VNU Journal of Earth and Environmental Sciences, Vol. 29, No. 3 (2013) 14-25

Diatom Responses to Holocene Environmental Changes in the Tiền Delta - Mekong River System

Nguyễn Thị Thu Cúc[*,1], Doãn Đình Lâm[2]

[1]*VNU University of Sciences, Vietnam*
[2]*Institute of Geosciences, Vietnam Academy of Science and Technology*

Received 12 August 2013
Revised 30 August 2013; Accepted 12 September 2013

Abstract: The environmental changes in the Tiền delta during the Holocene were revealed by diatom investigation of 3 deep boreholes along the coastal zone of the Mekong delta, Vietnam. The data shows that the studied area was transformed from a terrestrial condition to coastal area at about 8000 years BP. The dominance of marine diatoms species from 40m to 15m in the borehole $LKBT_2$, from 36.5m to 18m in the borehole $LKTB_3$ and from 20m to 14 m in the borehole $LKTB_1$ indicates that studied area at about 5000-7000 years BP was dominated by marine environment such as lagoon or estuary. This change is a result of the Flandrian transgression. The sandy bar or supratidal flat characterized by the strong decrease of diatoms in number of species and individuals shows a regression time at about 4000 years BP. The dominance of diatoms in the uppermost part in the 3 boreholes shows a coastal environment in the late Holocene.

Keywords: Diatoms, environmental changes, Holocene, Tiền delta, coastal environment.

1. Introduction

The Mekong River is one of the largest rivers in Southeast Asia. It flows from the Tibetan Plateau southward through the Indochina Peninsula towards the East Sea, where it forms one of the largest deltas in Southeast Asia as well as in the Vietnam [1]. The coastal system of the Mekong River evolved from an estuarine system, formed from 13 to 8-9 ka Bp while sea level was rapidly rising, to an aggradational deltaic system, formed between 8-9 and 6-7 ka Bp as sea level slowly rose. It became a regressive deltaic system over the past 6ka Bp while sea level has been stable [2, 3, 4].

The Mekong delta is composed of two systems: The Tiền delta system and the Hậu delta system. The Tiền delta system has six river mouths (Cửa Tiểu, Cửa Đại, Ba Lai, Hàm Luông, Cổ Chiên and Cung Hầu) (Fig 1.).

At present, studies on sedimentary environment of the Tiền delta mainly focus on the delta evolution and sea level change [5, 6, 1, 2, 4, 7]. Recently, Proske et al [8] investigated pollen and spore to reconstruct the pale environmental development of the north eastern and the north of Vietnamese Mekong Delta. The southern part of the Mekong Delta has not yet been a major focus for geological investigation in

* Corresponding author. Tel.: 84-904277814
E-mail: thucuc.kdc@gmail.com

paleo environmental development [3]. This paper aims to reconstruct the paleoenvironmental development of the southern part of the Tiền delta (Mekong delta) by investigating changes in diatom assemblages of three boreholes along the coastal area of the Delta.

2. Material and Methods

2.1. Material

Diatom samples of three deep boreholes ($LKBT_{1,}$, $LKBT_2$, $LKBT_3$; Fig. 1) were collected from the Tiền delta plain in summer 2007 during implementation of the Project KC09.06/06-10). The depth of $LKBT_1$ is 27,4m; $LKBT_{2:}$ 57,5m and $LKBT_{3:}$ 53,5m.

The borehole cores were described, photographed and finally split. Diatom samples were collected from boreholes. Totally 116 samples were collected. Twelve samples were AMS C^{14} dated using plant fragments and mollusc shells (Table 1) at the Geological Institute in Vietnam Academy of Science and Technology.

Fig. 1: Map of the Tiền delta and location of the cores $LKBT_1$, $LKBT_2$ and $LKBT_3$.

Table 1. AMS C^{14} dated using plant fragments and mollusc shells

$LKBT_1$ ($09^O53'31.6"N$, $106^O34'14.6"E$) An Nhơn, Thạnh Phú, Bến Tre			$LKBT_2$ ($10^O01'55.6"N$, $106^O34'56.9"E$) An Đức, Ba Tri, Bến Tre			$LKBT_3$ ($10^O10'21.2"N$, $106^O41'59.9"E$) Bình Chiến, Bình Đại, Bến Tre		
No	**Depth (m)**	**C^{14} age (yr)**	**No**	**Depth (m)**	**C^{14} age (yr)**	**No**	**Depth (m)**	**C^{14} age (yr)**
1	14.1-14.5	5860 ± 160	1	10.1 - 11	4090 ± 260	1	5	3280 ± 145
2	28	12200 ± 110	2	31.2-31.3	4640 ± 95	2	13,5	3860 ± 150
			3	39 - 40	8118 ± 115	3	22,7	5060 ± 175
						4	30 - 30.7	6030 ± 195
						5	32,8	7050 ± 230
						6	54	10130 ± 110
						7	53.7-53.8	12070 ± 135

2.2. Methods

Diatom sample preparation included dispersion in Tetrasodium Pyrophosphat and enrichment with Sodium polytungstat (density = 2.5 g cm^{-3}). A known amount of spores of Lycopodium clavatumwas added in order to quantity pollen concentrations (cf. Stockmarr, 1971). Samples were analysed with a Zeiss Axiolab microscope (x400, x630 and x1000). Identification follows Hustedt 1959 [9], Jouse 1977 [10], Frank Eric Round, R. M. Crawford, D. G. Mann, 1990 [11], Trương Ngọc An, 1993 [12]). Diatom abundance is expressed as a percentage of a total sum (Fig. 2,3,4) and as concentrations (Fig 2,3,4). Diagrams were produced in C_2 (Steve Juggins, Ver. 1.6.6). Diatoms are grouped into four ecological groups: marine, coastal water, brackish and fresh water (Table 2). Zonation of diatom diagrams were completed using stratigraphically constrained cluster analysis based on species records exceeding 5% TDV (total diatom valves) per slide.

