern river mouth sandy bar facies

Modern tidal channel sandy mud facies

Tidal flat sand with strong wave facies

Modern tidal flat mud facies

Modern river mouth inlet mud facies

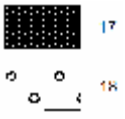
Modern delta front muddy sand facies

Modern delta front sandy mud facies

Modern prodelta mud facies

Modern coastal shallow marine muddy sand facies

III. Early – Middle Holocene lithofacies in shallow sea



Ancient shallow marine sand facies

Ancient shallow marine gravelly sand facies

Fig.7. Map of Holocene lithofacies distribution in the coastal zone of Mekong delta.

The holocene stratigraphy

Saurin E. (1973) [9] consider all Holocene deposits as an young deposits. Nguyen Ngoc Hoa (1991) [5] divided Holocene deposits in study area into 2 formations: Hau Giang formation and Cuu Long formation. Le Duc An (2004) [1] divided Holocene deposits of the Mekong delta into Hau Giang Formation and Cuu Long Formation. Nguyen Huy Dung (2003, 2004) [3, 4] divided the Holocene deposits like above authors but called them stages "Hau Giang and Can Gio".

Sequence stratigraphy

According to Allen and Posammentier, 1993, [2] the Holocene deposits in the study area are composed of three depositional system tracks: early-middle Holocene depositional transgressive system track (from 10Ky Bp to 5Ky Bp), highstand depositional system tracks (from 5Ky Bp to 1.5Ky Bp) and recent transgressive system track (from 1.5 Ky Bp to recent).

Transgressive depositional system track

Transgressive depositional system track is coincided with a classic transgressive section with declining upward grainsize. Coarsest sediments are gravelly sands and lateritic sands that covered the surface of the Late Pleistocene mottle clay. This erosion surface has an age from 18Ky Bp when a sea level was at -180m water depth to 5Ky Bp when sea-level rose up to +5m. Therefore a ravinement surface is a cross boundary between two sequence stratigraphy units: Regressive depositional system track (Q_1^{3b}) and transgressive depositional system track (Q_2^{1-2}). This boundary is crossing both in time and in space, therefore it is not boundary between Pleistocene and Holocene (in Geochronology this boundary starts at 10Ky Bp) (Tab.3), (Borehole LKBT3, LKBT2, LKBT1, LKTV and LKST).

Highstand depositional system track

According to sequence stratigraphy, highstand depositional system track corresponds to regressive deposits after maximum of Flandrian transgression. The Flandrian transgression had reached highest level at 5Ky Bp and it reached +5m above present sea level. This event is proved by very clear morphology of wave cut-off, sand ridges along coast and ^{14}C dating as well as by very important Holocene geological events. Three levels of wave cut-off at different altitudes could be clearly observed in Ninh Binh, Phu Quoc, Ha Tien and Ha Long bay areas: +5m, +3,5m and +2,5m. Wave cut-off at +5m is evidence of maximum transgression at 5Ky Bp. Wave cut-off at +3,5m and +2,5m in limestone as well as +1m height marine terrace along recent coast are evidences of still stand of sea level during Late Holocene lowering. This process plays an important role in creating a vast delta plain such as Red River plain, Mekong River plain and coastal plains in Middle VietNam [8, 14, 15].

