

# Late Pleistocene - Holocene seismic stratigraphy of Nha Trang Shelf, Central Vietnam

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## Abstract

*The late Pleistocene - Holocene stratigraphic architecture on the steep and narrow shelf off Nha Trang, Central Vietnam has been explored by high resolution seismic profiles integrated with sediment core data. Sequence stratigraphic results reveal five major seismic units and three bounding surfaces which are composed of two distinctive sequences. Those sequences are bounded by two regional unconformities (SB1, SB2) which have been formed in response to different sea-level regimes during Marine Isotope Stage (MIS) 5e to the Last Glacial Maximum (LGM) period. The revealed relict beach-ridge deposits at a water depth of about ~ 130m below the present water depth indicate that the LGM sea-level in this area was lower than in neighboring areas and probably resulted from subsidence due to a high sedimentation rate and/or neotectonic movements of the East Vietnam Fault System. The late Pleistocene - Holocene high amplitude of sea-level change during a long fourth-order and superimposed by shorter fifth-order cycle is the principal factor in reorganizing the formation of the Nha Trang continental Shelf sequence. Other local controlling factors such as fluctuations in sediment supply, morphological variations of the LGM surface, subsidence rate and hydrodynamic conditions provided the distinctive features of the Nha Trang Shelf sequence stratigraphic model in comparison to neighboring areas.*

## 1. Introduction

The Nha Trang Shelf is located on a passive continental margin (Fig. 1). Following the Last Glacial Maximum (LGM) about 20ky BP (Before Present), the shelf was submerged rapidly due to its narrow and steep gradient during the post-glacial sea-level rise and therefore many older deposits were protected from erosion during the deglacial transgression. Well preserved relict deposits provide an excellent example for testing sequence stratigraphic concepts which are applied worldwide on continental shelves.

Previous studies on Holocene sedimentation on the Vietnamese Shelf has revealed high sediment accumulation rates off Central Vietnam reaching up to 50 - 100cm/ky [30]. It is also indicated that the surface sediments of the inner shelf in this area were dominated by relict sand [1, 13, 34, 35]. Different sand-barrier generations at Hon Gom Peninsula were dated between

BP [12]. Detailed studies on the late Quaternary sequence stratigraphy on the nearby shelf were concentrated on the central Sunda Shelf [18, 19, 20].

Results of sequence stratigraphy on the Central Vietnam Shelf were mainly focused on the offshore Cenozoic basin evolution and hydrocarbon potential [16, 23], but the late Quaternary sequence stratigraphy on the Central Vietnam Shelf was not investigated in detail. In this research, we will apply the concept of sequence stratigraphy to the interpretation of shallow seismic high-resolution profiles on the Nha Trang Shelf (Fig. 1). The general aims of this study are therefore to:

- + Analyze the late Pleistocene - Holocene seismic stratigraphic architecture.
- + Reconstruct the late Pleistocene - Holocene evolution of the shelf and propose a general sequence stratigraphic model.

+ Compare the Nha Trang Shelf to other sequence stratigraphic models to distinguish local controlling factors.

**2. Regional setting**

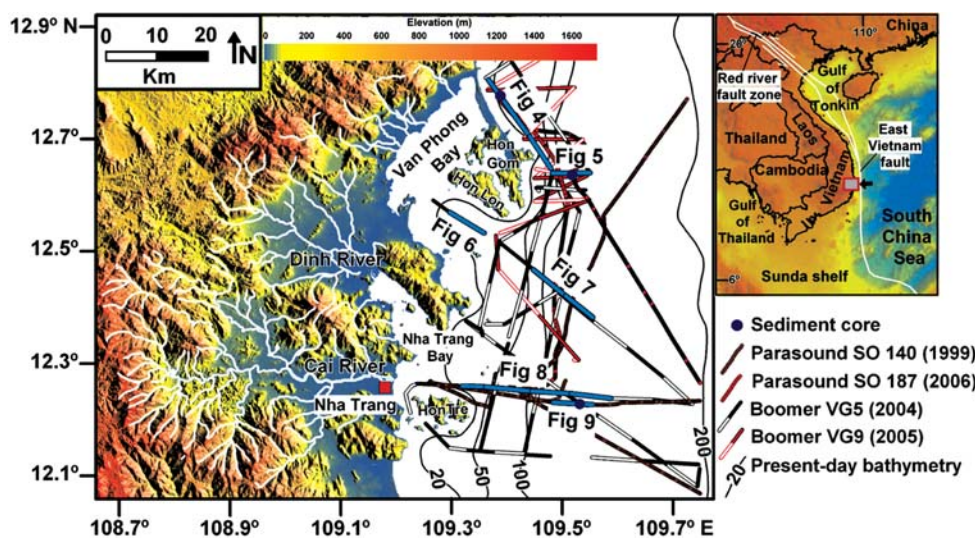
The Nha Trang Shelf is bordered by the Vietnamese coastline to the West and the East Sea (SCS) to the East (Fig. 1). The continental shelf is narrow and separated from the deep East Sea by the N-S directed East Vietnam Fault System on the continental slope and rise (Fig. 1). This fault system is generally considered to be the Southward extension of the Red River strike-slip fault zone and runs almost parallel to the shoreline along the 110° - longitude [11, 16, 23]. The continental shelf of the study area is 40km wide on average, steep in the middle and gentle in the inner-outer shelf (Fig. 1). There are two bays in the study area: Van Phong in the Northern and Nha Trang in the Central part. The climate and hydrodynamic conditions of the study area are driven by the East Asian monsoon system with winds mostly from the NE during winter (October to March) and the SW during summer (April to September) [27]. Most of the sediments are supplied to the shelf by numerous small and short rivers which drain the high relief with maximum elevation of 2,000m (Fig. 1). Estimated total suspended sediment load of all small rivers in the study area ranges from 1.7 - 4 × 10<sup>6</sup> ton/year, of which the Cai and Dinh Rivers account

for about 90% [5]. About 70% of supplied sediments are transported to the shelf during short periods of the rainy season (September to December) and 30% in the dry season (January to August). Long-term monitoring data (1985 - 1995) collected in Nha Trang station indicate an average temperature of 27°C and average rainfall of 96.7mm/month. The study area is dominated by a semi-diurnal to diurnal tide regime with amplitude of 0.4m in neap and 2.5m in spring tides [27, 34]. Average wave height in this area ranges from 0.5m and 2.0m during fair-weather and can reach up to 7.5m during storm conditions [38].