3. Results

83 diatoms species of the 34 genera were identified in the three boreholes from the Tiền delta (Table 2.). Based on ecological spectra, these diatoms are grouped into four ecological groups, namely marine, coastal water, brackish and fresh water (Table 2).

3.1. The borehole $LKBT_1$

It located in An Nhơn-Thạnh Phú District-Bến Tre Province, its coordinate: $09^0$53’31.6”N, $106^0$34’14.6”E.

Table 2. Diatom species in the Tiền delta

Order	Group	Species
1	Marine	*Actinocyclus divisus* Hustedt, *Actinocyclus ellipticus* Grun., *Actinocyclus subtilis* Hustedt, *Actinoptychus splendens* (Schadb.) Ralfs, *Actinoptychus trilingulatus* Brightwell, *Actinoptychus undulatus* (Bailey) Ralfs *Actinoptychus vulgaris* Schumann, *Asteromphalus robustus* Castracane, *Bacteriastrum hyalinum* Lauder, *Biddulphia rhombus* (Ehr.) W. Sm, *Cerataulina* sp., *Coscinodiscus asteromphalus* Ehr., *Coscinodiscus gigas* Ehr., *Coscinodiscus janischii* A. Schmidt, *Coscinodiscus lineatus* Ehr., *Coscinodiscus marginatus* Ehr., *Coscinodiscus nodulifer* A. Schmidt, *Coscinodiscus oculus-iridis* Ehr., *Coscinodiscus perforatus* Ehr., *Coscinodiscus pseudoincertus* Kazalina, *Coscinodiscus radiatus* Ehr., *Coscinodiscus subtilis* Cleve, *Planktoniella sol* (Wallich) Schutt, *Rhizosolenia bergonii* Peragallo, *Rhizosolenia hebetata* (Bailey) Gran., *Rhizosolenia styliformis* Brightwell, *Thalassiosira decipiens* (Grun.) Jorgensen, *Thalassiosira excentrica* (Ehr.) Cleve, *Thalassiosira kozlovii* Makarona, *Thalassiosira lineata* Jouse, *Thalassiosira oestrupii* (Ostenfeld) Pr. Lavrenko, *Thalassiosira pacifica* Gran et Angst., *Thalassiosira polychorda* (Gran) Jorgensen
2	Coastal water	*Caloneis formosa* (Greg.) Cleve, *Campylodiscus* cf. *parvulus* W. Sm., *Campylodiscus* cf. *undulatus* Greville, *Campyloneis* aff. *notabilis* J. Brun., *Cyclotella stylorum* Brightwell, *Diploneis interrupta* (Kutzing) Cleve, *Diploneis smithii* Cleve, *Diploneis splendida* Greg., *Diploneis subcincta* (Sch.) Cleve, *Diploneis suborbicularis* (Greg.) Cleve, *Diploneis weissflogii* (Schm.) Cleve, *Grammatophora marina* (Lyng.) Grun., *Hyalodiscus scoticus* (Kutz.) Grunow, *Navicula glacialis* Cleve, *Navicula hennedyi* W. Smith, *Navicula lyra* Ehr., *Navicula spectabilis* Greg., *Nitzschia cocconeiformis* Grun., *Nitzschia granulata* Grun., *Nitzschia marina* Grun., *Nitzschia panduriformis* Greg., *Nitzschia ritscherii* (Hust.) Hasle, *Nitzschia sicula* (Castracane) Hust., *Paralia sulcata* (Ehrenberg) Cleve, *Pleurosigma aestuarii* Breb., *Pleurosigma normanii* Ralfs, *Schuettia annulata* (Wall.) De Toni, *Surirella comis* A. Sm., *Surirella fastuosa* Ehr., *Thalassionema nitzschioides* Grun., *Trachyneis aspera* Cleve, *Triceratium favus* Ehr., *Triceratium scitulum* Brightwell
3	Brackish water	*Achnanthes brevipes* C. Agardh, *Achnanthes hauckiana* Grun., *Actinocyclus ehrenbergii* Ralfs, *Cocconeis placentula* Ehr., *Coscinodiscus lacustris* Grunow, *Cyclotella striata* (Kutzing) Grunow
4	Fresh water	*Achnanthes inflata* (Kutzing) Grun., *Aulacosira granulata*, *Cymbella affinis* Kutzing, *Cymbella cymbiformis* Agardh, *Epithemia* sp., *Eunotia* sp., *Gomphonema longiceps* Ehr., *Navicula pusilla* W. Smith, *Pinnularia* sp.

51 species of 22 genera of diatoms were identified in $LKBT_1$ borehole. Diatom floras in the $LKBT_1$ borehole were classified into three diatom zones, $LKBT_1$ - 1, $LKBT_1$ - 2, and $LKBT_1$ - 3 in ascending orders base on the change number of species and the ecological spectra.

