

## QUANTITATIVE ANALYTICAL RESULTS ON TOPOGRAPHIC FEATURE OF THE VIETNAM'S CONTINENTAL SHELF WITHIN COORDINATES 11.7 - 14.0<sup>0</sup> AND 109.5 - 110.2<sup>0</sup>

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**ABSTRACT:** *This paper presents some analytical results of bathymetry data according to three maps: Three dimensions (3D), slope, aspect on the continental slope and shelf area in the central part of Vietnam within the coordinates of 11.7 - 14.0<sup>0</sup> and 109.5 - 110.2<sup>0</sup>. The obtained results have reflected clearly the geomorphic characteristics in this area. For example, on the 3D map, the continental slope exists three steps at the depths of 500 - 700 m, 1,250 m, and 1,500 - 1,700 m, running along the meridian 109.7<sup>0</sup>, about 250 km long. These results are also shown on the slope and aspect map. On the slope map, from the depth of about 250 m to the first step base, the slope angle varies within 5 - 20<sup>0</sup> and from the first step base to second step base, the slope angle varies within 5 - 10<sup>0</sup>; In the remaining part, the slope angle varies within 2 - 8<sup>0</sup>. The other analytical results from the aspect map are also shown clearly, the aspect direction on the wall of three slope steps varies from 50 to 100<sup>0</sup>, reflecting the topographic slope towards the east, where is abyssal plain. The existence of Pliocene - Quaternary sediments along with steep continental slope caused landslide phenomenon in this area.*

**Keywords:** *Three dimensional (3D) map, slope map, aspect map, continental slope, slope angle.*

### INTRODUCTION

The continental shelf area in the central part of Vietnam within coordinates 11.7 - 14.0<sup>0</sup> and 109.5 - 110.2<sup>0</sup> has the most unique characteristics of geomorphology in the East Vietnam Sea. The abrupt changes of seabed topography from the depths of 250 m to over 2,000 m formed the angle of slope surfaces from 5<sup>0</sup> to 15<sup>0</sup>, somewhere over 20<sup>0</sup>. It can be considered as one of the places that has the highest slope angle of seabed topography in the East Vietnam Sea.

The continental shelf and slope within the studied area belong to Phu Khanh basin, formed by sediments in Cenozoic and

Quaternary periods, while the thickness of Quaternary sediments can be up to a thousand meters. The weak cohesion of young sediments and their high angle of continental slope surface is one of the main reasons causing the landslide in this area [1, 2].

The submarine landslides can cause the telecommunication cable to cut or destroy the underground infrastructure; Especially, the large landslide blocks can also cause tsunami ... affecting the socio-economic and human activities. Therefore, the marine investigations into topography, geomorphology, geology and geophysics must be continued to assess the status in detail to provide appropriate solutions for preventing and mitigating damage.

The studies on geomorphology, geology and geophysics in this area and adjacent regions were conducted through the Vietnam national projects and the projects of the Vietnam Academy of Science and Technology from the last century. There are a lot of papers on geological and geomorphic characteristics of this area that have been published by [3-5]. However, the results of the projects or published papers have not yet considered the characteristics of topography and geomorphology as well as submarine landslides in detail and quantification. Recently, the studies of [1, 2, 6] mentioned the submarine landslides in this area, but the studied results have not yet discussed the characteristics of geomorphology in detail.

In this study, the author uses the bathymetry data of GEBCO\_08 and the softwares of Surfer, Mapinfo and Visual Basic 6.0 programming language to analyze the geomorphic characteristics in detail on the continental slope and shelf area in the center part of Vietnam within coordinates 11.7 - 14.0° and 109.5 - 110.2°.

## MATERIAL AND METHODS

### Material

Data used in this study is General Bathymetric Chart of the Oceans (GEBCO\_08), a continuous terrain model for ocean and land with a spatial resolution of 30 arc-seconds. This data is largely generated by combining quality-controlled ship depth soundings with predicted depths between the sounding points guided by satellite-derived gravity data.