**3. Methods and available data**

About 620km of 2D high resolution seismic profiles have been analyzed on the Nha Trang Shelf (Fig. 1). Those data have been collected at the beginning of the SW monsoon season (April and May) during different cruises in the framework of the Vietnamese - German cooperation project: SO 140 [41], VG5 (2004), VG9 (2005), SO187 [42]. Seismic data were acquired with two different sound-sources: boomer and parasound. Since the objective of the research concentrates on the continental shelf, most of the profiles are located at water depths between 20 and 200m (Fig. 1). The boomer system (EG & G Uniboom) is a single channel system which includes an electrical energy supplier and an electromagnetic

transducer that transforms the discharged energy to electro-dynamic acoustic pulses. During the surveys, the transducer of the boomer source was employed in a catamaran that was towed along with a hydrophone-streamer receiver (with 8 hydrophones) astern of the vessel. The average speed of the vessel was 4 knots. The boomer source regularly produced from 2 - 2.67 shots per second at 150 Joules. The main working frequencies of the system range between 0.3 - 11kHz resulting in a typical penetration of 20 - 100m below the seabed



**Fig. 1.** Map of Nha Trang Shelf with modern bathymetry and available data (seismic profiles and sediment cores). Locations of geological faults adapted from Fyhn et al (2009) and Clift et al (2008). Elevation data of the land part is extracted from Shuttle Radar Topography Mission (SRTM) digital elevation models (<http://srtm.usgs.gov>).

depending on the acoustic impedance (product of velocity and density) of the sediments. The sound waves were reflected when reaching the reflection surfaces which are regarded as acoustic-impedance contrast boundaries. The hydrophone-streamer received the pressure reflection signals and converted them into voltage responses before transmitting them to the computer. Seismic traces were digitally recorded and displayed using NWC software. A GPS (Global positioning system) was used to guarantee the accurate positions of the recorded seismic traces. Parasound is a hull-mounted system which combines a narrow beam echosounder with a sub-bottom profiler. The system is operated with a fix primary frequency of 18kHz and a secondary primary frequency variable from 20.5 - 23.5kHz. Both primary frequencies are transmitted simultaneously in a narrow beam (~5°) and the constructive interference of these frequencies (parametric effect) allows to generate a working frequency (secondary frequency) within the beam of 2.5 - 5.5kHz [17]. In our research, the parasound data was collected with secondary primary frequency of 22kHz resulting in secondary working frequency of 4kHz. The data was digitally recorded and sampled at a frequency of 40kHz. Navigation data were supplied by the ship's GPS.

For data processing, the frequency high/low pass filtering has been applied for the recorded data. The frequency band - pass filtering of 2.5 - 6kHz for parasound and 0.5 - 7kHz for boomer data are applied for all seismic profiles on the Nha Trang Shelf. The interpreted seismic surfaces are then picked with the software Kingdom Suite SMT 8.4. Average sound velocity of 1,500m/s in sea water and 1,550m/s in subsurface sediments has been assumed for Two-way travel time (TWT) - depth conversion. The seismic data are interpreted on the basis of the sequence stratigraphic concept which was initiated by Mitchum and Vail [26], Vail [49], and then further refined by numerous authors. The seismic units are distinguished from each other by their reflection continuity, amplitude, frequency and configuration (Fig. 2).

Besides, the termination patterns of the seismic reflectors at the bounding surface as toplap, onlap, offlap, downlap and truncation (Fig. 2) are also important

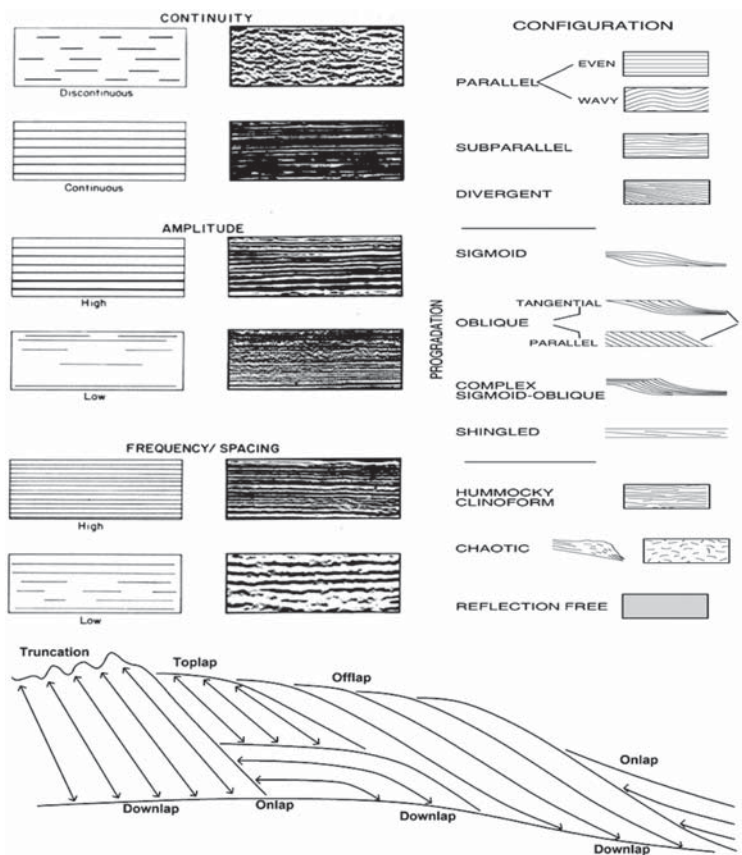


Fig. 2. Classification of seismic facies and related depositional environments adapted from Badley (1985), Vail (1987), Catuneanu (2002) and Veenken (2007)

