# SEDIMENT FACIES AND EVIDENCE OF MIDDLE HOLOCENE TRANSGRESSION IN THE VL1 CORE, MEKONG RIVER DELTA

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***ABSTRACT:*** *A detailed description of sediment facies, diatom and $^{14}C$ ages of a new 42 m long core (VL1) is one of the basic data to study Holocene sedimentation in the Mekong River Delta. This core is divided into seven sediment facies on the basis of sedimentary properties, diatom assemblages, and $^{14}C$ ages. These facies show changes from transgression to regression in relation to the late Pleistocene-Holocene sea-level changes.*

*The Postglacial transgression caused by a sea-level rise led to formation of open bay muddy sediments. This muddy facies, around 10 m thick, is characterized by abundant marine planktonic diatoms. This facies indicates the maximum Holocene marine influence was around 5,000 cal yr BP at the VL1 site.*

*The regressive succession is composed of deltaic sediments from prodelta, delta front, sub- to inter-tidal flat and floodplain in ascending order. $^{14}C$ ages indicate that prodelta and delta front passed the core site at approximately 4,000 to 3,600 cal yr BP. The accumulation rates were closely related to the sediment facies: low rate for prodelta facies, high rate for delta-front facies.*

## Introduction

The Mekong River Delta has been studied by many geologists with interests in geology, sedimentology, tectonics and geomorphology. However, until now a detailed description of sediment facies and microfossil assemblages of subsurface sequences has not been undertaken. Moreover, there is a paucity of $^{14}C$ ages from subsurface sediments. Recently other large deltas in Asia have been studied in detail by using borehole samples and high-resolution $^{14}C$ dating. In December 1998, a 42 m long core was drilled in the VinhLong province located in the lower delta plain of the Mekong River Delta (Fig. 1).

This paper presents the detailed description of sediment facies with diatom assemblages and $^{14}C$ ages, and discusses the relationship between these facies successions, and the latest Pleistocence-Holocence sea-level changes with the evidence of Holocene transgression in VL1 core.

## Methods

The core samples were split, described and photographed. X-radiographs of slab samples were taken throughout all split cores. Sand and mud contents were measured every 20 cm throughout the core. Sand samples were 5 cm thick and mud samples were 2 cm thick. After organic materials were removed with 10% $H_2O_2$, sands were separated on a 63-μm sieve under pored water. After measuring the dry weight of sand portion, sand contents were calculated. Diatoms were identified and counted under optical microscope. Six $^{14}C$ ages were measured on plant fragments and molluscan shells by accelerator mass spectrometry

(AMS) at Beta Analytic Inc. Calendar ages were calculated by the INCAL98 calibration curve.

**Lithological features**

On the basis of sedimentary characteristics and $^{14}C$ ages, the VL1 core can be divided into seven lithological units (Fig.2) as follows:

*Unit L1* (-40.0 to -35.0 m) in the lowest part of the core and consists of stiff, slightly oxidized, yellowish grey silty sand and fine-medium sand bearing scattered quartz pebbles and laterite. Sand content is 30-52 %. Parallel laminae are common. Some isolated lenticulars consisting of very fine sand with 3-8 mm in thickness can also found.

*Unit L2* (-35.0 to -33.90 m) generally consists of yellowish-colored, poorly sorted sand, gravel and pebbles. The matrix is composed of yellowish fine sand or sandy silt. Sand content is 70-20 % decreasing upward. It contains marine shell fragments and microfossils such as foraminifera and sponge spicules as well as the laterite pebbles.

*Unit L3* (-33.90 to -25.90 m) mainly consists of homogeneous greenish gray mud in a fining-upward succession. The sand content decreases from 38 to 2 %. Massive bioturbated clay with very thin discontinous parallel and parallel laminae. Small shell fragments, foraminifera and sponge spicules are scattered all the unit.

*Unit L4* (-25.90 to -14.0 m) consists of dark grey laminated silt, silty clay. Sand content is very low, about 2-3 % excepting 8-11 % in the sandy silt laminae. Very thin parallel laminae (1 mm in thickness) are common. Yellowish grey-clay layers with the thickness of several mm to 20 mm are abundant in the middle to lower part of this unit. Wavy and lenticular bedding are found. Calcareous nodules exist in some of clay layers. Organic materials are common but burrows, bioturbations and shell fragments decrease upward. Plant fragments are found in -18.6 m.