Zone $LKBT_1$ - 1 (27,4m to 14, 1m) is characterized by marine and coastal water and brackish water groups. It is mainly composed of 10% to 15% marine species, 60% to 80% coastal species and 5 to 20 % brackish species. The highest abundance belongs to *Cyclotella stylorum* and *Paralia sulcata*. In addition, it is characterized by the abundance of diatom's number of individuals as well as the number of species in the fossils assemblage. Moreover, it is also characterized by the absence of fresh water group in the fossil assemblage. Diatom assemblage of this zone indicates the transition from brackish to marine habitat.

Zone $LKBT_1$ - 2 (from 14,1m to 9,1m) is characterized by the absence of diatom in the upper and lower parts of the zone. Also, the

number of individuals as well as the number of species is very few. However, *Cyclotella stylorum* has a highest percentage rate in the diatom assemblage.

Zone $LKBT_1$ - 3 (from 9,1m to 0m) is characterized by the abundance of diatoms. Especially, there is presence of fresh water group in the diatom assemblage. *Cyclotella stylorum* still represents an essential component in fossils assemblage. In this zone, the number of individuals of *Paralia sulcata* has been greatly reduced, about 5 to 10% in the fossils assemblage.

3.2. The borehole $LKBT_2$ (located in An Đức, Ba Tri, Bến Tre, latitude $10^0$01'55.6"N, longitude $106^0$34'56.9"E)

62 species of 27 genera were identified in this borehole. Diatom floras in the $LKBT_2$ borehole were classified into four diatom zones, $LKBT_2$ - 1, $LKBT_2$ - 2, $LKBT_2$ - 3, and $LKBT_2$ -4 in ascending orders based on the change of the total diatom percentages diagram.

Zone $LKBT_2$ - 1 (from 57,5m to 40,0m) is characterized by absence of diatom or it scarcity in the sediment.

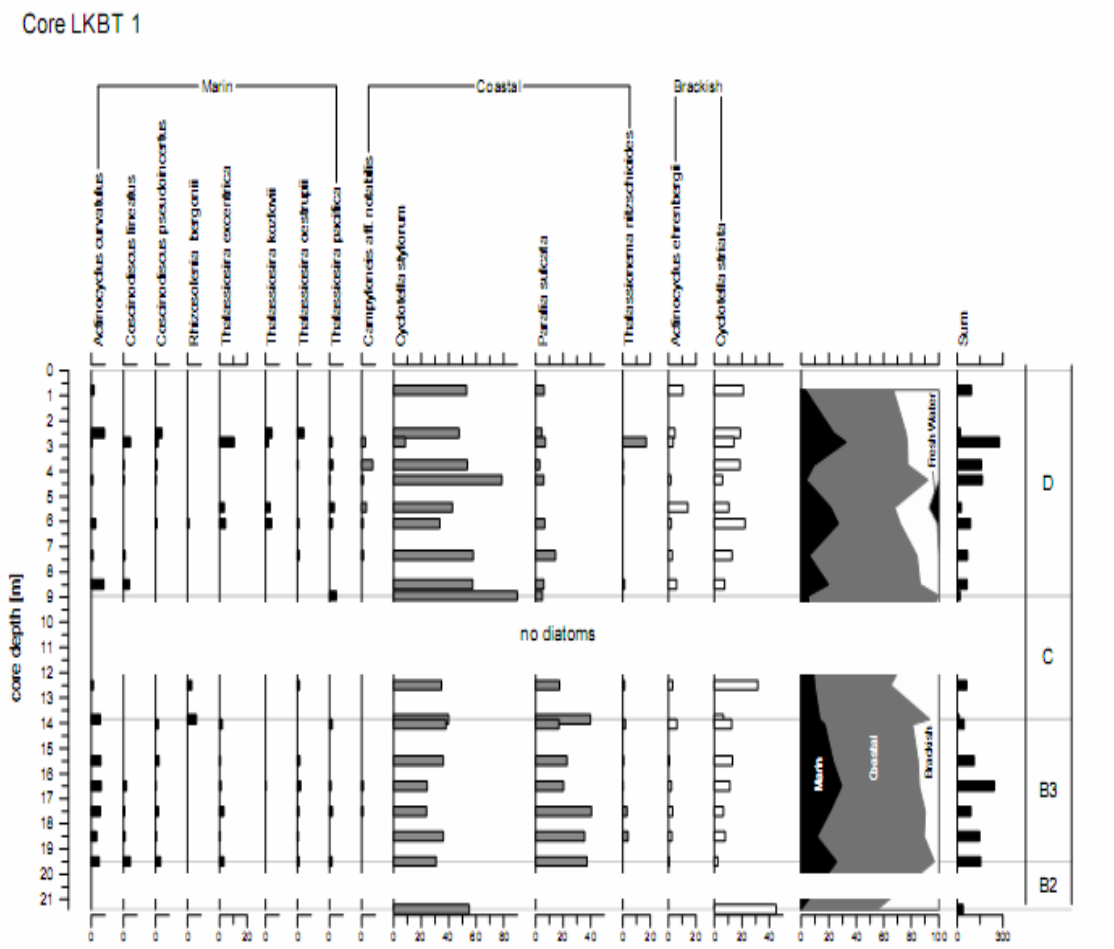

Fig. 2. Summary diatom percent diagram of sediment in the core $LKBT_1$ (An Nhon- Thanh Phu- Ben Tre) with diatom zonations. Only selected species are shown (> 5%) and sum percentages of four group and sum total valves diatom per slide.