criteria for identifying depositional trend [8]. The interplay between base level changes (combined effect of eustasy, tectonics, sediment compaction, and environmental energy) and sedimentation rate controls the formation of sequence systems tract (Fig. 3). For simplicity (by neglecting the energy of waves and currents), the base level is equated with the sea level [8]. Hence, the concept of base level change is identical with the relative sea-level change. Accommodation is defined as the space available for sediments to accumulate and its variations depend on base level changes. In this research, we apply the four-fold division of systems tract to divide the sedimentary architecture into different stages in relation to sea-level fluctuations [8, 9]:

- + Falling stage systems tract (FSST) is formed entirely during the stage of relative sea-level fall (forced regression) and it occurs independently with ratio between sedimentation rate/accommodation spaces.

- + Lowstand systems tract (LST) is formed during sea-level lowstand and slow sea-level rise when the rate of rise is lower than the sedimentation rate (normal regression).

+ Transgressive systems tract (TST) is formed during the stage of relative sea-level rise when the rate of rise is higher than the sedimentation rate.

+ Highstand systems tract (HST) is formed during the late stage of relative sea-level rise and when the rate of rise is lower than the sedimentation rate.

#### 4. Results

##### 4.1. Sequence stratigraphic analysis

In general, five seismic units and three major bounding surfaces are identified on the seismic profiles. The seismic units and their reflection configurations are summarized in Table 1.

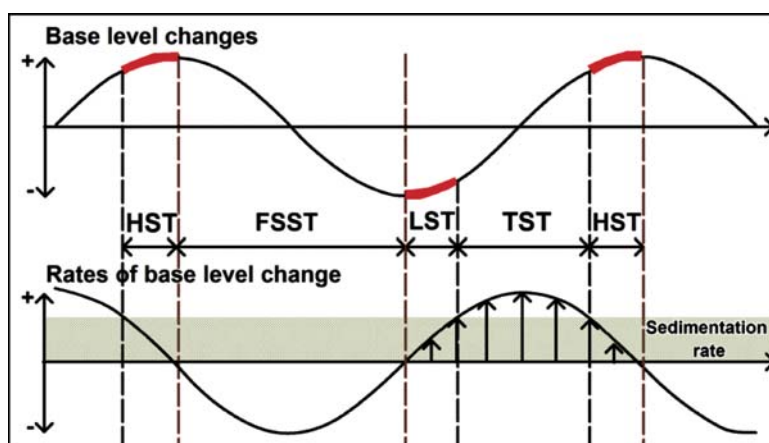


Fig. 3. Sequence stratigraphic systems tracts as defined by the interplay between base level changes and sedimentation rate (modified from Catuneanu 2002). For simplicity, the sedimentation rate is kept constant during the base level fluctuations

Table 1. Summarize of seismic unit, reflection patterns and interpretation systems tracts on the Nha Trang Shelf. Abbreviation: FSST = Falling state systems tract, LST = Lowstand systems tract, TST = Transgressive systems tract, HST = Highstand systems tract

	Systems tract	Seismic units	Acoustic facies and configuration	Occurrence	Thickness (m)	Seismic image
Sequence 1	HST	U4	Low to moderate amplitude, variable frequency, medium continuity, locally transparent, parallel to sigmoid downlap	The entire shelf	0-25	
	TST	U3	Moderate to high amplitude, high frequency, high continuity, backstepping onlap, aggradation	The entire shelf	0-50	
	LST	U2	Moderate to high amplitude, variable frequency, high continuity, oblique tagential downlap, toplap	Outer shelf	20	
Sequence 2	FSST	U1	Moderate to high amplitude, high frequency, high continuity, oblique parallel downlap, toplap truncated	Outer shelf	20	
	HST+TST	U0	Low to moderate amplitude, transparent, parallel	The entire shelf	0-15	

- Major bounding surfaces:

+ SB1 is marked by high continuous and strong amplitude reflectors on seismic profiles (Figs. 4 - 9). This surface can be traced across shelf (20 - 140m deep).

+ The SB2 surface is the lowest reflection surface recorded on seismic profiles. It is presented as high continuous and strong amplitude reflectors (Figs. 4 - 9). Landward, it is mostly merged with the upper SB1 surface. However, this surface can be traced occasionally on the inner shelf where it is crossed by the SB1 surface as channel incision (Fig. 6).

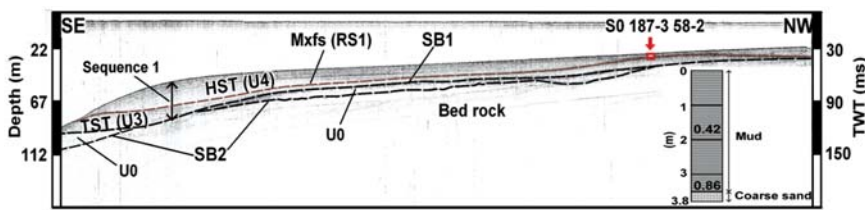
+ RS1 is first surface which appears below the modern seabed (Figs. 4, 5, 7 and 8). It is characterized by medium but continuous reflectors on the mid and outer shelf.