### Methods

This study adopts analytical methods of GIS with the help of the Surfer software, MapInfo software to build maps of topography, slope, aspect and Visual Basic 6.0 programming language to calculate slope angle of each cross section. The function of each software is described briefly as follows: Surfer software helps to simulate DEM map; Mapinfo software helps to build maps of topography, slope and aspect; Visual Basic 6.0 programming language aids in calculating slope angle of each section.

## ANALYTICAL RESULTS

The location of the studied area within coordinate of 11.7 - 14.0° and 109.5 - 110.2° is shown in figure 1.

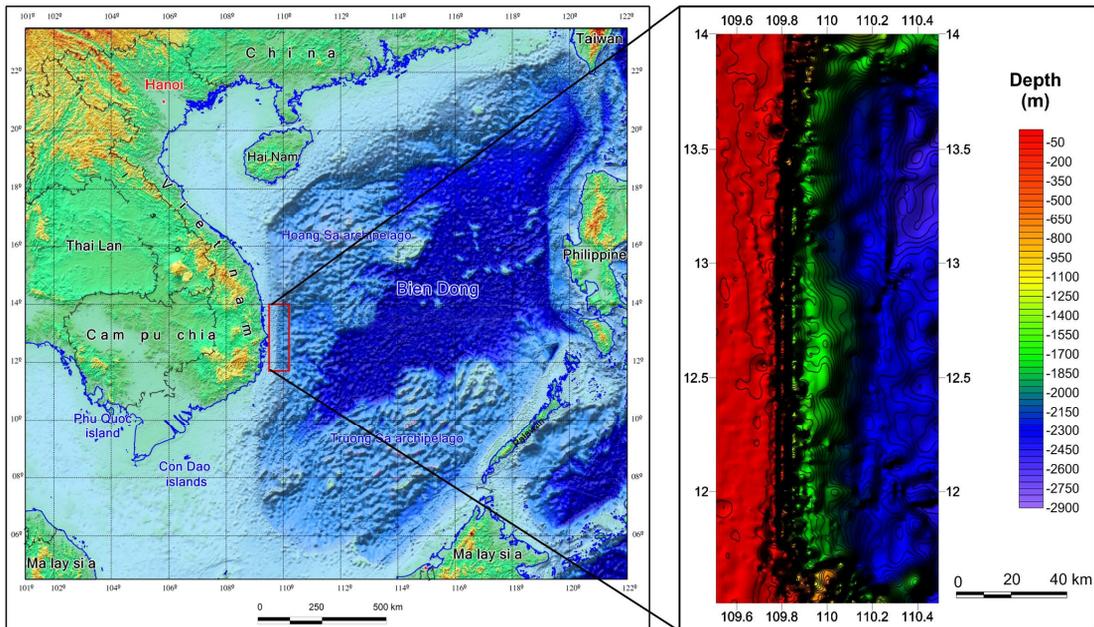


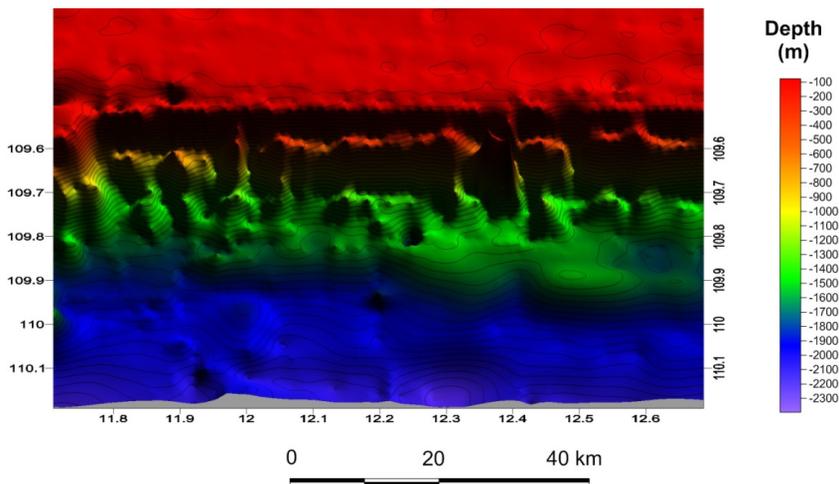
Fig. 1. Location map of studied area

### Topographic map

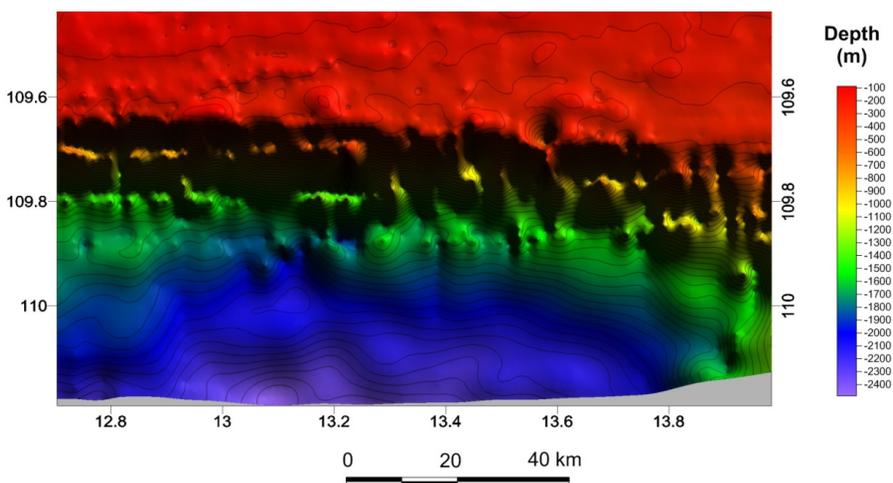
The analytical results of bathymetric data within the studied area in 3D space are illustrated as figures 2 and 3.

The figures 2 and 3 are two topographic maps of the continental shelf in the northern and southern parts of the studied area. These maps reflect clearly the contrasting terrain among the shelf, slope and continental rise. The division of the studied area into two regions on two maps is to show more clearly their individual characteristics. On both maps, the continental shelf is relatively flat with the slope