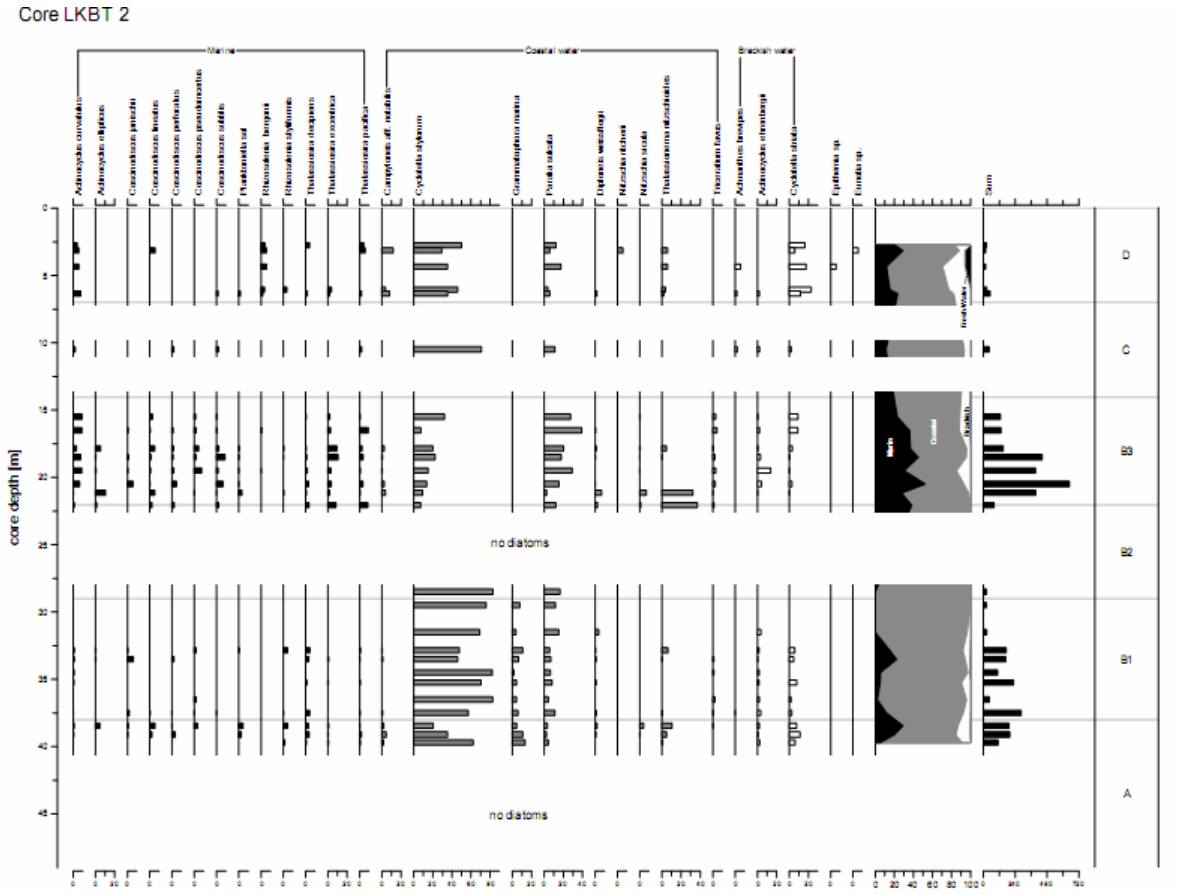

Fig. 3. Summary diatom percent diagram of sediment in the core $LKBT_2$ (An Duc- Ba Tri- Ben Tre) with diatom zonations. Only selected species are shown (> 5%) and sum percentages of four group and sum total valves diatom per slide.

Zone $LKBT_2$ - 2 (from 40,0m to 15,0m) is characterized by the abundance of diatoms. Based on the diagram, zone B can be divided into three subzones ($LKBT_2$ - 2a, $LKBT_2$ - 2 b, $LKBT_2$ - 2c). Subzone $LKBT_2$ - 2 a (from 40,0m to 32m) is characterized by marine and coastal and brackish water group. It is dominated by coastal water group in fossils assemblage. *Cyclotella stylorum* has a highest abundance. Besides, there is a presence of *Grammatophora marina*, *Paralia sulcata*, *Thalassionema nitzschioides* in coastal group. However, the abundance of *Paralia sulcata* is much lower than *Cyclotella stylorum*. In addition, it is characterized by the abundance of diatom's number of individuals as well as the number of species in the fossils assemblage. Marine group contains *Actinocyclus curvatulus, A. ellipticus, Coscinodiscus janischii, C. perforatus, Thalassiosira decipiens, T. excentrica, T. pacifica* and is from 5% to 10% in TVD. Brackish group contains *Actinocylus ehrebergii* and *Cyclotella striata*, which has a high abundance in brackish group.. Moreover, marine and brackish diatom group have lower abundance than coastal group. Diatom assemblage of this zone indicates a brackish to marine habitat.

Subzone $LKBT_2$ - 2b (from 32m to 23m) is characterized by rare diatom in the lower part

and absence of diatom in upper part. Moreover, it is also characterized by only coastal group in the fossils assemblage

Subzone $LKBT_2$ - 2c (from 23m to 15m) is characterized by the abundance of marine group and coastal group and a few of brackish groups. Marine group increases in number of individual as well as a percentage of the group than subzone B_1. Marine group occupies 30 to 40% in diatoms assemblage. The highest abundance belongs to *Cyclotella stylorum* and *Palaria sulcata* in this subzone. Also *Thalassionema nitzschioides* is the highest in the lower part of this zone. Another feature of this subzone is the most abundance species on the number of individuals as well as the number of TVD in the middle of this subzone. Diatom assemblage of this subzone indicates the transition from brackish to marine habitat in this borehole again.