*Unit L5* (-14.0 to -4.30 m) mainly consists of intercalated greenish grey silt and sandy silt in a coarsening-upward succession. Sand content is 2-25 %. This coarsening-upward succession is result of the increase of sand lamination and parting in the silt clay. Parallel laminae, current ripples, wavy bedding and lenticucular bedding are common. Organic matter are condensed in the thin layers (5-10 mm in thickness), burrows and bioturbations occurred throughout the unit. Plant fragments are also found.

*Unit L6* (-4.3 to 0.0 m) consists of dark grey sandy silt and fine sand in a fining-upward succession. Sand content is 2-23 %. Parallel laminae are common all the unit. Wavy bedding, current ripples are in the lower part and discontinuous parallel laminae occurred in the middle and upper part. Organic matter and rootlets become abundant in the uppermost part. Bioturbation and burrows markedky decrease upward.

*Unit L7* (0.0 to +2.0 m) consists of grey brownish silty clay with rich organic matter, rootlets and mica flakes. It lacks well-defined bedding. Very thin parallel laminae are in the lower part and become less common to the top. Gypsum and jarosite are crystallized on the surface of dried samples. Plant fragments are found in +0.45 m

**Stratigraphical changes of diatom flora**

Stratigraphical changes of diatom flora in VL1 core can be divided into six diatom divisions labeled D1, D2, D3, D4, D5 and D6 in ascending order. The relatively abundant genera and species in this core are shown in Fig. 3.

*Division D1* (-31.42 to - 30.42 m) is characterized by the increase of marine plankton and marine-brackish species group as well as the decrease of brackish and fresh-water species

group. It is composed of 38.2-55.4 % marine plankton, 31.0-9.0 % brackish water and 15.0-20.0 % fresh water. Marine plankton species are represented by *Coscinodiscus radiatus, C. nodulifer, Thalassiosira excentrica and Thalassionema nitzschioides.* Fresh-water species such as *Stephanodiscus astrea, Synedra* spp., and brackish water species such as *Paralia sulcata, Cyclotella caspia* are common but decrease upward. They indicate a marine habitat.

*Division D2* (-30.42 to - 23.42 m) shows that marine plankton species markedly increase and reach the highest portion in all divisions while fresh water species decrease. It is composed of 58.7-68.7 % marine plankton, 6.7-19.3 % brackish water and 17.0-10.0 % fresh water. Marine plankton species including *Coscinodiscus radiatus, C. nodulifer, Thalassiosira excentrica* and especially *Thalassionema nitzschioides* are abundant. Brackish water and fresh water such as *Paralia sulcata, Cyclotella caspia* are commonly present, *Synedra* spp., and *Aulacoseira granulata* occur with low frequency. They indicate a marine habitat.

*Division 3* (-23.42 to - 14.86 m) points out that marine plankton species are less abundant in comparison to the below division D2. Brackish-water species increase measurably and fresh water species gradually increase upward. It is composed of 56.2-46.3 % marine plankton, 27.0-17.0 % brackish water and 9.0-20.0 % fresh water. *Coscinodiscus radiatus, Coscinodiscus nodulifer* and *Thalassiosira excentrica* are abundant. *Thalassionema nitzschioides* decreases in individual. Brackish water species such as *Paralia sulcata* and *Cyclotella caspia* and fresh water such as *Synedra* spp., *Stephanodiscus astrea* and *Aulacoseira granulata* are common. This indicates that a marine habitat has been effected by fresh and brackish-water sources.

*Division D4* (-14. 86 to -5. 8 m) presents marine plankton species still abundantly exist, brackish-water species decrease but fresh-water species obviously increase. It is composed of 41.0-49.0 % marine plankton, 9.5-20.8 % brackish-water and 20.0-31.0 % fresh-water species. *Coscinodiscus radiatus, C. nodulifer, Thalassiosira excentrica, Cyclotella caspia, Aulacoseira granulata* and *Synedra* spp. are common. *Thalassionema nitzschioides, Cyclotella styrolum* and *Stephanodiscus astrea* occur with low frequency. This indicates an increasing in influence of fresh-water.

