

Sequence stratigraphy of Quaternary depositions on the land and at the continental shelf of Vietnam

Tran Nghi*, Dinh Xuan Thanh, Tran Thi Thanh Nhan, Nguyen Dinh Thai

College of Science, VNU

Received 8 April 2009; received in revised form 14 April 2009

Abstract. The sequence stratigraphy units of the Quaternary sediments at the continental shelf of Vietnam have been compared with the lithofacies and depositional cycles in relation to sea level changes. During the regression phases corresponding to the lowstand systems tract has being formed the alluvial lithofacies, shelf deltaic complex and shelf edge fans complex. The maximum regression remarked by erosion boundaries has corresponded with the lowstand sea level characterized by the slope fan turbidite complex. The transgression phase has led to form the ravinement surfaces and the transgressive systems tract deposits for the end of each sequence (depositional cycle).

Keywords: Lowstand sea level; Highstand sea level; Lowstand system tract; Transgressive system tract; Highstand system tract; Deep water turbidite; Progradation; Healing phase.

1. Introduction

So far, the Quaternary stratigraphy, lithofacies - paleogeography, sea bottom sediments, depositional cycles in relation to sea level changes and tectonic movement,... have been carried out by Tran Nghi, Trinh The Hieu, Nguyen Bieu (1991 - 2008).

The types of data used for analysis are based on the following principles:

- The lithologic composition, thickness of Quaternary formations in the continental shelf of Vietnam are related with the sea level changes and tectonic movements.

- The Quaternary sediments have cyclic composition (granulometry, mineralogy, petrology, geochemistry, environmental geochemistry, especially lithofacies associations). The boundaries of cycles have

been divided based on fluvial erosion surface of transgressive system tract (Vinh Phuc formation) was typically remarked by the spotted yellow - red lateritized.

- The principles of the sea level fluctuation during Quaternary period are the older the shoreline (marine terraces) the higher it is (if it is on land) and the deeper it is (if it is at the sea bottom).

2. Sequence stratigraphy of Quaternary sediments

2.1. Lower Pleistocene sediments (Q_1^1)

In fact the lower Pleistocene sediments (Q_1^1) has corresponded with a sequence bounded by erosion fluvial surface at the base and marine flooding surface on the top. Upward the section of a sequence there are 3 systems tract.

- Lowstand systems tract (LST) (fig. 1,2)