Zone $LKBT_2$ - 3 (from 15m to 7,5m) is characterized by the absence of diatom in the upper and lower parts of the zone. Also number of individuals as well as the number of species is very few. However, *Cyclotella stylorum* is highest percent rate in diatom assemblage.

Zone $LKBT_2$ - 4 (from 7,5m to 0m) is characterized by the appearance of fresh water group in the diatom assemblage. *Cyclotella stylorum* still represents an essential component in fossils assemblage. In this zone, the number of individuals of *Paralia sulcata* has greatly reduced, about 5 to 10% in the fossils assemblage. *Cyclotella striata* increases in diatom assemblage. However, diatom is absent in the upper part of this zone (2m to 0m).

3.3. $LKBT_3$ (Bình Chiến, Bình Đại District, Bến Tre Province, ($10^0$10'21.2"N, $106^0$41'59.9"E)

63 species of 26 genera were identified in this borehole. Diatom floras in the $LKBT_3$ borehole were divided into four diatom zones, $LKBT_3$ - 1, $LKBT_3$ - 2, $LKBT_3$ - 3, and $LKBT_3$-4 in ascending orders based on the change of the number of species and the ecological spectra.

Zone $LKBT_3$ - 1 (from 53,5m to 37,5m) is characterized by absence of diatom in the sediment.

Zone $LKBT_3$ - 2 (from 37,5m to 18m) is characterized by the abundance of three diatom groups, marine, coastal and brackish. It is mainly composed of 30% to 40% marine species, 50% to 60% coastal species and 5% to 10% brackish. *Cyclotella stylorum* and *Paralia sulcata* have the highest abundance. The most abundance marine diatoms were *Actinocyclus curvatulus, Coscinodiscus subtilis, Thalassiosira excentrica, Thalassiosira pacifica*. For example, from 27m to 25m, a diatom assemblage was identified with 600 total diatom valves and 37 species. Moreover, it is also characterized by the absence of fresh water group in the fossils assemblage. Diatom assemblage of this zone indicates the transition from brackish to marine habitat.

Zone $LKBT_3$ - 3 (18m to 10,6m) is characterized by the absence of diatom in the upper and lower parts of the zone. Also, the number of individuals as well as the number of species has been very few. However, *Cyclotella stylorum* has the highest percentage rate in diatom assemblage.

Zone $LKBT_3$ - 4 (10,6m to 0m) is characterized by the appearance of fresh water group in the diatom assemblage. *Cyclotella stylorum* still represents an essential component in fossils assemblage. In this zone, the number of individuals of *Paralia sulcata* has greatly reduced, about 5 to 10% in the fossils assemblage. *Cyclotella stylorum* dominated in the lower parts of this zone. The part from 5m to 2m in this zone is characterized by an abundance of diatoms assemblage again. However, in the upper part of this zone, diatom is absence or present with very few numbers of diatoms.