On the mid-shelf, the RS1 surface is clearly defined on seismic profiles as the boundary of the lower backstepping onlap and upper seaward downlapping reflectors (Figs. 8). Toward the outer shelf, the RS1 surface is locally identified as a strong amplitude reflection surface resting on the lower concave-up reflection layer (Fig. 5).

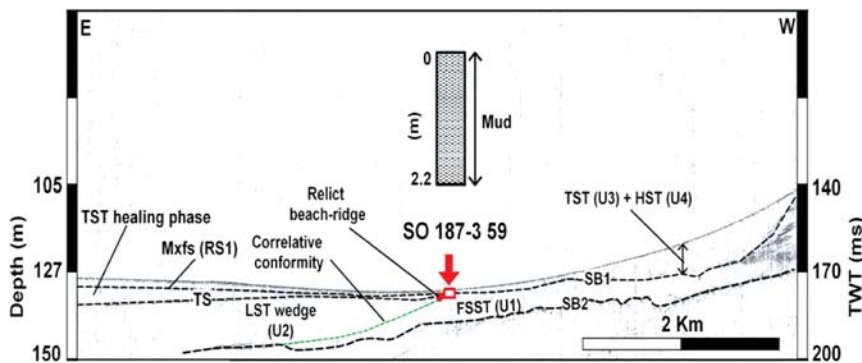
- Seismic units:

+ U0 is the lowest unit identified on seismic profiles. It is recorded across the shelf and bounded by the SB1 (upper) and SB2 (lower) surfaces (Figs. 4 - 8). This unit is characterized by horizontal and transparent reflectors on seismic profiles. The thickness of this unit is strongly variable and ranges from 0 - 15m.

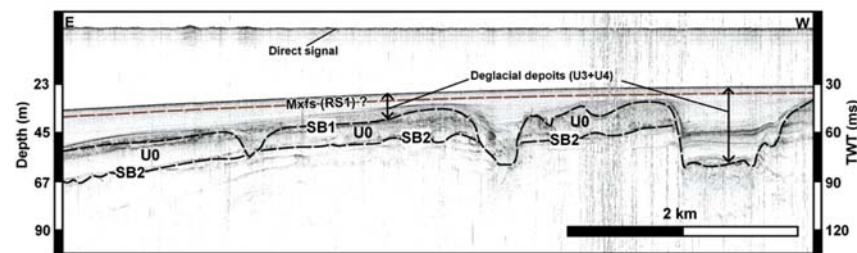
+ U1 is characterized by oblique parallel configuration with seaward dipping reflectors. It is truncated toplap by the overlying erosional surface SB1 and contacts tangential downlap with the lower U0 unit (Fig. 5). On some seismic profiles (Figs. 8 and 9), U1 unit forms tangential downlap directly to the SB2 surface where the U0 unit is absent. In the seaward direction, it is overlain by a concave reflection unit (Fig. 5). U1 unit is only recorded on the outer shelf and pinches out landward at water depths of 100 - 120m. The estimated thickness of this unit on seismic profiles is approximately 20m.



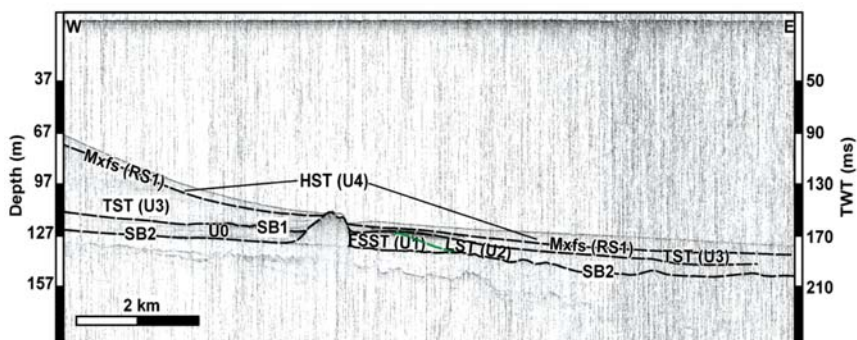
**Fig. 4.** Seismic profile of the transition from inner to outer shelf on the Northern part off Hon Gom Peninsula. AMS dating indicates very young highstand deposits (0.42 and 0.86ky BP). Core data adapted from Wiesner et al (2006)



**Fig. 5.** Seismic profile on the outer shelf off Hon Gom Peninsula with the complete recorded of systems tracts. Core data adapted from Wiesner et al (2006)



**Fig. 6.** Seismic profile on the inner shelf of Van Phong Bay with aggradational stacking patterns of deglacial deposits. Discrimination between HST and TST is hardly resolved



**Fig. 7.** Seismic profile on the middle-outer shelf of Van Phong Bay

+ U2 unit is developed as a seaward continuation of U1 unit and is separated landward from the U1 unit by a concave surface (Fig. 5). This unit is represented by oblique wedge shape with seaward dipping reflectors. On top of

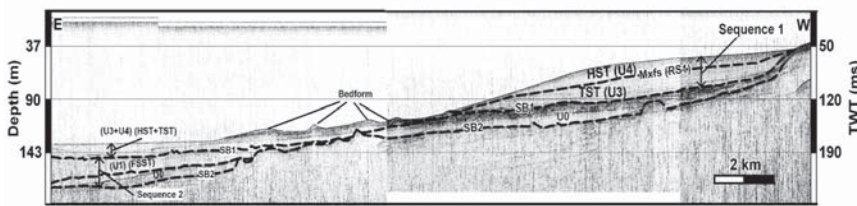
this unit, it forms top lap with the overlain smooth surface (Figs. 8 and 9). The angle of dip of seismic reflectors of U2 unit is slightly smaller than those of the U1 unit. The average thickness of this unit is about 20m. The U2 unit is only detected on the Northern shelf off the Hon Gom Peninsula (Fig. 5).