*Division D5* (-5.8 to +0.18 m) shows marine plankton and brackish water species gradually decrease while fresh water species obviously increase. It is composed of 34.3-50.2 % marine plankton, 12.0-20.6 % brackish water and 27.0-40.0 % fresh water. *Coscinodiscus nodulifer* and *Synedra* spp. are abundant. *Coscinodiscus radiatus, Thalassiosira excentrica, Cyclotella caspia, C. styrolum* and *Stephanodiscus astrea* are common., indicating a marine-brackish water habitat. *Thalassionema nitzschioides* and *Thalassiosira excentrica* are obviously decreased. This division shows a marine-brackish water environment with influence of fresh water.

*Division D6* (+0.18 to +2.0 m) shows fresh water diatom species obviously increase while the marine plankton species decrease upward. It is composed of 43.0-19.4 % marine plankton, 8.0-16.0 % brackish water and 37.0-55.0 % fresh water. Fresh water species are predominant upwards. *Synedra* spp. and *Aulacoseira granulata* are abundant and increase appreciably while *Coscinodiscus nodulifer, C. radiatus, Cyclotella caspia, C. styrolum* occur with low frequency. This indicates a fresh-brackish water habitat.

**Sediment facies**

On the basis of combining lithological units, divisions of diatom and foraminifer, and $^{14}C$ ages, the sediment facies of the VL1 core are interpreted as follows (Fig.2):

*Undifferentiated late Pleistocene sandy silt facies*

This facies is in the lowest part of the core and coincides with unit L1. It is composed of stiff, slightly oxidized, yellowish grey silty sand and fine-medium sand bearing scattered quartz pebbles and laterite. Parallel laminae and lenticular sands are identified. Colors of the sediment materials suggest an oxidation and a weathering condition. It could suggest a non-marine environment, the deposits exposed and have been strongly weathered and eroded.

*Sandy lag facies*

This facies corresponds to unit L2. It is mainly consisted of yellowish-colored, poorly sorted pebbly sand and pebbles. The grain size texture decreases upward. The mixture of the terrigeneous materials such as laterite pebbles and marine shells as well as the age of overlying facies indicate the deposition under transgressive phase. It could be interpreted transgressive sandy lag facies and gradually changes to the overlying open bay mud facies.

*Open bay mud facies*

This facies mainly consists of homogeneous greenish grey mud in a fining-upward succession. It coincides with unit L3 and the lower part of unit L4. Massive bioturbated clay with discontinuous parallel laminae and parallel laminae are present in the upper part. The silty clay to clay in lithology and intensive bioturbation represent deposition under low energy conditions. Small shell fragments, foraminifera and sponge spicules are scattered. The sediment corresponds to the diatom division D1 and D2. Marine plankton species are predominant and reach 65-68 %. Marine plankton species such as *Coscinodiscus radiatus*, *C. nodulifer*, *Thalassiosira excentrica* and especially *Thalassionema nitzschioides* are abundant. Shell fragments from -33.66 m indicate an age of 6,111 cal yr BP. This suggests that this facies is open bay mud facies.

*Pro-delta mud facies*

This facies corresponds to the upper part of unit L4. It consists of dark grey silty clay and very fine sand. Very thin parallel laminae are common. Wavy and lenticular beddings are in the middle and lower parts . The increase of organic materials suggest the effect of terrigenous material due to deltaic progradation. This sediment is correlated with diatom division D3 in which marine plankton species are less abundant. Brackish-water species increase measurably and fresh-water species gradually increase upward. *Coscinodiscus radiatus, C. nodulifer* and *Thalassiosira excentrica* are abundant. *Thalassionema nitzschioides* decreases in individual. Brackish-water species such as *Paralia sulcata* and *Cyclotella caspia* and fresh-water such as *Synedra* spp., *Stephanodiscus astrea* and *Aulacoseira granulata* are common. All indicate that a marine habitat has been effected by brackish and fresh-water sources. Plant fragment from -18.6 m gave an age of 4,628 cal yr BP. These data may interpret this is pro-delta mud facies.

*Delta front sandy silt facies*

This facies coincides with unit L5, mainly consists of intercalated greenish grey silt, sandy silt and fine sand in a coarsening-upward succession. The coarsening-upward succession indicates deltaic sediments. Parallel laminae, current ripples, wavy bedding and lenticucular bedding are common. Organic materials are condensed in the thin layers and become more common upward, but burrows and bioturbations decrease upward. The sediment corresponds to diatom division D4 in which marine plankton species are still abundant, brackish-water species decrease but fresh-water species obviously increase. *Coscinodiscus radiatus, C. nodulifer, Thalassiosira excentrica, Cyclotella caspia, Aulacoseira granulata* and *Synedra* spp.

are common. *Thalassionema nitzschioides, Cyclotella striata* and *Stephanodiscus astrea* occur with low frequency. This indicates an increasing in influence of fresh water. Three plant fragments collected from -13.8 m, -9.96 m and -7.94 m indicate ages of 3,794 cal yr BP, 3,622 cal yr BP, and 3,636 cal yr BP. It could be interpreted as a deltafront deposit.