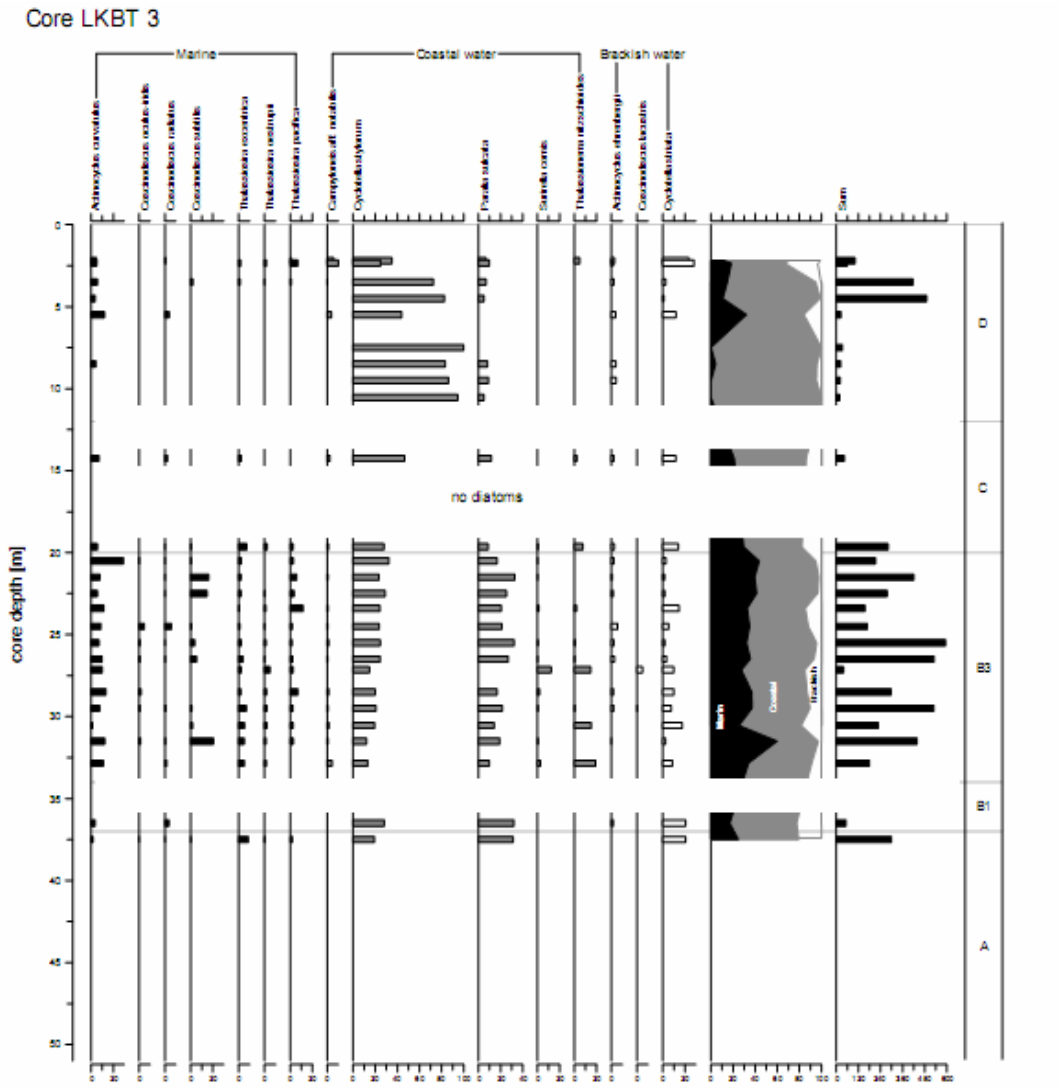

Fig. 4. Summary diatom percent diagram of sediment in the core $LKBT_3$ (Binh Chien- Binh Đai- Ben Tre) with diatom zonations. Only selected species are shown (> 5%) and sum percentages of four group and sum total valves diatom per slide.

4. Discussion

4.1. Diatom zone

Based on the result of ecological zones of three boreholes $LKBT_1$, $LKBT_2$ and $LKBT_3$ shown in the result part, after contact with the sediment composition and C^{14} analysis results show that we can be divided into 4 ecological zones: A, B, C and D in which zone $LKBT_2$ - 1 and $LKBT_3$ - 1 are the same, called zone A; $LKBT_1$ - 1 corresponds to $LKBT_2$ -2 and $LKBT_3$ - 2, called zone B; $LKBT_1$ - 2 corresponds to $LKBT_2$ - 3 and $LKBT_3$ - 3, called zone C; $LKBT_1$ - 3 corresponds to $LKBT_2$ - 4 and $LKBT_3$ - 4, called zone D (Fig 2, fig 3 and fig 4).

Zone A (57,5m-40m in the borehole $LKBT_2$, and 53,5-38m in the borehole $LKBT_3$) was formed in the early Holocene.

This zone is characterized by absence of diatom or its scarcity in the sediment. It suggests that sedimentary environment is continent (?).

Zone B (40- 15m in the borehole $LKBT_2$, and 38-18m in the borehole $LKBT_3$) was formed in the early Holocene and middle Holocene.

It is characterized by the highest abundance of diatom assemblage. It could be divided into three subzones. Subzone B_1 is the lowest in the zone. It is characterized by a dominance of coastal diatom, for example *Cyclotella stylorum, Paralia sulcata, Diploneis weissflogii, Thalassiosira nitzschioides.* Besides, marine plankton diatom groups also are present. Their number of species in this zone is very high. The first is *Actinocylus curvatulus, A. ellipticus*, *A. divisus, Coscinodiscus asteromphalus, Cos.lineatus, Cos. pseudoincertus, Cos. perforatus, Planktoniella sol, Rhizosolenia bergonii, Rh. hebetata, Rh. styliformis, Thalasiosira excentrica, Thalassiosira pacifica.* And this subzone is marked by a brackish water group. They are *Actinocylcus ehrenbergii, Cyclotella striata, Diploneis smithii.* The concentrate of three groups: marine plankton, coastal and brackish diatom is indicator for coastal environment or estuary in study area. It suggests that in his time sea had invaded this area. Subzone B_1 could be observed in the borehole $LKBT_2$ (at 40- 32m) and the borehole $LKBT_3$ (38- 36,5m).

Subzone B_2 could be revealed in $LKBT_1$ (27,5- 20m) and in $LKBT_2$ (32- 23m) and in $LKBT_3$ (36,5- 34m ?). It is characterized by absence of diatom or its scarcity in the sediment. The diatom assemblage is *Cyclotella stylorum, Cyc. striata, Gramatophora marina and Paralia sulcata, Thalassionema nitzschioides.* This picture shows that in this area sea-level fall during this time.

Subzone B_3 was formed in the Middle Holocene. It is remarked by abundance of diatom assemblage. Marine plankton group occupied from 20 % to 40 % TDV per slide, coastal water group is from 35 % to 60 % TDV and brackish group is 5 -25% TDV. In this zone, the number of species and TDV are the most abundance in the entire borehole sediments. It suggests that depositional environment in this time was estuarine. It remarks a sea-level rise in Middle Holocene in this area.

Zone C is characterized by poverty of the fossil group or an absence of fossil groups. It suggests that sediment was deposited in the supratidal environment. Zone C is from 14 m to 9m in the borehole $LKBT_1$, and 14 m to 7,5m in the borehole $LKBT_2$ and 18m to 10,6m in the borehole $LKBT_3$.