angle below  $0.5^{\circ}$ ; The continental slope has three steps, running along the meridian direction and being interrupted clearly. The discontinuity of these steps may be in relation to the landslide, subsidence of Pliocene-Quaternary sediments to form a canyon [5, 6]. The largest disruption of the steps is in the northern part of the studied area, within the latitudes of  $13.0 - 13.15^{\circ}$  and  $13.3 - 13.8^{\circ}$ , corresponding to the length of about 17 km and 55 km. In the interrupted parts, there is no step, the seabed terrain is changed abruptly from the depths of about 250 m to 1,700 m and above 2,000 m.

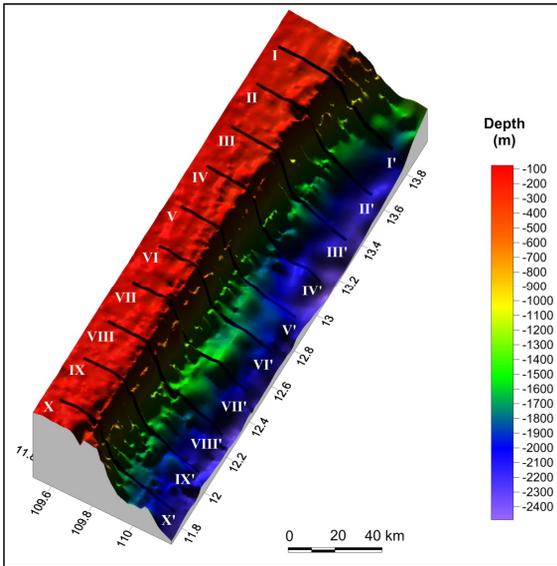


**Fig. 2.** Topographic map of the central part of Vietnam within coordinates  $11.7 - 12.7^{\circ}$  and  $109.5 - 110.2^{\circ}$



**Fig. 3.** Topographic map of the central part of Vietnam within coordinates  $12.7 - 14.0^{\circ}$  and  $109.5 - 110.2^{\circ}$

In order to understand clearly the characteristics of the terrain steps within the studied area, 10 section lines are designed evenly and perpendicularly to the surface of the shelf and slope as shown in figure 4. The sections are used to analyze the quantitative parameters of slope, length of the continental slope. The obtained results of the study have important significance to support the risk assessment of submarine landslide in this area.