* Corresponding author. Tel.: 84-4-38542489.
E-mail: tranngghi@vnu.edu.vn

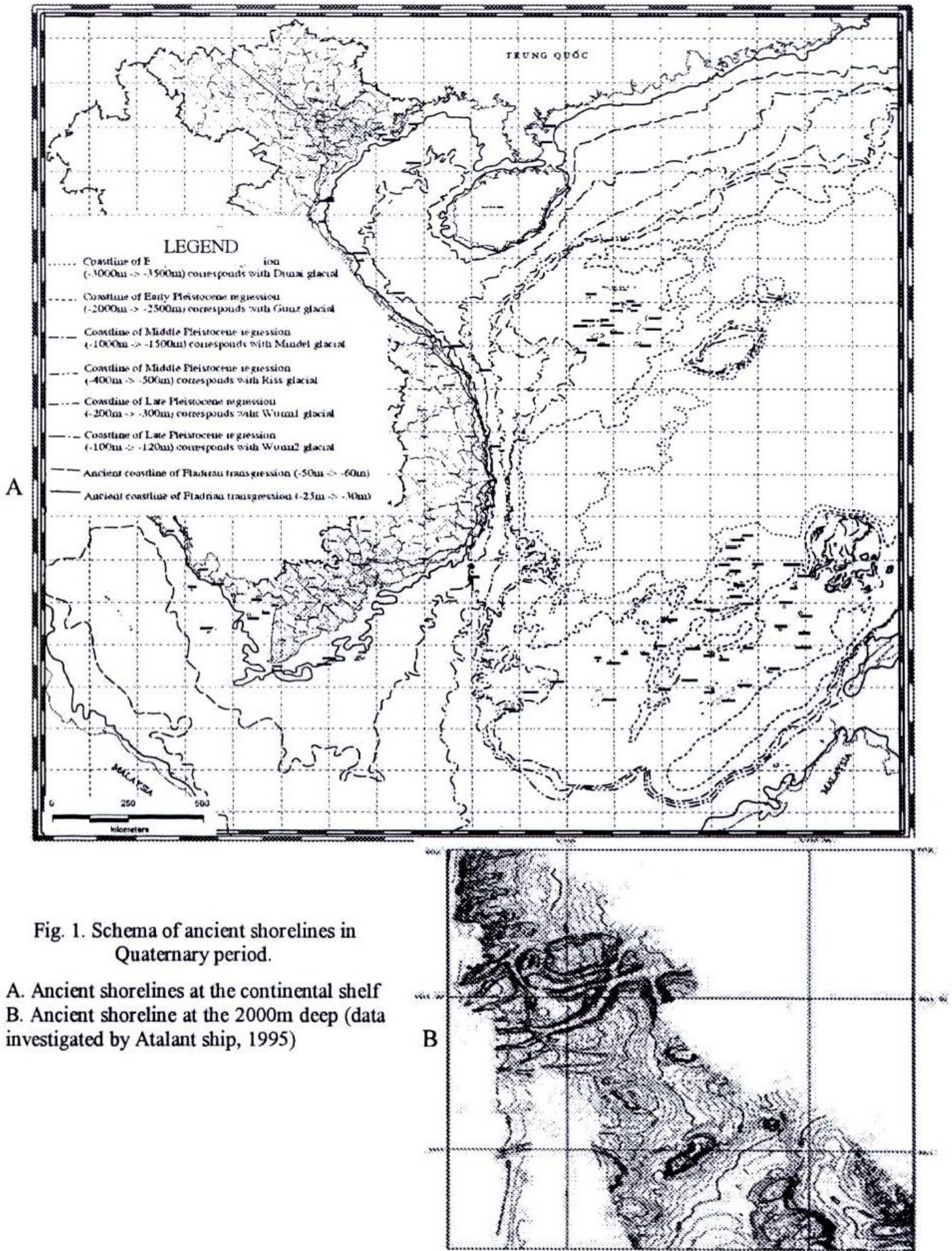


Fig. 1. Schema of ancient shorelines in Quaternary period.

A. Ancient shorelines at the continental shelf
 B. Ancient shoreline at the 2000m deep (data investigated by Atalant ship, 1995)

The river channel cobble layer corresponds with the regression phase (sea level fall) influenced by Gunz Glacial overlying the cobble formation is a flood plain silt – clay layer. In fact lowstand systems tract have been varied from the mainland to the continental shelf area following to moving of older shoreline during sea level fall (fig.1, tab.1). Anyway the granulometric variation upward from the base to the top of LST situated on land as well as in the sea level is finer grain size.

For the lowstand sea level, on the continental shelf of Vietnam, the shoreline has been found at the depth of 2000 – 2500m. The sea bottom sediments have composed of

volcanic rock fragment, gravels, sands and lime, clay solitic muds, which have been constituted by turbidite constructure (fig.1,2).

- Transgressive systems tract (TST)

Transgressive systems tract has composed of deltaic, shallow sea silty – clay facies distributing following the movement of older shoreline from 1500m deep water (present deep) to coastal plains. In the continental shelf area it is clear to discover the boundary between lowstand systems tract and transgressive systems tract [1,2]. The base of transgressive systems tract sediments composed of coarse grain size composition of rounded fragments of laterite, quartzs and rocks.

Table 1. Comparison of chronostratigraphy, sequence stratigraphy lithological units, depositional cycles and lithofacies of Quaternary deposits of Vietnam

Chronostratigraphy		Sequence stratigraphy units	Lithological units	Depositional cycles		Sea level changes	Depositional environments	
Age	Symbol			On land	Sub-marine		On land	Sub-marine
Late Holocene	Q ₂ ¹ 3 ka	TST		5	VI		a	am, m
		LST					am	am
Late Pleistocene to early middle Holocene	Q ₂ ^{2a} 70 ka	HST		4	V		mb, m	m
		TST					a	a, am
Early part of late Pleistocene	Q ₂ ^{2b} 125 ka	LST		3	IV		am	am
		HST					m, am	m
		TST					a	a, am
Late part of middle Pleistocene	Q ₂ ^{2c} 700 ka	HST		2	III		am, m	am
		TST					m, am	m
		LST					a	a, am
Early part of middle Pleistocene	Q ₂ ^{2d} 700 ka	HST		1	II		am	am
		TST					m, am	m
		LST					a	a, am
Early Pleistocene	Q ₁ ¹ 1600ka	HST		1	I		am	am
		TST					m, am	m
		LST					a	a, am