Tab.1. ^{14}C dating of boreholes in coastal zone of Mekong river

Age		Lithofacies	LK BT3		LK BT2		LK BT1		LK TV		LK ST	
Substage	Symbol		x: $10^0$01'21.2" y: $106^0$42'00"		x: $10^0$01'55.62" y: $106^0$34'56.94"		x: $9^0$53'31.56" y: $106^0$35'14.6"		x: $9^0$41'37.5" y: $106^0$30'20"		x: $9^0$29'52.74" y: $106^0$12'3.7"	
			Depth (m)	Conventional ^{14}C age (ka)	Depth (m)	Conv. ^{14}C age (ka)	Depth (m)	Conv. ^{14}C age (ka)	Depth (m)	Conv. ^{14}C age (ka)	Depth (m)	Conv. ^{14}C age (ka)
Late Holocene	Q_2^3	Sandy silty clay of retro gradational delta (amHST)	5,5	3280±145	11	4090±260			8	2380±195	20 25	3840±155 4990±175
3,000												
Middle Holocene	Q_2^2											
	Q_2^2	Maximum transgressive estuarine greyish pale clay (mTST)	22 25 30	5060±150 6030±195 7050±230			16	5860±160	22	5540±		
5,000												
Early Holocene	Q_2^1	Sandy silt clays of transgressive delta (amTST)			40	8118±115			24	7470±240		
7,000												
Late Pleistocen	Q_1^{3b}	Silty sand of flood plain (afLST)	55	12070±135			29	12200±110				
10,000												

Tab.2. Sedimentary parameters of the Holocene deposits in coastal zone and shallow sea of the Mekong delta

Age		Dep. System track	So	Ro	Sf	pH	Eh	Kt	TOC	Q	F	R	Moll-usc	Clay minerals			Lithology
Chronostrati-graphy	Symbol													K	H	M	
Ka			-	-	-	-	mv	-	%	%	%	%	%	-	-	-	
Late Holocene	Q_2^3	TST 1.500BP	1.3-2.5	0.5-0.8	0.5-0.8	≥7.2	>2.0	>1.2	<0.5								
		HST	1.3-2.0	0.3-0.6	0.5-0.8	≤70	-20 → +100	0.8-1.2	0.5-2.0	30-70			5-10	++	++	-	- Quartz sand - Litic quartz sand - Rich in organic muds - Peat
Middle Holocene	Q_2^2	5000BP mTST	1.8-2.0	-	-	7.5-8.0	10 → 150	≥1.5	<0.5	-	-	-	5-25	+	+	++	- Grey-greenish clays rich in montmorillonite and well preserved molluscs
		7000BP															
Early Holocene	Q_2^1	amTST	1.3-2.5	0.3-0.8	0.5-0.7	7.0-7.5	-10 → +100	≤1.0	>0.5	25-55	15-25	20-35	5-15	+	+	+	- Peat layers - Mud contains montmorillonite - Sandy mud with lateritic gravels - Litic quartz sand - Sand with lateritic gravels
		10000BP															

Note:

So – Sorting coefficient
Ro – Roundness coefficient
Sf – Spherical coefficient
pH – Acid index
Eh – Red-ox potential
Kt – Kation exchange index
TOC – Total organic content

Q – Quartz
F – Feldspar
R – Fragments of rock
K – Kaolinite
H – Hydromica
M - Montmorillonite

Tab.3. Changing rate of Holocene river mouth channel and coastline in the coastal zone of Mekong plain

Age		Depositional system track	Column	Thickness and rate of sedimentary accumulation		Length and coastline migration rate		Width and river channel migration rate		Lithofacies	
Substage	Symbol			d (m)	v (mm/year)	L (m)	V (m/year)	d (m)	v (m/year)	Symbol	Principle lithofacies
Late Holocene	Q_3^1	amTST	1500Bp	7.0	4.5						Mangrove mud facies
3.000Bp		amHST		22.7	6.5	155 000	50	3,000	1.0	amR	River mouth channel muddy sand facies Tidal flat muddy sand facies Sand ridge facies
Middle Holocene	Q_2^2		5 000Bp								
		mTST		31	6.0	150 000	75	-	-	m	Estuarine prequaternair clay facies
7.000Bp											
Early Holocene	Q_2^1	amTST				5,000	1.0	1,200	0.3	amT	Coastal swamp mud facies Tidal muddy sand facies River mouth channel sand facies Shallow sea gravely sand facies
10.000Bp											

Note: amT: Transgressive delta amTST: Deltaic clayish silt facies of transgressive system track
m: Marine mTST: Estuarine clay facies of transgressive system track
amR: Regressive delta amHST: Clayish silt facies of Highstand system track