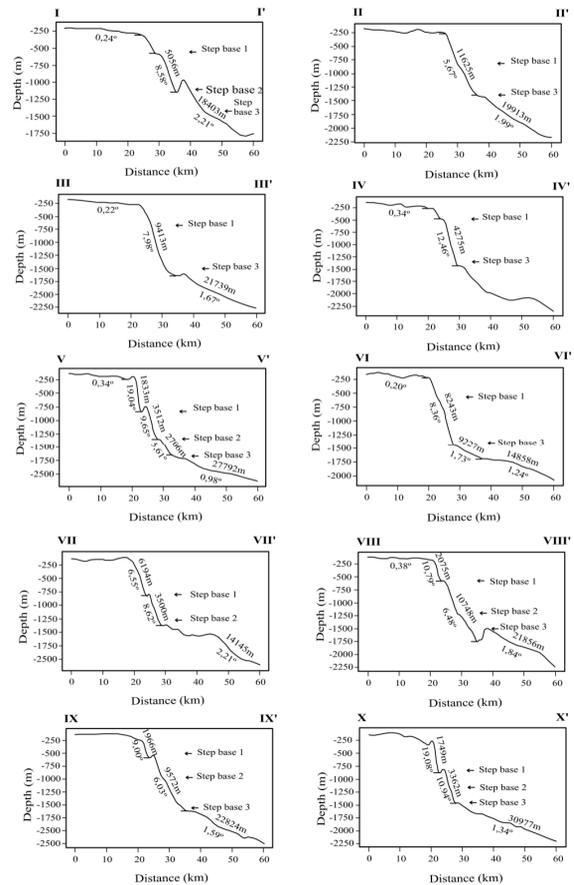
**Fig. 4.** 3D model of continental shelf and slope in the central part of Vietnam within coordinates of 11.7 - 14.0° and 109.5 - 110.2° and section lines

The cross sections of the continental shelf and slope in figure 4 are used to analyze the slope length and their slope angles in detail as figure 5.

The analytical results from the cross sections in figure 5 show that the surface of the continental slope is divided into three different steps at the depths of 500 - 750 m, 1,250 m and 1,500 - 1,750 m. The steps are about 1 km and 2 km wide, like the consequence of the subsidence along the fault due to tectonic activities.

The slope length of the steps is not similar to each other and they are 2,000 - 6,000 m in the first wall, 3,000 - 6,000 m in the middle

wall and from 2,000 m to over 10,000 m in the low wall, corresponding to the slope angle changes of 5 - 20°, 5 - 10° and 2 - 8°.



**Fig. 5.** Cross sections on continental shelf and slope in the central part of Vietnam within coordinates 11.7 - 14.0° and 109.5 - 110.2°

### Slope map

The differences between the continental shelf and slope within the studied area are reflected clearly on a slope map by their values of color zones in figure 6b.

The analytical results of slope map in figure 6b indicate that there are three narrow red color regions on the surface of the continental slope, corresponding to the slope of three walls. The interposition of these walls are two green color regions, they are step bases. The change of color regions on the slope map reflects well the topographic characteristics of figure 6a.