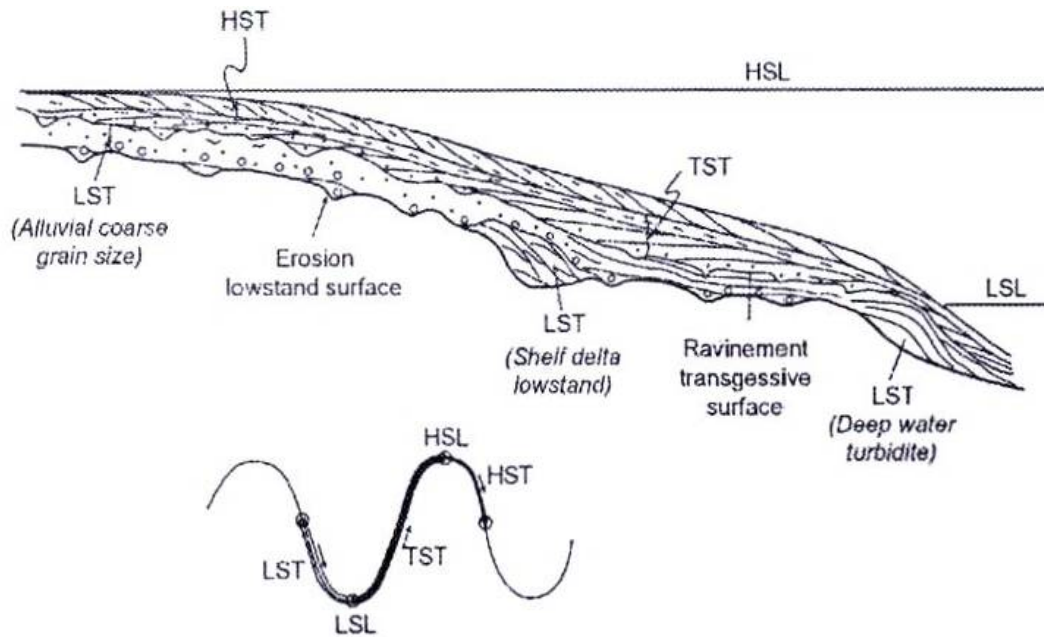


Fig. 2. Sequence stratigraphy units.

The upper part of the transgressive systems tract is lagoonal greenish grey clay layer at the Red river plain, Cuu Long river plain and central plains corresponding with the highstand sea level stage.

2.2. Middle Pleistocene sediments (Q_1^2)

- Lowstand systems tract: During the sea level fall may be influenced by the Mindel – Riss glaciations. On the coastal plains occurred a regression phase making an fluvial erosion surface with river channel filled by coarse grain size sediments. This unconformity continues to develop as long as relative sea level continues to fall and the coastal onlap remains a zone of non-deposition [4] (fig.1,2,3).

- The Middle Pleistocene cobbles and gravels of alluvial facies belonging to lowstand sea level overlie with unconformity the highstand systems tract deposits of lower Pleistocene sequence.

- Transgressive systems tract deposits were characterized by the cement grey silty clay of

estuary facies at the Red river, Cuu Long river plains and sandy bars formation. According to the results of quartz thermoluminescent dating of the sample collected at Suoi Tien, Mui Ne, Phan Thiet shows that the absolute age of Middle Pleistocene red sand is of more than 204 Ka (Tran Nghi, 1997, 1999).

- Highstand systems tract deposits have been found the margin plain terrace at the 20 - 25m high above present sea level which composed of deltaic grey silty sand facies.