Zone D is characterized by presence of the freshwater group in the diatom assemblage. It shows a role of the Mekong river systems in transportation and sedimentation. However, coastal group is the highest in the diatom assemblage. In particular, *Cylotella stylorum* has the highest percentage in the entire zone. Besides, the fact that brackish group increases and marine group decreases shows that sediment was formed in estuarine environment.

4.2. The paleoenvironmental development

The paleoenvironmental development of the southern part of the Tiền delta (in Mekong delta) can be described in three phases as follow:

4.2.1. The paleoenvironment development in the early Holocene (11,7ka - 8 ka BP)

Sea-level change is an important factor that influenced not only the relative position of the shoreline, but also the characteristics of coastal

stratigraphic systems. The change in modern coastal landforms is pertinence to Holocene sea-level change over the past 10,000 years [5]. Sea- level change in the early Holocene is expressed by sedimentary characteristics and diatom assemblage. Sedimentary characteristics expressed in gradual reduction of grain size from coarse size to fine. The Mekong delta was initiated at about 8.0ka Bp in response to a stable sea level after a rapid sea-level rise from 8.8 to 8.2 ka Bp [4].

4.2.2. The paleoenvironment development in the middle Holocene (8 - 4 ka BP)

During the mid-Holocene when sea level was between 2.5 and 4.5 m above present level [6,7], diatom assemblage in the Tiền delta had reached the highest abundance. It is indicated by a dominance of coastal water diatom, for example *Cyclotella stylorum, Paralia sulcata, Diploneis weissflogii, Thalassionema nitzschioides.*

Cyclotella stylorum has a highest abundance in the diatom assemblage of sediment in this period. It is the most of valves in TDV per slide. Some samples have up to 160 valves per slide. The species is commonly found in marine inshore plankton [12]. This is an evidence for coastal environment.

Paralia sulcata is a brackish to marine diatom with robust, chain-forming valves. It has a wide distribution and often found in both planktonic and benthic microphyte communities of temperate coastal waters. The thick walls of *P. sulcata* sink readily and are relatively resistant to dissolution; both factors contribute to its abundance in coastal sediment records [13]. It is very abundance in the sample and varies by location of deposits in the borehole.

Thalassionema nitzschioides is a cosmopolitan diatom species, occurring in all seas with an exception of high-latitude Arctic and Antarctic oceans [14], and it often occurs in large numbers. *Thalassionema nitzschoides* is observed in the borehole in this study. It is indicator for coastal environment.

In addtion, marine plankton diatom groups are also present. They are very abundant in number of species in the middle Holocene. The first is *Actinocyclus curvatulus, A. ellipticus*, *A. divisus, Coscinodiscus asteromphalus, Cos. lineatus, Cos. pseudoincertus, Cos. perforatus, Planktoniella sol, Rhizosolenia bergonii, Rh. hebetata, Rh. syliformis Thalassiosira excentrica, Thalassiosira pacifica.*

Contribution in this period is significant in the presence of brackish water group. They are *Actinocyclus ehrenbergii, Cyclotella striata, Diploneis smithii. Cyclotella striata* is a brackish species, often abundance in estuaries as planktonic species [12] reported as littoral species and often occur in coastal zone in Vietnam. It has a lower abundance than *Cyclotella stylorum* in this study.

Concentration of the three groups: marine plankton, coastal water and brackish. Diatom is indicator for coastal environment or estuary in study area. Holocene sea-level high stand is reported to be at about 5 to 6 ka BP in southern Vietnam [2, 6].

4.2.3. The paleoenvironment development in the late Holocene (4ka to present)

The paleoenvironment development in the late Holocene is described in diatom zone C and D. The poverty of the fossil group and the absence of diatom fossil in zone C show that the supratidal environment was formed in the early late Holocene. The abundance of four diatom groups in diatoms assemblage reflects an intertidal environment.

5. Conclusion

The paleoenvironment development of Tiền delta during the Holocene is reflected in four

diatom zone. Zone A was formed in the early Holocene, it responses a rising sea-level change. Zone B indicated a maximum transgression in the middle Holocene. The sandy bar or supratidal flat characterized by the strong decrease of diatoms in number of species and individuals. Zone C shows a regression time at about 4000 years BP. The dominance of diatoms in the uppermost part of the 3 boreholes (zone D) shows a coastal environment in the late Holocene.

6. Acknowledgements

This study is a part of the author PhD.thesis, carried out at the Hanoi University of Science (Vietnam National University, Hanoi, Vietnam). Material from KC06-09/06-10 Project was used for this work.

We thank the Institute of Botany and Landscape Ecology, University of Greifswald; and the TRIG A and TN 13-23 projects of the Hanoi University of Science (Vietnam National University, Hanoi, Viet Nam) for the support to complete the manuscript at the Department of Peatland Studies & Palaeoecology, Institute of Botany and Landscape Ecology, University of Greifswald, Germany; Institute of GeoSciences (VAST) and Department of Geology and Minerals of Vietnam.

References

[1] Thi Kim Oanh Ta., Van Lap Nguyen., Masaaki Tateishi, Iwao Kobayashi, Susumu Tanabe, Yoshiki Saito,, 2002b. Holocene delta evolution and sediment discharge of the Mekong River, southern Vietnam. Quatern. Sci. Rev. 21, 1807-1819.

[2] Van Lap Nguyen, Thi Kim Oanh Ta., Masaaki Tateishi, ,2000. Late Holocene depositional environments and coastal evolution of the Mekong delta, Southern Vietnam. J. Asian Earth Sci. 18, 427-439.