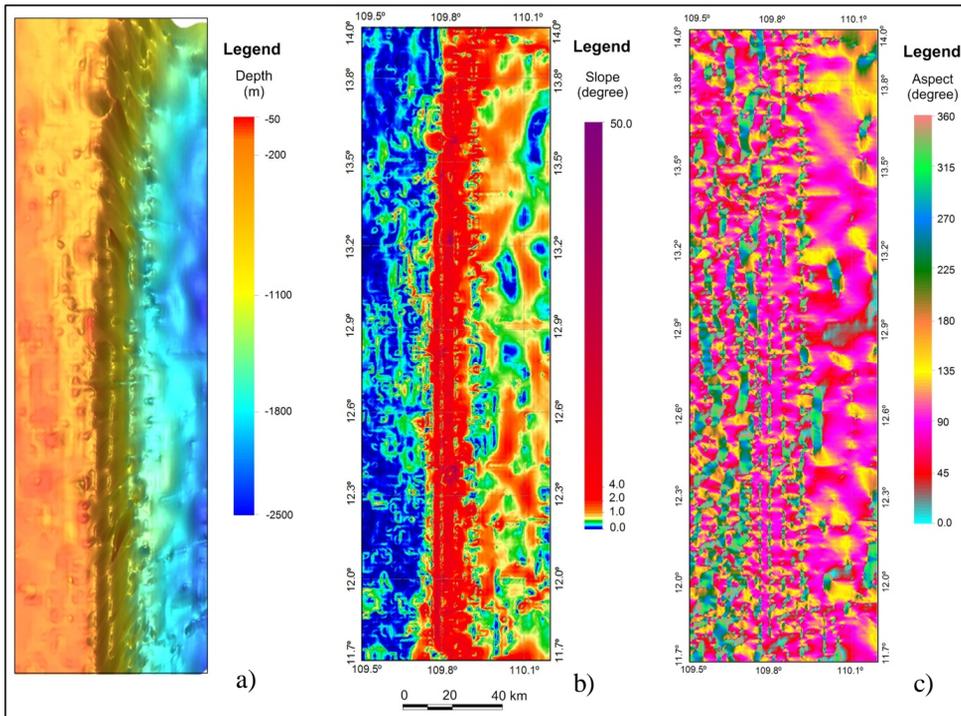


Fig. 6. a) Topographic map; b) Slope map; c) Aspect map

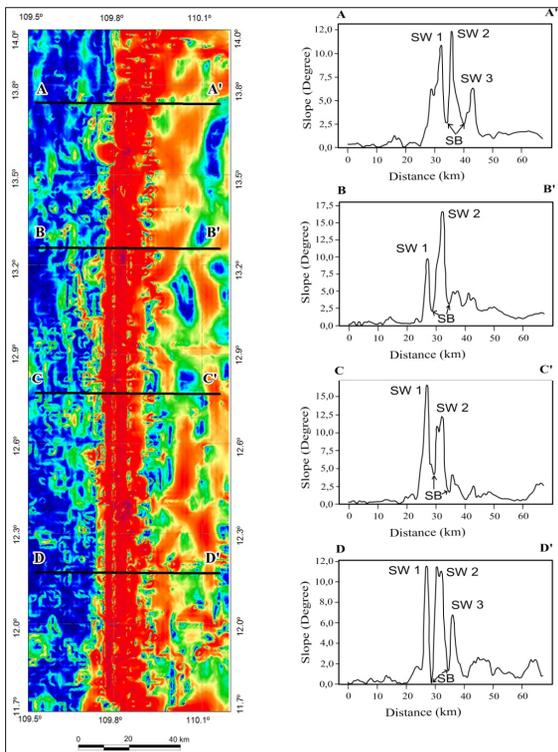


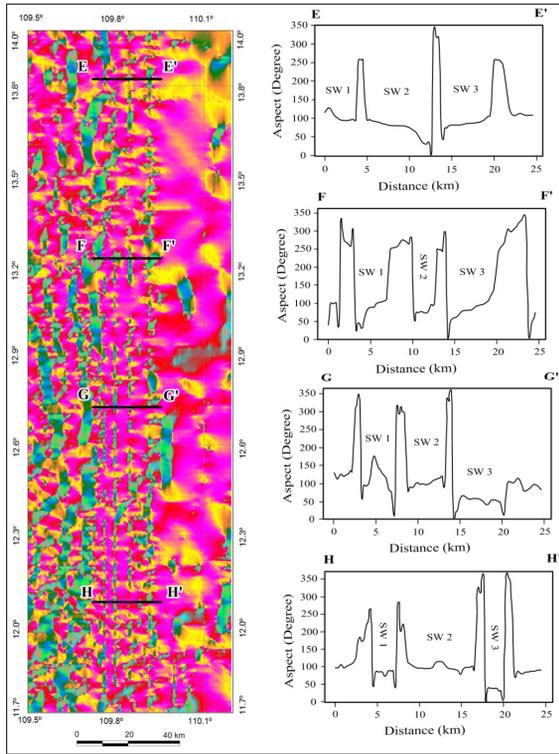
Fig. 7. Slope map and cross sections (SW: Step Wall; SB: Step Base)