2.3. Upper Pleistocene sediments (Q_1^{3a})

- Lowstand systems tract deposits:

The beginning of the late Pleistocene epoch was corresponded with regressive phases influenced by the glaciations of Würm 1. The eroded alluvial surface filled by coarse grain size sediment has been corresponded with lowstand sea level showing at the depth of 200 - 300m. This is an ancient shoreline zone characterized by lithofacies and geomorphology (fig. 1,3).

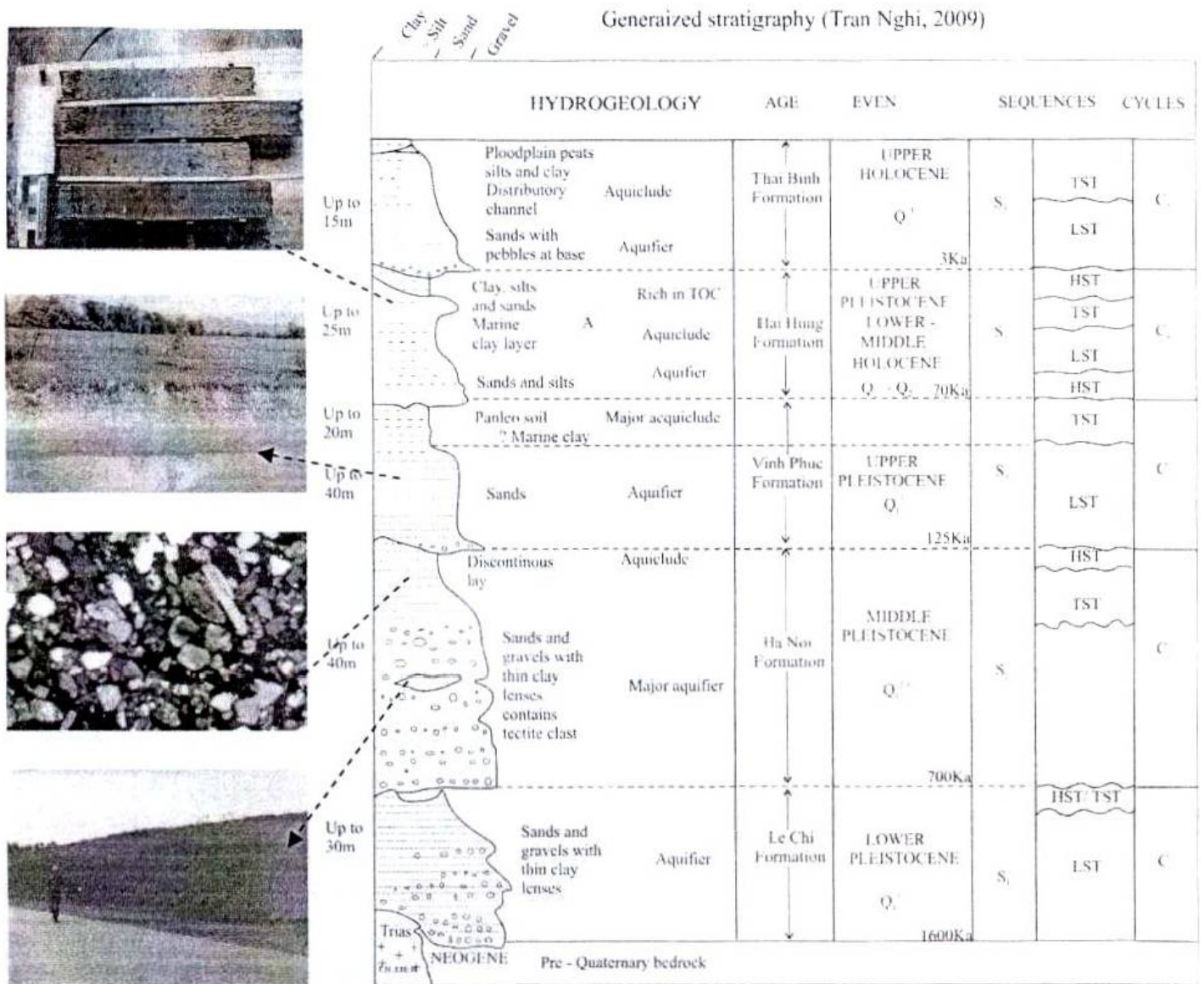


Fig. 3. Sequence stratigraphy units of Quaternary deposits at the Red river.