4. Study river mouth and paleocoast line changes based on lithofacies analysis

4.1. River mouth changes

In study area, a continental regime was dominated during time from 20Ky Bp to 12Ky Bp. A presence of alluvial deposits during 10Ky Bp from the depth 50-80m in boreholes had proved it. But river channels always migrated horizontally, so a river channel gravelly sand appears only one time in stratigraphic column. All three river mouths had moved to the South, at about 100-300m from recent river [7]. From 12 Ky Bp to recent in a stratigraphic column alternatively appear well sorted river mouth sand ridge, river mouth channel silty sand, coastal swamp mud and tidal flat muddy sand. Repetition of rive channel sand and sand ridges is relatively high. It proves the fact that river mouth had migrated in both directions in the Holocene. Although river mouth's migration occurred periodically, but position of river channel always changed from the South to the North and upward according a cross line. On the map of depositional environment, distance between Late Holocene paleoriver channels to the recent one is about 200 to 1000m to the south (Fig.7).

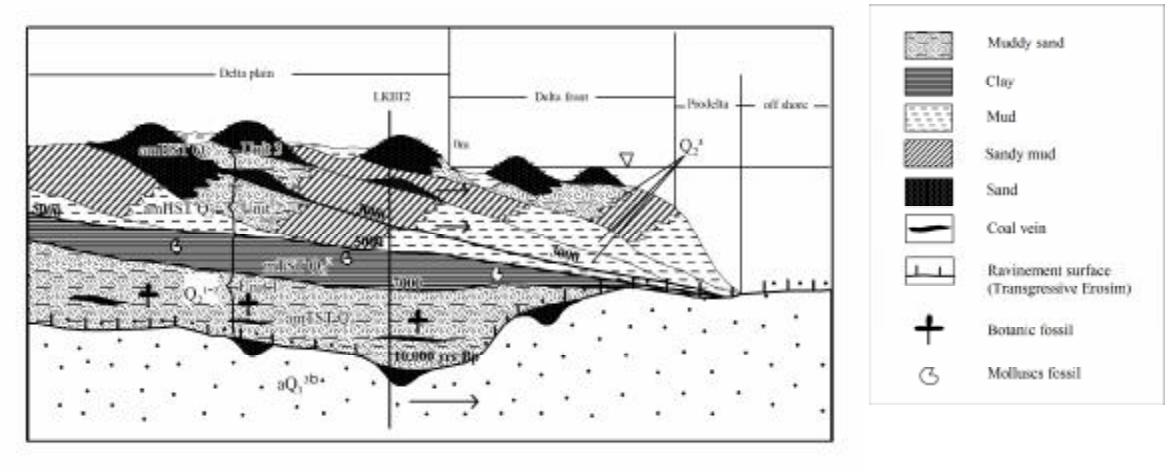


Fig.8. Showing 3 groups of lithofacies association corresponded with 3 depositional units and 2 sedimentary systems tract (Transgressive and highstand systems tract).