Based on the color values of the slope map in figure 7, the studied area can be easily divided into three different regions: Continental shelf, slope and rise. Besides, according to color values in figure 7, the slope angle values of the continental shelf vary from 0 to below  $0.5^{\circ}$ , the continental slope varies from  $5^{\circ}$  to  $20^{\circ}$  and the continental rise varies from below  $1^{\circ}$  to  $5^{\circ}$  (fig. 5). The difference of slope values among three regions is also easily recognized in the cross sections of figure 7 and the biggest slope angle values belong to the continental slope region.

### Aspect map

The aspect map is used to analyze the direction of the topographic surface according to different color regions. The aspect values change within 0 - 360 degree, depending on the direction of topographic surface. The analyzed aspect is carried out by a combination of the following eight directions: NNE, ENE, ESE, SSE, SSW, WSW, WNW and NNW, corresponding to color polygons of intervals: 0 -  $45^{\circ}$ , 45 -  $90^{\circ}$ , 90 -  $135^{\circ}$ , 135 -  $180^{\circ}$ , 180 -  $225^{\circ}$ , 225 -  $270^{\circ}$ , 270 -  $315^{\circ}$  and 315 -  $360^{\circ}$ .

After analyzing, the color polygons on the aspect map are represented as figure 8.



**Fig. 8.** Aspect map and cross sections

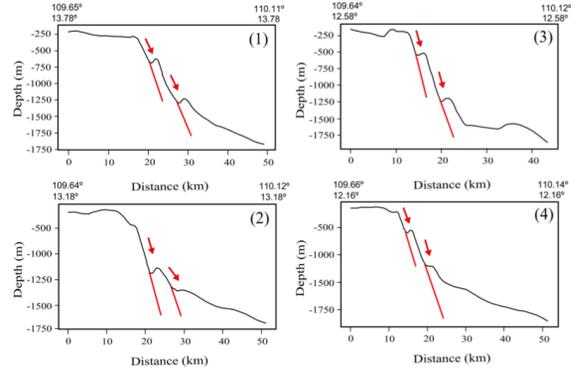
Similar to the analyses of the above map, the aspect values within the continental slope also form three respective color regions, corresponding to three walls and two thin step bases. The aspect value of the walls varies from  $50^0$  to  $100^0$  and step base varies from  $250^0$  to  $300^0$ , reflecting well the direction of topographic surface (fig. 8).

The difference of aspect values in figure 8 can be easily recognized as a boundary zone between the continental shelf and rise.

**DISCUSSIONS**

In the studied area, the slope terrain is divided into three steps and abruptly changed from 250 m to above 2,000 m in depth by tectonic activities along the meridian fault zone in the eastern area of Vietnam. The subsidence of these terrain steps is clearly reflected on the maps of topography, slope and aspect,

especially on the four cross sections of topographic map in figure 9.