+ U3 unit is recorded across the shelf (Figs. 4 - 9). This unit is bounded by the RS1 surface on top and SB1 surface at the base. It appears as moderate amplitude reflectors with wedge-shaped configuration on the outer shelf (Fig. 5). On the mid shelf, U3 unit is expressed as high amplitude reflectors with backstepping onlap configuration (Figs. 4 - 8). Toward the inner shelf, its seismic configuration becomes aggradational stacking patterns (Fig. 6). The thickness of this unit shows low variability over the shelf with no significant depocenter. Its thickness is occasionally reduced or it is absent on seismic profiles when the basement structures come close to the surface (Fig. 8).

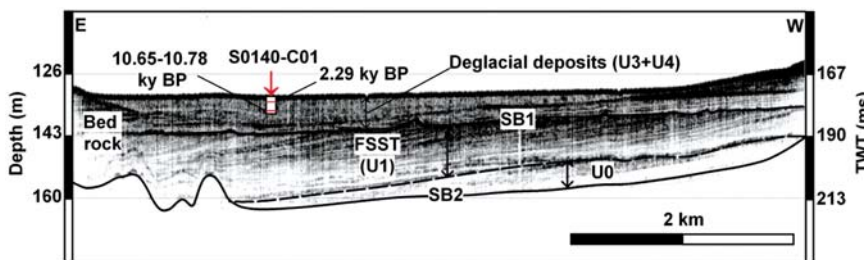
+ U4 is the uppermost unit on seismic profiles (Figs. 4 - 9). It is thin (average of 0 - 5m) on the inner and outer shelf with parallel and transparent seismic reflectors. Thick deposits of this unit are mostly concentrated on the mid shelf where it appears on seismic profiles as thick seaward dipping reflectors (Figs. 4 and 8). The maximum thickness of this unit reaches 20 - 25m on the mid shelf of Van Phong and Nha Trang Bay and it reduces toward the inner and outer shelf (Fig. 8).

**4.2. Sedimentary characteristics and age of deposits in other studies**

Coring station at a water depth of 29m (core SO187-3 58-2) on the Northern part off Hon Gom Peninsula shows a transition from coarse sand in the lowermost part to homogenous mud in the upper part of the sediment core



**Fig. 8.** Seismic profile of transition from the inner to outer shelf of Nha Trang Bay



**Fig. 9.** Seismic profile offshore Nha Trang Bay. Regressive unit (U1) is top-lap truncated by the lowstand surface (SB1) and overlain by deglacial/Holocene deposits (U3 and U4). Core data adapted from Schimanski and Statteger (2005)

(Fig. 4). Two radiocarbon datings of this core provide ages of 0.42 and 0.84ky BP (Fig. 4). The 2.2m long sediment core at water depth of 133m off Hon Gom Peninsula shows a homogenous muddy layer (Fig. 5). Radiocarbon dating of sediment core at water depth of 134m on the Nha Trang Shelf (core SO 140-C01, Fig. 9) covers the age interval of 2.29 - 10.78ky BP. The sediments have a muddy composition, low sand content and abundant shell fragments along the core [30]. Earlier study on the outer Sunda Shelf indicated an age of 25 - 30ky BP of the late Pleistocene soil surface [20]. The ages of the seaward dipping clinoforms (regressive unit), at a water depth of 80 - 126m, below the LGM soils surface on the Sunda Shelf were dated as 50 - 30ky BP [19, 20]. Also, a 6.2m long core taken on the top of seaward dipping clinoforms (at water depth of 152m) on the outer Sunda Shelf indicated an age of 39 - 36ky BP for the clinoform deposits and 4.0ky BP for the overlying thin mud layer [31]. On the Southeast Vietnam Shelf, radiocarbon dating of sediment core at a water depth of 156m reaching the upper part of the lowstand wedge shows an age of 24.33ky BP [30].

#### 4.3. Proposed sequence stratigraphic model for the Nha Trang Shelf over the last 120ky

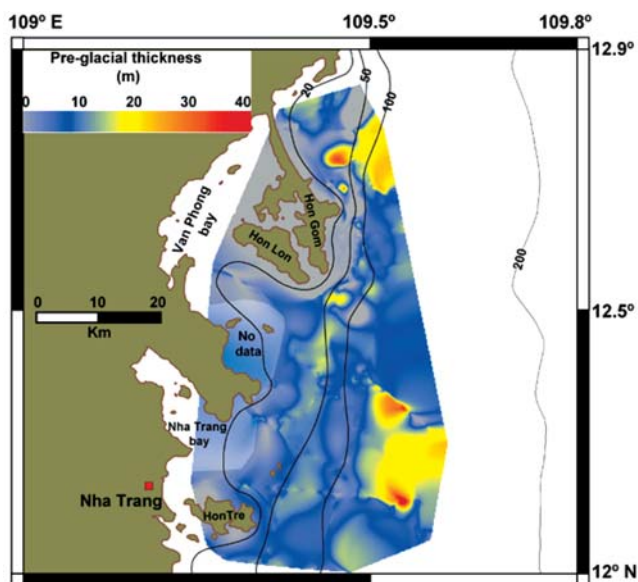
##### 4.3.1. Falling stage (FSST) and Lowstand system tracts (LST)

The FSST and LST are well recorded on the modern outer shelf (Fig. 10). The age of these units are derived by correlation with the regressive deposits on the