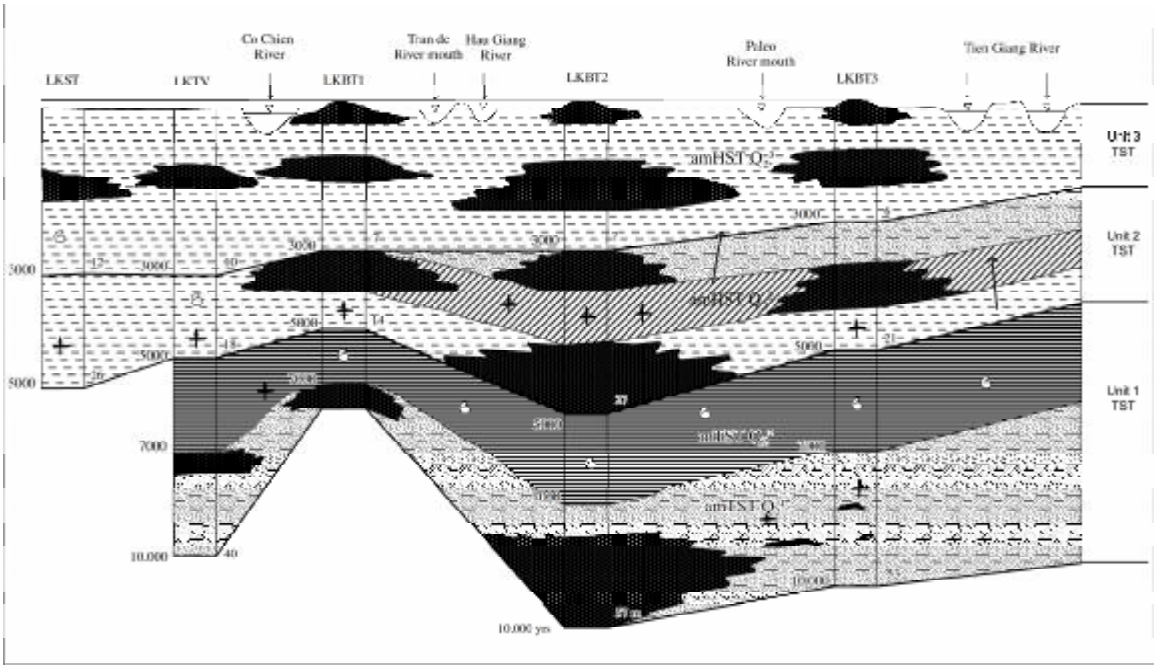


Fig.9. Cross section along coast of the Mekong river mouth.

4.2. Coast line changes

Based on the stratigraphic columns and analyzed data, two depositional environment maps were created, reflecting paleogeography of the early Holocene and late to recent Holocene. Map of Early Holocene lithofacies shows that a paleocoast in this time was so far from recent coast about 1000-2000m and stabilized during 3000 years. From 7Ky Bp to 5Ky Bp the coast migrated westward with a rate of 75m/year. This means that sea-level rising during the Holocene was not the same. During the Early Holocene sea-level rose slower than in the Middle Holocene (7Ky-5Ky). From 5Ky to 1.5Ky a delta prograded quickly and as a result the coast migrated seaward with a rate of 50m/year (Tab.3).