*Sub- to intertidal flat sandy silt facies*

This facies coincides with unit L6 and consists of dark grey sandy silt and fine sand in a fining-upward succession. Parallel laminae are common. Wavy bedding is common in the lower part, current ripples and discontinuous parallel laminae occurred in the middle and upper parts. Organic matter and rootlets are common in the uppermost part. Bioturbation and burrows markedky decrease upward. The sediment is coincides with diatom division D5 which shows marine plankton and brackish-water species gradually decrease while fresh-water species obviously increase in comparison with the underlying delta front sandy silt facies. *Coscinodiscus nodulifer* and *Synedra* spp. are abundant. *Coscinodiscus radiatus, Thalassiosira excentrica, Cyclotella caspia, C. striata* and *Stephanodiscus astrea* are common. It indicates a marine-brackish water habitat. It could be interpreted as sub- to intertidal flat sandy silt facies.

*Subaerial delta plain facies ( marsh/floodplain)*

This facies coincides with unit L7 consisting of a homogeneous mixture of grayish brown silty clay with rich organic matter, rootlets and mica flakes. On occasion, thinly laminated silt is present, brought in during floods. Gypsum and jarosite are crystallized on the surface of dried samples. Lithology is similar swamp deposit (Reineck and Singh, 1980). It can be correlated to diatom division D6 that shows fresh-water diatom species obviously increase while the marine plankton species decrease upward. Fresh-water species are predominant. *Synedra* spp. and *Aulacoseira granulata* are abundant and increase appreciably while *Coscinodiscus nodulifer, C. radiatus, Cyclotella caspia, C. striata* occur with low frequency. This indicates a fresh-brackish water habitat. This facies is interpreted as subaerial delta plain facies ( marsh/floodplain). A plant fragment from +0.45 m indicates an age of 3,425 cal yr BP.

**Sea level change and sediment facies**

The sediments from the VL1 core are 35m thick and represent the Holocene succession overlying weathered Pleistocene sediments. The formation of sediment facies responds to the sealevel changes. Estimation of the last Glacial low stand of sea-level is about -120 m in Southeast Asia at around 18,000 to 20,000 $^{14}$C yr BP. [1, 5]. Most of the Sunda Shelf area was subaerially exposed and formed shelf-wide regressive incisions. The basement strata are oxidized facies of Late Pleistocene sediments that were recovered in the VL1 core. Since the last Glacial episode, sea level has risen rapidly. The soft homogenous mud, about 15 m thick, is characterized by abundant marine planktonic diatoms. The sedimentary succession indicates that a maximum transgression occurred at about ca. 5,000 cal yr BP in the VL1 core. That correlated with the maximum Holocene transgression in the Bentre province [3, 4]. These data coincide with the maximum Holocene transgression at around 5,000 $^{14}$C yr BP, with sea level + 3.5m above the present level [2]. Thus, this is the evidence of the existance of Holocene transgression in VinhLong area.

The subsequent regression was caused by the combined effect of sea-level fall and high sediment supply. A deltaic succession of pro-delta, delta front and subaqueous delta plain deposits suggest a regressive stage in the core, and its age is estimated to be 4,000 to 3,000

yr cal yr BP based on the $^{14}C$ ages. The sub-to-intertidal flat and floodplain sediments in the uppermost part of the core complete the regressive sedimentary succession.

**Relationship between accumulation rate and sediment facies**

The accumulation rate and sediment facies are closely related. At the VL1 site, accumulation rates were high at 11.7 to 13.4 mm $y^{-1}$ in the open bay from 6 to 4.8 ka; 7.0 mm $y^{-1}$ in the prodelta from 4.8 to 3.8 ka, and 38.6 mm $y^{-1}$ in the delta front from 3.8 to 3.6 ka. That indicates a low accumulation rate in the prodelta facies and a high accumulation rata in the delta front facies.