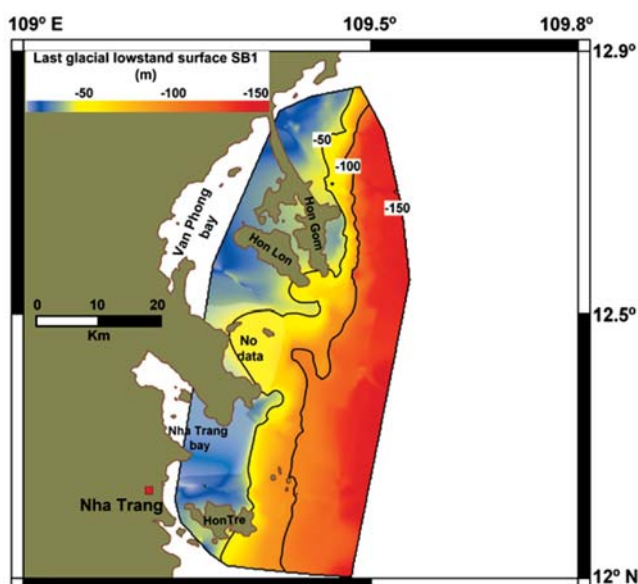
neighboring shelf areas. Ages of one sediment core taken on the top of the Sunda Shelf regressive wedge at water depth of 152m were identified as 34 - 31ky BP (39 - 36 calibrated) [31]. This can probably provide the upper age limit for the FSST deposits on the Nha Trang Shelf area. On the Sunda Shelf, the outer shelf lens-shaped regressive deposits (at ~110m water depth) were formed around 45ky BP. Therefore, the forced regressive deposits (FSST) in our research recorded at 120m water depth must be formed slightly after 45ky BP. Hence, the FSST on the Nha Trang Shelf was probably formed during

final stage of regression around 45 - 30ky BP (Fig. 14b). On the Vietnam Shelf, the upper part of the lowstand wedge at water depth of 156m yielded an age of 24.33ky BP [30]. This result fits well with data on the Sunda Shelf with age of 25 - 30ky BP for the late Pleistocene soil surface [20] that can be correlated with the SB1 surface on the Nha Trang Shelf. Hence, we deduce that LST deposits in our research were probably formed from 30ky BP to the LGM lowstand termination at 19.6ky BP [21]. Regressive deposits on the Nha Trang Shelf were well preserved on the modern outer shelf (at more than 100m water depth) and show seaward thickening with an average thickness of about 20 - 30m (Fig. 10). This is probably due to the fact that the outer part of the shelf was partly or entirely submerged during sea-level lowstand and therefore was protected from the effects of subaerial erosional processes. Further landward, the FSST deposits are absent in all recorded seismic profiles since the inner and mid shelf regressive deposits were subjected to long term erosional processes during the sea-level fall after MIS 5e highstand and were reworked again during the following transgression. The outer shelf lens-shaped regressive deposits documented on the Sunda Shelf [19] and the SE Vietnam Shelf [42] cannot be detected on the high-gradient shelf of Nha Trang area. We therefore consider the absence of the seaward dipping regressive deposits on the inner and mid shelf as a result of a long-term erosional hiatus (Fig. 14). The FSST unit is bounded on the top by the unconformity SB1. The SB1 surface (Fig. 11) in our work is an amalgamated surface which

was probably initiated after the MIS 5e, expanded until the LGM sea-level lowstand and was further reworked during the subsequent deglacial transgression (Fig. 14). The SB1 surface merges seaward with the TS ravinement surface which overlies the LST wedge (U2) and FSST (U1) (Figs. 5, 8 and 9).



**Fig. 10.** Total sediment thickness map of sequence 2 (U0, U1 units) and U2 unit. Thick deposits on the outer shelf resulted from well developed regressive units (U1 and U2) which are pinching out landward at water depth of 100 - 120m



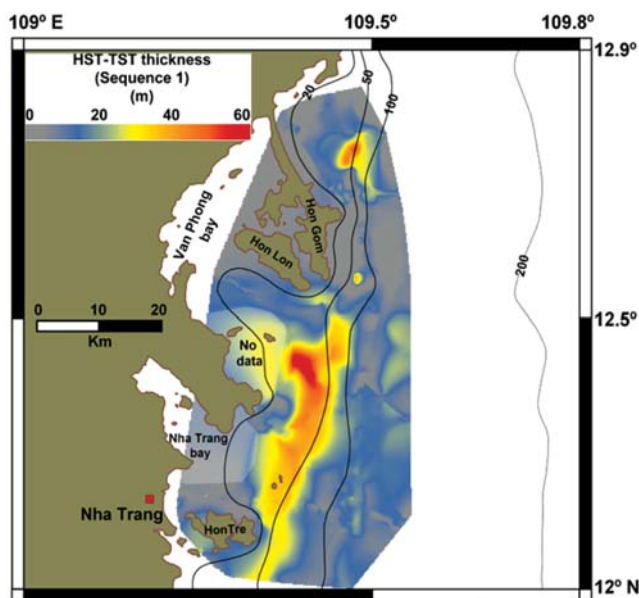
**Fig. 11.** Contour map of the LGM surface SB1 with reference to the modern sea-level constructed from seismic profiles. Basically the lowstand surface was blocked at the LGM sea-level around -125 to -130m and its seaward extension was merged with the transgressive surface (TS)