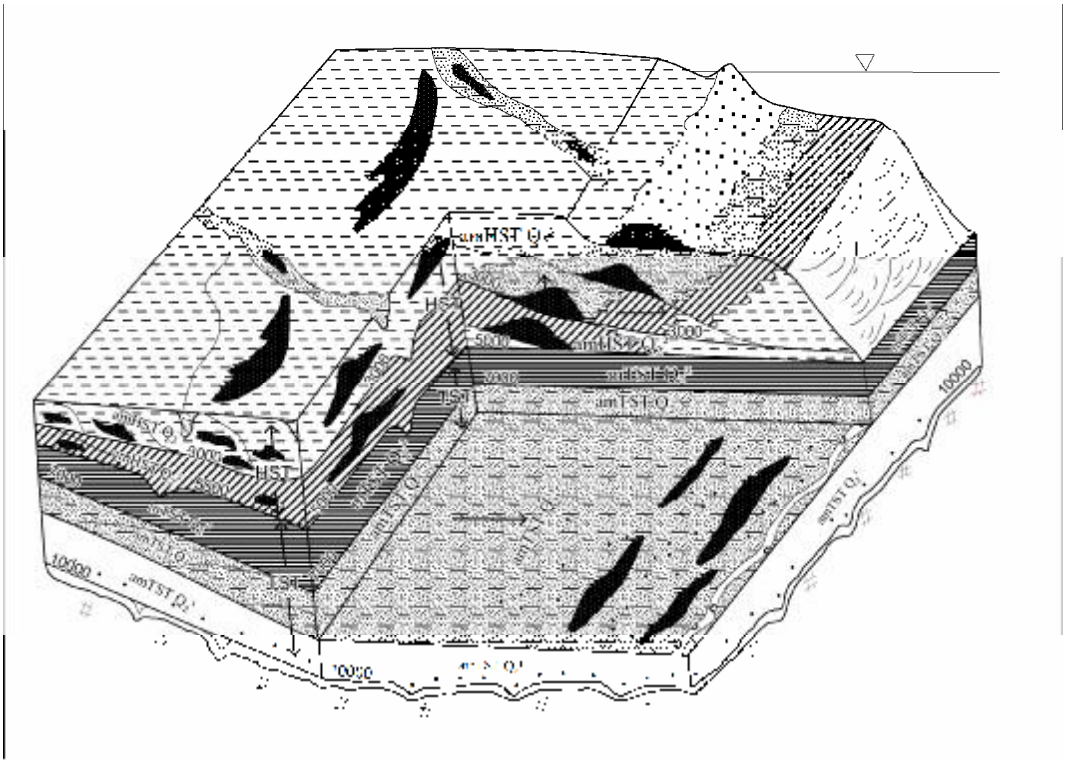


Fig.10. 3D relationship scheme of the Holocene sedimentary units in the Mekong coastal and shallow sea area.

Note:

- am TST Q_2^1: Deltaic lithofacies (am) corresponding with transgressive systems tract (TST) in Early Holocene period (Q_2^1)
- m TST Q_2^2: Marine lithofaies (m) coresponding with transgressive systems tract (TST) in Middle Holocene period (Q_2^2)
- am HST Q_2^2: Deltaic lithofaies (am) coresponding with highstand systems tract (HST) in Middle Holocene period (Q_2^2)
- am HST Q_2^3: Deltaic lithofaies (am) coresponding with highstand systems tract (HST) in Late Holocene period (Q_2^3).

5. Conclusion

1) The Holocene deposits in a coastal zone of the Mekong delta consist of 5 sedimentary types and 18 lithofacies, distributed from the land to the 25m water depth

2) Thickness of the Holocene deposits varies from 40 to 55 m, consist of silty sand and clay, coming from the Mekong river. A depositional balance in the Early Holocene and excess of sediment supply in the Late Holocene had proved that in all time deposit supplied by the Mekong river always higher than tectonic subsidence. Differentiation and sedimentation occurred in relationship with sea level change, mainly two important phases: Flandrian transgression and regression after maximum transgression.

3) From -10m water depth seaward high content of laterites clasts (>15%) in surface sediments is an evidence of erosion process by wave during Flandrian transgression and redepositional process by tide, longshore flows or waves. Laterite clasts came from late Pleistocene mottle clays but their age is Early-Middle Holocene or late Holocene when they play a role as a clasts in deposits.

4) Study sequence stratigraphy of the coastal Holocene deposits of Mekong Delta shown that from sequence stratigraphy point of view, geochronology is not suitable for depositional system track division. According to sequence stratigraphy the transgressive system track ended at 5Ky Bp, while from geochronology point of view the boundary between Middle Holocene and Late Holocene is 3Ky Bp- a regressive stage.

5) Study on facies association in boreholes allows to determine horizontal migration of river channels as a result of overwhelming sediments supply over amplitude of tectonic subsidence. Therefore it could be considered as a highly changing sensitivity of the strongly accumulative delta such as the Mekong Delta.

6) In circumstance of global climate change and sea-level rising, the Mekong geosystem will be changed much more. A progradational rate will be slowed down and many eroded coasts will be occurred with deposited coasts. Tectonic subsidence with a rate of 2 mm/year is an interior factor that diminished a coast's progradational process seaward. If the rate of sea-level rising is 2mm/year then sea bed will be subsided with a rate of 4mm/year (sedimentary supply is not considered yet). But recent rate of sediment accumulation is over 4mm/year [6,13], so the coastline continues to prograde seaward with a rate of 40m/year. The Mekong river mouths are migrating to East-North, and as a result geosystems and landscapes are changing. Therefore when making planning and coastal management, these unruly changes should be taken in account as a natural hazards to make reasonable measures for sustainable social-economic development in the future.

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