- Transgressive systems tract deposits:

After Würm 1 (Q₁^{3a}) there was a period of very strong transgression of global character that was named “Vinh Phuc” transgression. These sediments were characterized by the deltaic swamp mud facies (low part) and the lagoonal shallow sea silty clay facies extending from the continental shelf to the mainland coastal plains [3] (fig.4).

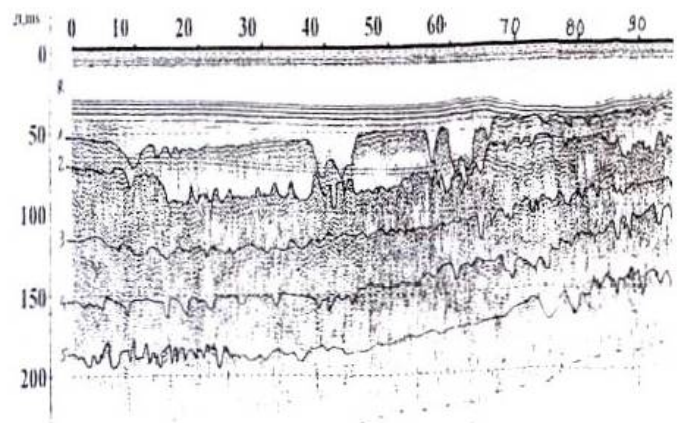


Fig. 4. Seismic profile showing fluvial eroded surface (lowstand sea level) and transgressive systems tract.

Corresponding to the above mentioned lithofacies at the Central Vietnam occurred to

form the sandy bars and Tombolo associated with bay-lagoonal mud facies [4] (fig.5).