[3] Van Lap Nguyen, Thi Kim Oanh Ta., Masaaki Tateishi,, Iwao Kobayashi, Masatomo Umitsu, Yoshiki Saito, 2005. Late Quaternary depositional sequences in the Mekong delta, Vietnam. In: Chen, Z.Y.,Saito,Y.,Goodbred Jr,S.L.(Eds.), Mega- deltas of Asia Geological Evolution.

[4] Van Lap Nguyen., Thi Kim Oanh Ta, Yoshiki Saito, 2010. Early Holocene initiation of the Mekong delta, Vietnam, and the response to Holocene sea-level changes detected from DT1 borehole analyses. Sedimentary Geology, 230 (2010) 146-155.

[5] Thi Kim Oanh Ta, Van Lap Nguyen, Masaaki Tateishi, Iwao Kobayashi, Yoshiki Saito, 2001. Sedimentary facies, diatom and foraminifer assemblages in a late Pleistocene–Holocene incised-valley sequence from the Mekong delta, Bentre Province, Southern Vietnam: the BT2 core. J. Asian Earth Sci. 20, 83-94.

[6] Thi Kim Oanh Ta., Van Lap Nguyen., Masaaki Tateishi, Iwao Kobayashi, Yoshiki Saito, Toshio Nakamura 2002a. Sediment facies and Late Holocene progradation of the Mekong delta in Bentre province, southern Vietnam: an example of evolution from a tide-dominated to a tide- and wave-dominated delta. Sed. Geol. 152, 313-325.

[7] Susumu Tanabe, Yoshiki Saito, Yoshio Sato, Yuichiro Suzuki, Sin Sinsakul, Suwat Tiyapairach, Niran Chaimanee, 2003. Stratigraphy and Holocene evolution of the mud-dominated Chao Phraya delta, Thailand. Quaternary Science Reviews 22 (2003) 789-807.

[8] Ulrike Proske, Till J.J. Hanebuth, Hermann Behling, Van Lap Nguyen, Thi Kim Oanh Ta and Bui Phat Diem, 2010. The palaeoenvironmental development of the northeastern Vietnamese Mekong River Delta since the mid Holocene. The Holocene published online 27 July 2010.

[9] Hustedt, F., 1959. Die Kieselalgen Deutschlands, O ¨ sterreichs undder Schweiz, 2 Teil. Koeltz Scientific Books, Koenigstein. English translation, 1985, 918 pp.

[10] Jouse, 1977. Atlas of microorganisms in bottom sediments of the oceans. Diatoms, radiolarian, silicoflagellates and coccoliths. Publishing house "Nauka". Moscow. (In Russia).

[11] F. E. Round, R. M. Crawford, D. G. Mann, 1990. The Diatoms: biology and morphology of genera. Cambridge University press. 747p.

[12] Trương Ngọc An, 1993. Planktonic diatom in the Bien Dong, Vietnam. Publishing House of Science and Technology(in Vietnamese).

[13] McQuoid M.R., Nordberg K., 2003. The diatom Paralia sulcata as an environmental indicator species in coastal sediments. Estuarine, Coastal and Shelf Science, 56 (2003) p.339-354.

[14] Hasle, G. R., & Syvertsen, E. E. (1996). Marine diatoms. In C. R. Lakes. Encyclopedia of Quaternary Science. Editor-in- chief Scott A. Elias. Vol. 1, p. 514-523, Elsevier

Diatomeae và sự thay đổi môi trường trầm tích Holocen khu vực cửa sông ven biển sông Tiền (thuộc hệ thống sông Mê Kông)

Nguyễn Thị Thu Cúc[*,1], Doãn Đình Lâm[2]

[1]*Trường Đại học Khoa học Tự nhiên, Đại học Quốc gia Hà Nội, Việt Nam*
[2]*Phòng Trầm tích - Viện Địa chất - Viện Hàn lâm Khoa học và Công nghệ Việt Nam*

Tóm tắt: Sự thay đổi môi trường khu vực cửa sông ven biển sông Tiền trong Holocen được khôi phục dựa trên nghiên cứu Diatomeae ở 3 lỗ khoan sâu trong đới ven biển khu vực cửa sông Tiền thuộc hệ thống sông Mê Kông, Việt Nam. Kết quả chỉ ra rằng sự thay đổi từ điều kiện lục địa sang đới ven biển trong khoảng 8000 năm cách ngày nay. Sự thống trị của Diatomeae ở độ sâu 40-15m trong lỗ khoan $LKBT_2$, 36,5-18m trong lỗ khoan $LKBT_3$ và 20-14m trong lỗ khoan $LKBT_1$ chứng tỏ rằng môi trường biển hay cụ thể hơn là vũng vịnh trong khu vực nghiên cứu ở khoảng 5000-7000 năm cách ngày nay. Sự thay đổi này là kết quả của biển tiến Flandrian trong khu vực nghiên cứu. Môi trường lục địa được đặc trưng bằng sự giảm mạnh đến vắng mặt của số lượng giống loài Diatomeae trong khoảng 4000 năm cách ngày nay. Sự thống trị của Diatomeae ở phần trên cùng của các lỗ khoan trên chỉ ra rằng môi trường ven biển tồn tại trong Holocen muộn.

Từ khóa: Diatomeae, thay đổi môi trường, Holocen, châu thổ sông Tiền, môi trường ven biển.