#### 4.3.2. Transgressive (TST)

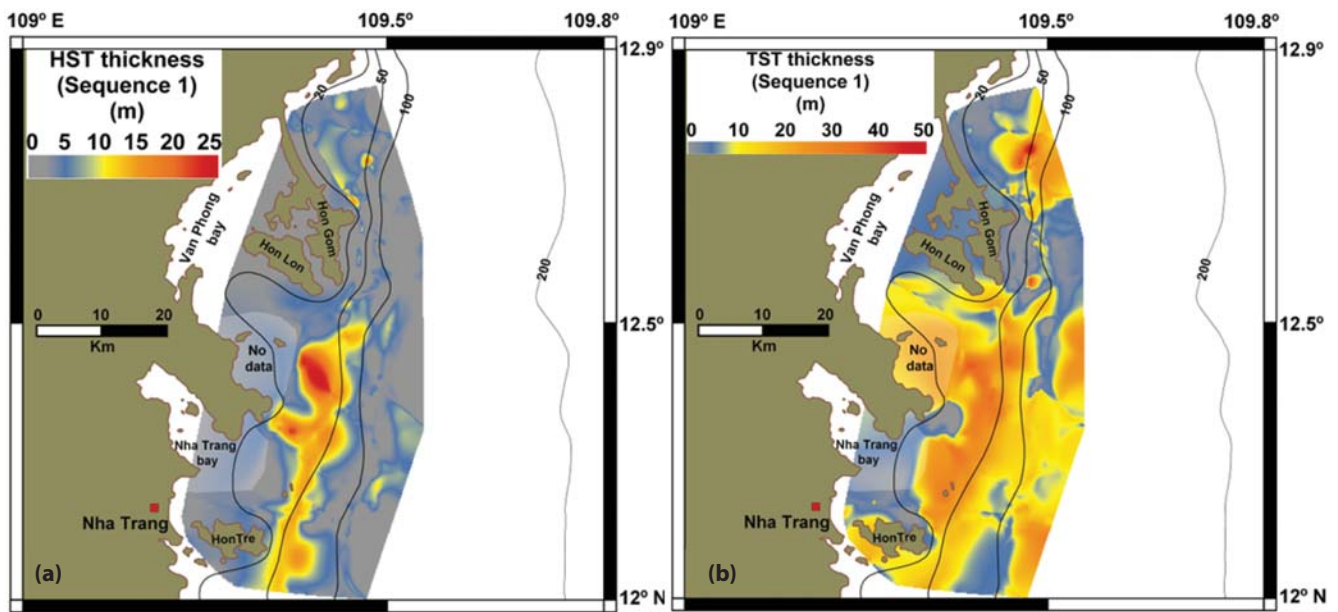
The time of maximum flooding on the Nha Trang Shelf remains unclear since the RS1 surface was not dated. However, its formation can be correlated to the initiation of the two nearby Red and Mekong River deltas which around 8.0ky BP [22, 36, 37]. We deduce that the ages of TST on the Nha Trang Shelf can range from 19.6 - 8.0ky BP. Configurations of the TST deposits show a wedge-shape on the outer shelf which represents early TST healing phase deposits. On the mid-inner shelf, its configuration changes from backstepping to aggradation stacking patterns that reflect the interaction between the rate of sea-level rise, sediment flux and the pre-existing LGM lowstand surface gradient.

#### 4.3.3. Highstand (HST)

The HST period on the Nha Trang Shelf began about 8.0ky BP. At the same time, the Mekong and Red river deltas were initiated. The modern highstand mud deposits observed on the Nha Trang Shelf have been formed following the maximum sea-level highstand of 1.5m above the modern level reached between 6 and 5.5ky BP [25]. The HST sediment depocentre appears as a NE-SW elongated sediment body on the mid-shelf and is almost absent in the Northern part of study area where the river influences are less profound (Fig. 13). Location of the HST

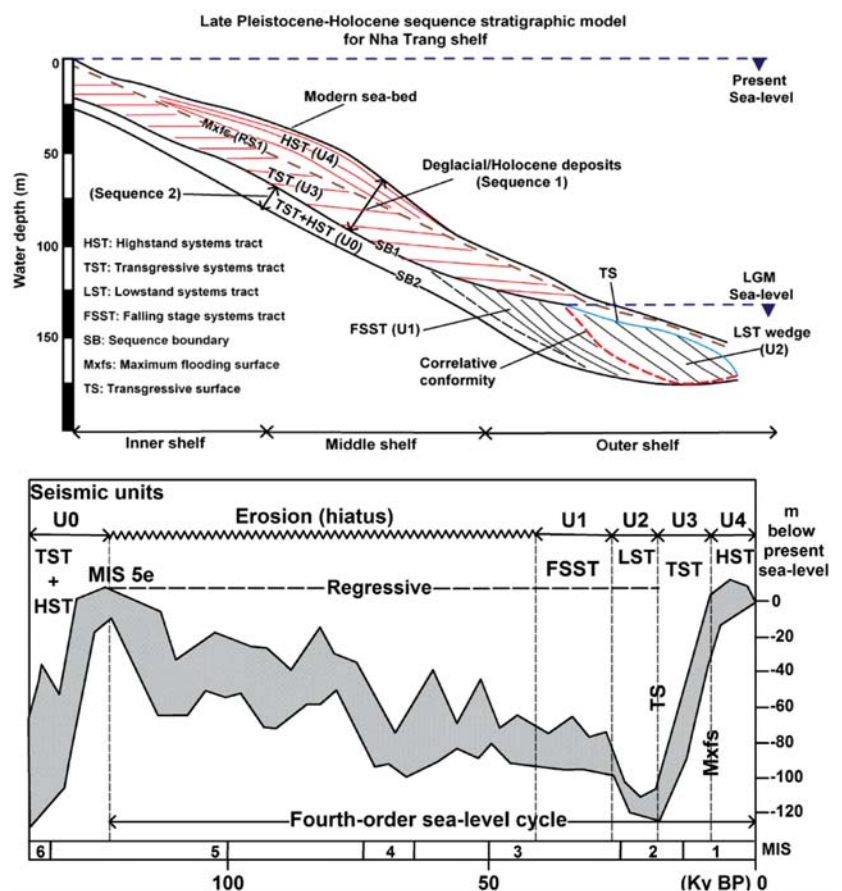


**Fig. 12.** Total deglacial/Holocene sediment thickness (sequence 1) including U3 and U4 units. The sediment depocentre is located on the mid shelf