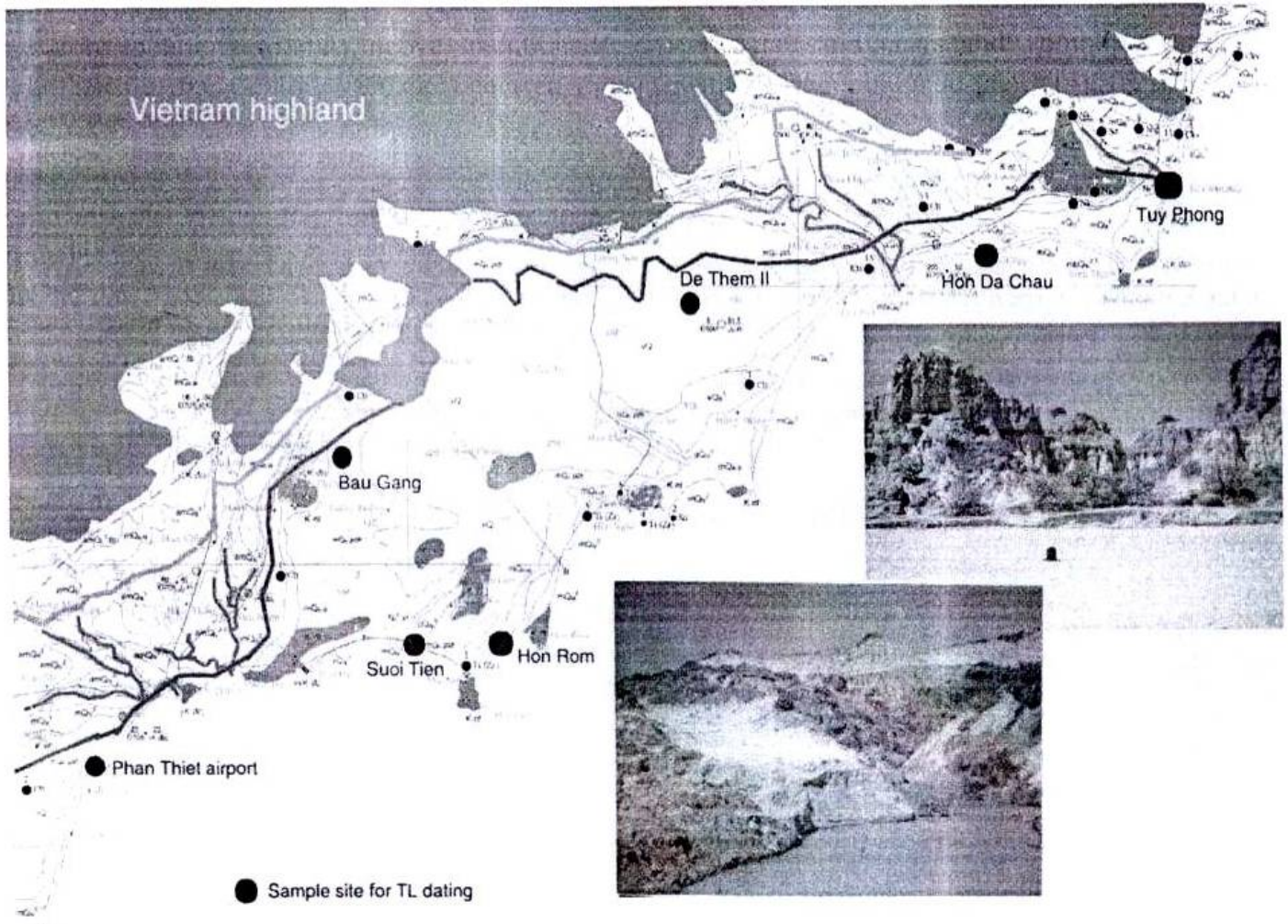
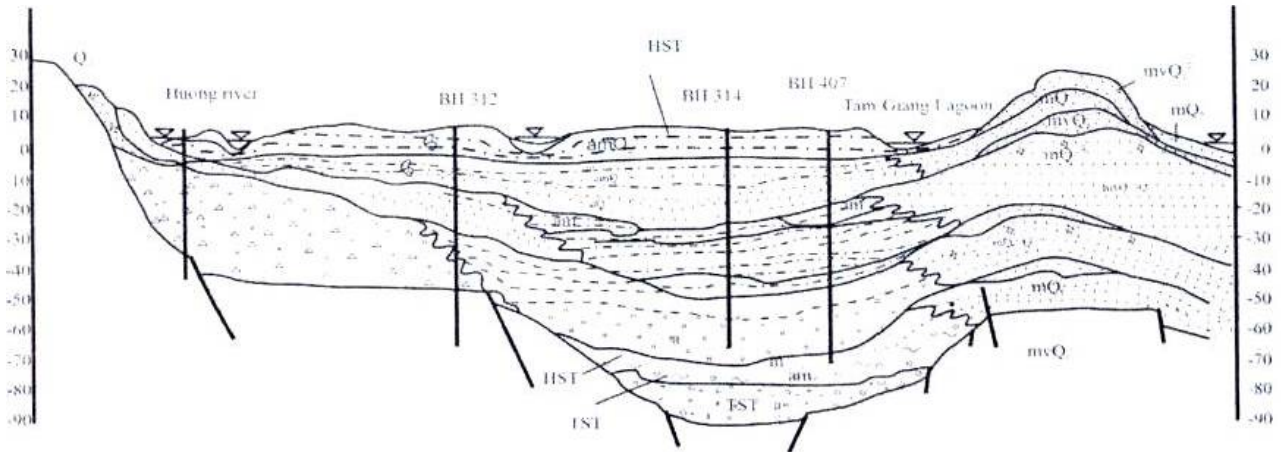


Fig. 5. The section of sandy sequences.

Highstand systems tract deposits overlying on the top of the marine flooding surface composed of the deltaic sand – silty clay which has been deposited together with sea level fall.

2.4. The upper Pleistocene to Lower-Middle Holocene deposits (Q_1^{3b} - Q_2^{1-2})

This epoch was subjected to 2 sea level changes phases: regression influenced by Würm 2 glaciation and Flandrian Transgression.

- Lowstand systems tract deposits (Q_1^{3b})

At the continental shelf of Vietnam may be found old shoreline zone at the depth of 100 - 200m (equivalent to the last glaciations - Würm 2). This period the mainland has been expanded to the main surface of modern continental shelf of Vietnam. The coarse grain size sediments of alluvial lowstand systems tract were distributed along the river valleys. Meanwhile, the others sides it occurred the weathering for the infiltration mechanism of the ground water action causing the motley color of “Vinh Phuc” transgressive systems tract.