**Conclusion**

This paper provides a detailed description of sedimentary structures, diatom flora, and $^{14}C$ ages obtained from a 42m-long sediment succession from the VL1 core in the Mekong River Delta. Based on these analyses, seven sediment facies were recognized in relation to sea-level changes since the latest Pleistocene.

The presence of an open bay mud facies, indicative of marine influence resulting from the Holocence transgression, was at a maximum at around ca. 5,000 cal yr BP at the VL1 site. The predominance of marine planktonic diatom species *Coscinodiscus radiatus*, *C. nodulifer*, *Thalassiosira excentrica* and *Thalassionema nitzschioides* obtained from the open bay mud facies is clear evidence of the maximum Holocene transgression. The subsequent regression appears as an upward shallowing sedimentary succession ranging from prodelta, through delta front, and sub- to inter-tidal flat to floodplain in the core.

$^{14}C$ ages from the core indicate that the accumulation rates were closely related to the sediment facies: low rate for prodelta facies, high rate for delta-front facies.

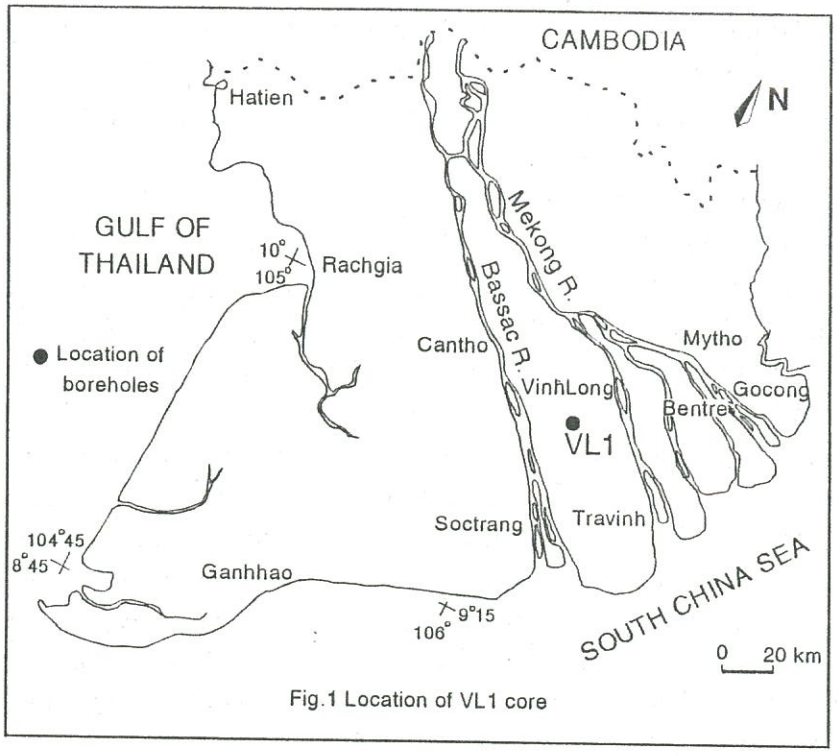


Fig.1 Location of VL1 core