**Fig. 13.** Sediment thickness map of HST (a) and TST (b) of sequence 1. HST depocentre is located on the mid shelf in front of Van Phong and Nha Trang Bay. HST deposits are probably transported along-shore Southward. The TST deposits develop over the shelf without significant sediment depocentre

mud wedge suggests the importance of local rivers as the major sediment sources of the sediment depocentre. Hydrodynamic modelling studies indicate that the surface currents on Nha Trang and Van Phong Bay are mainly oriented offshore during summer and southward along-shore during winter [3]. Therefore, the major sediment supply to the shelf during the rainy season (accounting for 70% of sediment supply) is almost coincident with the beginning of the winter season (September to December). Sediments will be transported along-shore by the dominant NE monsoon effects or they can settle only around the river plume outflow on the inner shelf. Dispersion of fine material directly to the mid and outer shelf by the cross-shore sediment transport during this period is not significant. Since the inner shelf surface sediments are dominated by sands, reasonable sources of the modern fine sediments on the mid and outer shelf are assumed to be redeposited from the inner shelf via advection processes as well as transported along-shore from the Northern shelf [35].



**Fig. 14.** Late Pleistocene - Holocene sequence stratigraphic model for the Nha Trang Shelf (a) with regional sea-level curve (b) (Shackleton 1987; Chappell et al., 1996; Fleming et al., 1998; Hanebuth et al., 2004)

## 5. Discussion and conclusions

The late Pleistocene high amplitude of sea-level change during a long fourth-order cycle (120ky) superimposed by several shorter fifth-order cycles is the principal factor in the organization of the Nha Trang continental shelf sequence (Fig. 14). The proposed sequence-stratigraphic model for the SE Vietnam Shelf basically follows the main features of the theoretical models of Vail and Zaitlin et al. [39, 43]. However, there still exist differences which are attributed to local controlling factors. On the Nha Trang Shelf, the thick mud highstand wedge is detached from the sediment source and forms the elongated mid-shelf mud belt. The formation of the mud-belt on the Nha Trang Shelf is probably correlated to the advection-dominated clinoform-progradation type according to Cattaneo's classification [7]. The LST deposits above the LGM surface on the inner and mid shelf are not documented on the Nha Trang Shelf since they were often eroded by subaerial and following marine erosional processes or they are not clearly discriminated by seismic resolution. Besides, the absence of the incised-channels due to transgressive erosional processes in this area did not allow the LST fluvial sediments, predicted to deposit at the bottom of the incised-channels, to be preserved [43]. Therefore the TS surface in the Nha Trang Shelf's model was mostly merged with the lowstand sequence boundary landward and TST deposits often rested directly on the LGM lowstand surface in the landward part of the LGM coastline. The variable gradient of the LGM surface influences the formation of sequence system tracts: The relative high-gradient on one hand has reduced the effects of the rapid transgression and on the other has prolonged the time for sediment reworking with a given amount of sea-level rise. As a result, the TST deposits on the Nha Trang Shelf were stacked thicker than their counterparts on the nearby low-gradient Sunda [20] and SE Vietnam [5]. On the other hand, the effect of transgression over longer time has also enhanced the marine erosional process of the lower regressive deposits and therefore reduced their preservation. This together with the high wave energy has resulted in the loss of the regressive deposits over the mid and inner part of Nha Trang Shelf.

The late Pleistocene - Holocene stratigraphic architecture on the shelf off Nha Trang area comprises five major seismic units and three bounding surfaces which can be attributed to four systems tracts: FSST, LST, TST and HST.

+ The lowermost unit U0 formed as transparent and parallel layer overlying the SB2 surface, and it is interpreted as deposits accumulated during MIS 5e transgression and highstand period of the last glacial cycle. The long gap between U0 and the following FSST unit is attributed to the erosional hiatus.

+ The FSST with unit U1 and LST with unit U2 are well preserved on the modern outer shelf but pinch out landward at water depths of 100 - 120m. FSST and LST units were primarily formed during the falling stage of sea-level from MIS 3 to the LGM sea-level lowstand of MIS 2. The LST wedge deposits on the central shelf are only recorded in the steep-gradient shelf off the Hon Gom Peninsula and they are almost absent in the other parts of study area. The relict beach-ridge deposits identified at a water depth of about ~ 130m below present sea-level indicate that the LGM sea-level lowstand in this area was lower than on the Sunda Shelf in the South. The difference probably resulted from subsidence due to high deglacial Holocene sedimentation and/or neotectonic movements of the East Vietnam Fault System.

+ Transgressive deposits (unit U3) were developed across the shelf with significant thicknesses. The TST shows a clear transition from backstepping to aggradational stacking patterns from outer to inner shelf which reflects the interplay between rate of sea-level rise, LGM surface gradient and sediment supply.

+ The thick highstand mud (unit U4) is documented on the mid shelf forming a shore-parallel sediment depocentre and its thickness decreases toward the inner and outer shelf.

+ The late Pleistocene high amplitude of sea-level change during a long fourth-order and superimposed shorter fifth-order cycle is the principal factor in reorganizing the formation of the Nha Trang continental shelf sequence. Local factors like geometry of the narrow shelf and high sediment supply from the mountainous hinterland provided specific features of the Nha Trang Shelf's sequence stratigraphy.

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