- Transgressive systems tract of lower - middle Holocene (Q_2^{1-2})

The transgressive phase “Flandrian” elongated from the lowstand sea level of 100 - 120m deep to the highstand sea level of 4.5 - 5.0m high is characterized by two main lithofacies complexes associating with each other in time and space coastal swamp mud facies (lower part) and liman greenish grey clay facies (upper part).

During the highstand sea level which may be found sea level notches at the limestone kliffs from Ninh Binh, Quang Binh, Ha Long bay areas. Corresponding to the middle Holocene highstand sea level in coastal zone of Central Vietnam has developed the white sandy bars associated with the lagoonal mud facies as

well as the white sandy Tombolos associated with the bay clay mud facies.

- Highstand systems tract of upper Holocene (Q_2^3)

In general, during late Holocene period after the Middle Holocene maximum transgression the deltaic plains were expanded together with the sea level fall.

In coastal of central Vietnam at the same time were formed the sand dunes deposited by the wave activities.

In the present transgression phase (from 1500a B.P to present) with a rate of 1 - 2 mm/a the Quaternary sediments in the coastal zone have been continuously changed in two ways: progradational sediments and erosion. Most of the coast line of Vietnam is being eroded except the coast of the Red river, Cuu long river and Western coast of Ca Mau peninsula where strong sedimentation is going on. Meanwhile, the Bach Dang and Soai Rap estuaries are being destroyed by the rising sea level, deficit of sediments and tectonic subsidence.

3. Conclusions and discussions

1. The methods of geophysical, lithostratigraphic data interpretation, sedimentary cycle analysis and other methods have allowed to delineate sequence stratigraphy units of the Quaternary sediments of the continental shelf of Vietnam which composed of 5 sequences and 15 parasequence sets.

The lower Pleistocene (Q_1^1)

The lower part of Middle Pleistocene (Q_1^{2a})

The upper part of Middle Pleistocene (Q_1^{2b})

The lower part of Upper Pleistocene (Q_1^{3a})

The upper part of Upper Pleistocene to upper Holocene (Q_1^{3b} - Q_2^3)

The Earth sequence corresponding to a sedimentary cycle has composed of 3 parasequence sets and 25 parasequences in with a parasequence was being equivalent to a lithofacies group.

2. There are of 7 older shorelines at the different depths: 2000 - 2500m (Q_1^1); 1000 - 1500m (Q_1^{2a}); 700 - 800m (Q_1^{2b}); 300 - 400m (Q_1^{3a}); 100 - 120m (Q_1^{3b}); 50 - 60m (Q_2^1); 25 - 30m (Q_2^{1-2}).

3. The lowstand systems tract comprise the incised valley fill of the river channel, continental shelf edge lowstand delta complex and deep - water turbidite of 1500 - 2000m deep at the Central Vietnam.

4. The process of forced regression and transgression phase deposits that developed seaward of the last clinof orm of the lowstand progradational units.

References

- [1] G.P. Allen, H.W. Posamentier, *Sequence stratigraphy and facies model of an incised valley fill: The Gironde estuary, France*, Sequence stratigraphy workshop-concepts and applications - January 18-20, 1995, Hanoi, Vietnam, 1995.
- [2] H.W. Posamentier, D.P. James, *An overview of sequence - stratigraphy concepts: uses and abuses*, Spec publs int. Ass. Sediment, 1993 18.3-18.
- [3] D.M. Duc, T. Nghi et al., Sediment distribution and transport at the nearshore zone of the Red river delta, Northern Vietnam, *Journal of Asian Earth Sciences* 29 (2007) 558-565.
- [4] Colin V. Murray-Wallace, Brian G. Jones, Tran Nghi, David M. Price, Vu Van Vinh, Trinh Nguyen Tinh, Gerald C. Nanson, Thermoluminescence ages for a reworked coastal barrier, southeastern Vietnam: a preliminary report, *Journal of Asian Earth Sciences* 20 (2002) 535-548.