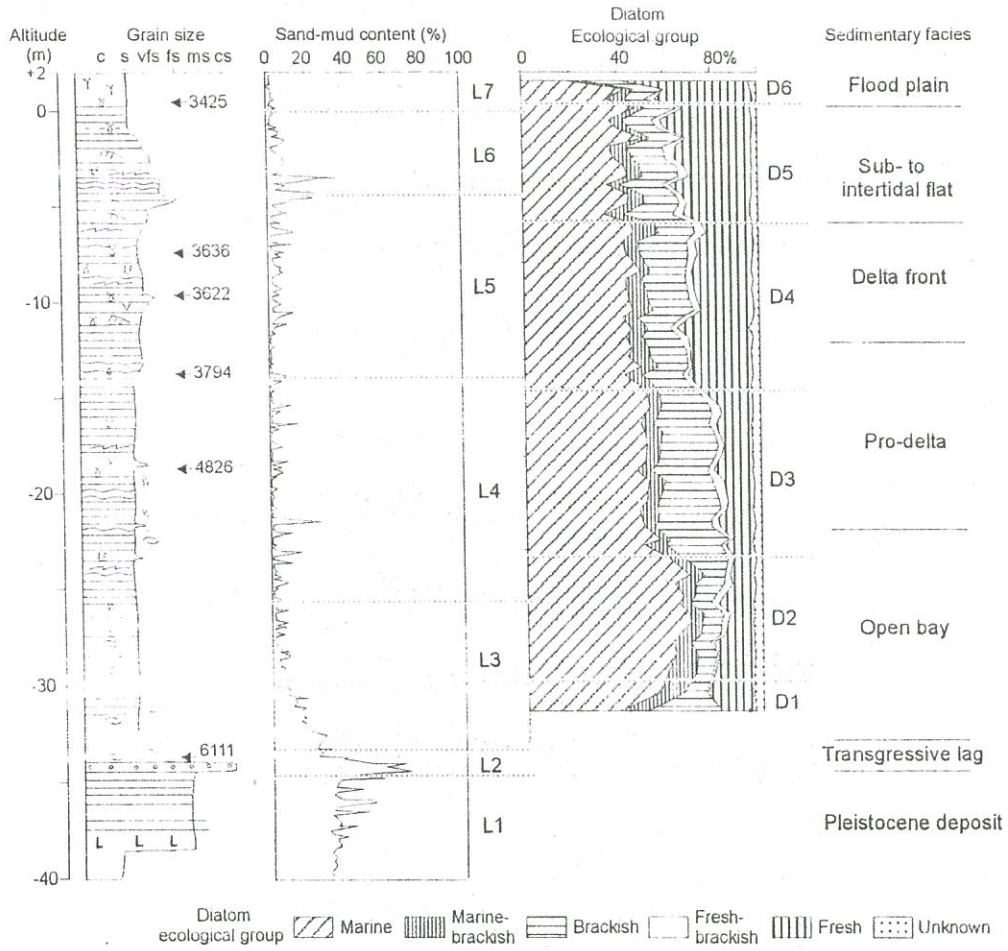


Fig. 2 Sedimentary facies of VL1 core

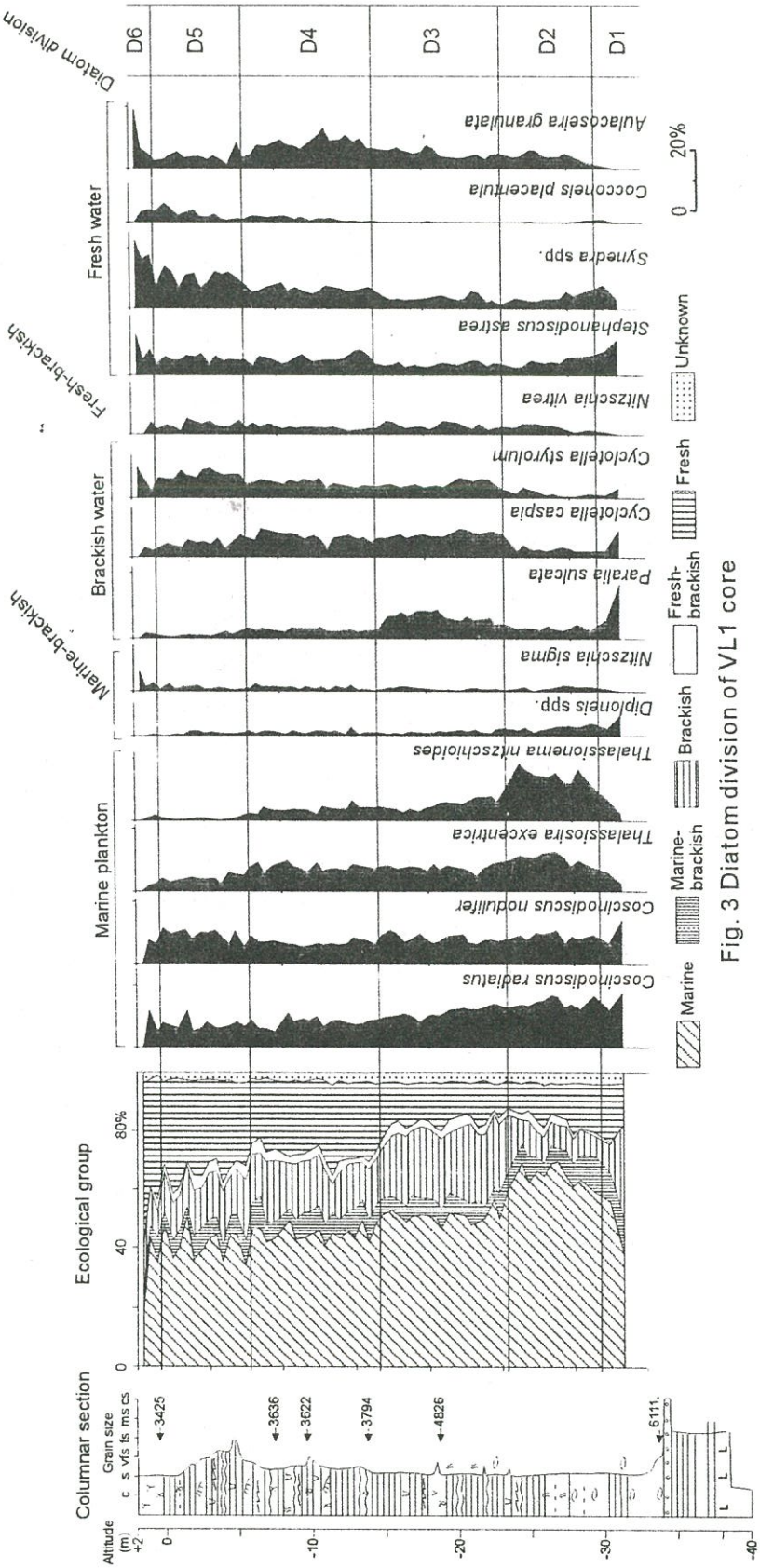


Fig. 3 Diatom division of VL1 core

# TƯỚNG TRẦM TÍCH VÀ CHỨNG CỨ BIỂN TRÀN HOLOXEN GIỮA TRONG LỖ KHOAN VL1, ĐỒNG BẰNG SÔNG CỬU LONG

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**TÓM TẮT:** Kết quả phân tích tướng trầm tích, tảo silic và tuổi tuyệt đối $^{14}C$ của lỗ khoan VL1 (42 m) là một trong những tài liệu cơ bản góp phần nghiên cứu trầm tích Đồng bằng sông Cửu Long. Lỗ khoan này được phân chia ra 7 tướng trầm tích trên cơ sở đặc điểm trầm tích, phức hệ tảo silic và tuổi tuyệt đối $^{14}C$. Các tướng trầm tích này được thành tạo từ giai đoạn biển tràn đến biển lùi tương ứng với sự thay đổi mực nước biển vào giai đoạn cuối Pleixtoxen-Holoxen.

Biển tràn sau thời kỳ băng hà làm mực nước biển dâng thành tạo trầm tích bùn vịnh biển. Tướng trầm tích biển này có chiều dày khoảng 10 m, được đặc trưng bởi tảo silic phù du phong phú, là bằng chứng của biển tràn Holoxen 5.000 năm trong lỗ khoan VL1.

Chuỗi trầm tích biển lùi tiếp theo gồm các tướng trầm tích tam giác châu: prodelta, delta front, tam giác châu dưới nước và đồng lụt. Tuổi tuyệt đối $^{14}C$ cho thấy prodelta và delta front hình thành tại lỗ khoan VL1 vào khoảng từ 4000-3600 năm trước hiện tại. Tốc độ tích tụ liên quan chặt chẽ với tướng trầm tích: prodelta có tốc độ trầm tích thấp còn delta front có tốc độ trầm tích cao.

## REFERENCES

[1] Hanebuth, T., Stattegger, K., Grootes, P.M., 2000. Rapid flooding of the Sunda Shelf: a late-Glacial sea-level record. Science 288, 1033-1035.

[2] Nguyen, V.L., Ta, T.K.O., Tateishi, M., 2000. Late Holocene depositional environments and coastal evolution of the Mekong River Delta, Southern Vietnam. Journal of Asian Earth Science 18, 427-439.

[3] Ta, T.K.O., Nguyen, V.L., 2000. Diatom-indicator of sedimentary environments and sea-level changes in late Pleistocene-Holocene. Journal of Science of the Earth 22, 226-233 (in Vietnamese with English abstract).

[4] Ta, T.K.O., Nguyen, V.L., 2002. Latest Pleistocene-Holocene deposits and progradation of the Mekong River Delta in Ben Tre area. Journal of Science of the Earth 24, 103-110 (in Vietnamese with English abstract).

[5] Woodroffe, C.D., 1993. Late Quaternary evolution of coastal and lowland riverine plains of Southeast Asian and north Australia: an overview. Sedimentary Geology 83, 163-175.