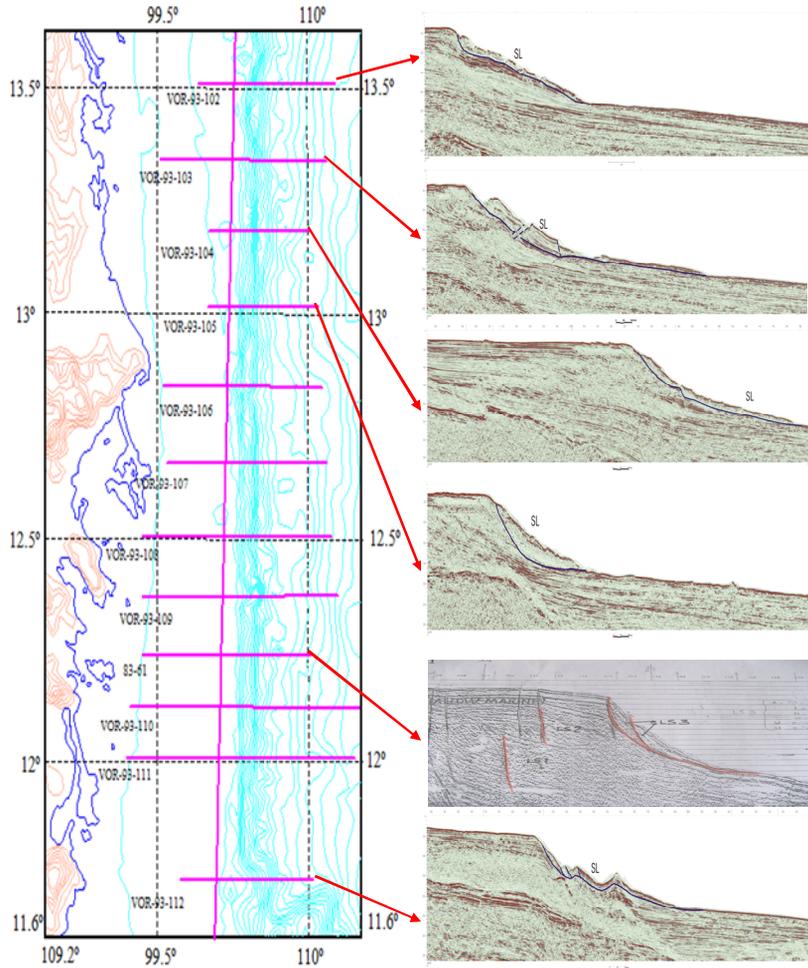
**Fig. 9.** The typical cross-sections illustrate the subsidence of younger sediments on the continental slope, within the coordinated intervals: Cross section (1):  $109.65^0, 13.78^0 - 110.11^0, 13.78^0$ ; Cross section (2):  $109.64^0, 13.18^0 - 110.12^0, 13.18^0$ ; Cross section (3):  $109.64^0, 12.58^0 - 110.12^0, 12.58^0$ ; Cross section (4):  $109.66^0, 12.16^0 - 110.14^0, 12.16^0$

However, the subsidence of terrain on the continental slope can also be caused by a gravity slide of young unconsolidated sediments of one side (positive terrain) and another side (negative terrain).

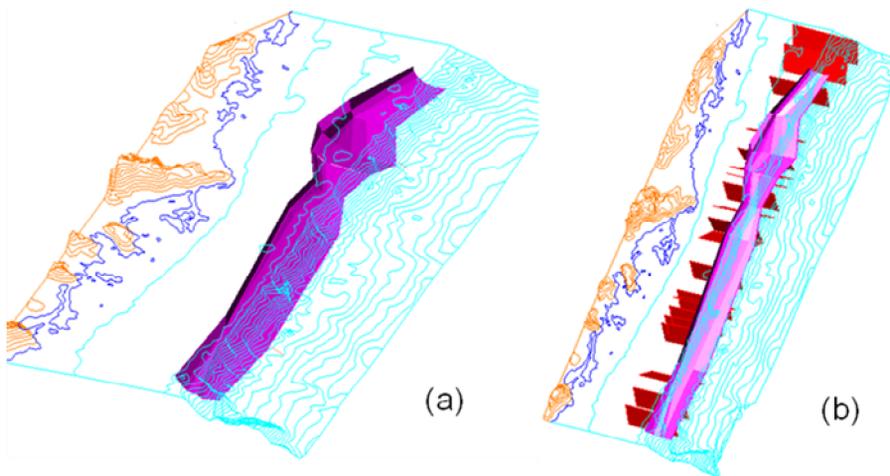
These evidences have been reflected in the analytical results of the seismic profiles, which are perpendicular to the continental shelf and slope (belonging to the Vietnam national projects): “Assessing the danger of earthquakes and tsunamis in coastal areas and islands of Vietnam and proposing solutions to prevent and mitigate”, Bui Cong Que et al., (2007-2010) and “Researching and warning the submarine landslide potential on the continental shelf in the central part of Vietnam”, Tran Tuan Dung et al., (2012-1015).

In addition, in a recent study, [5] has also built a 3D model of the base boundary of landslide block according to seismic data and fault system as in figure 11.

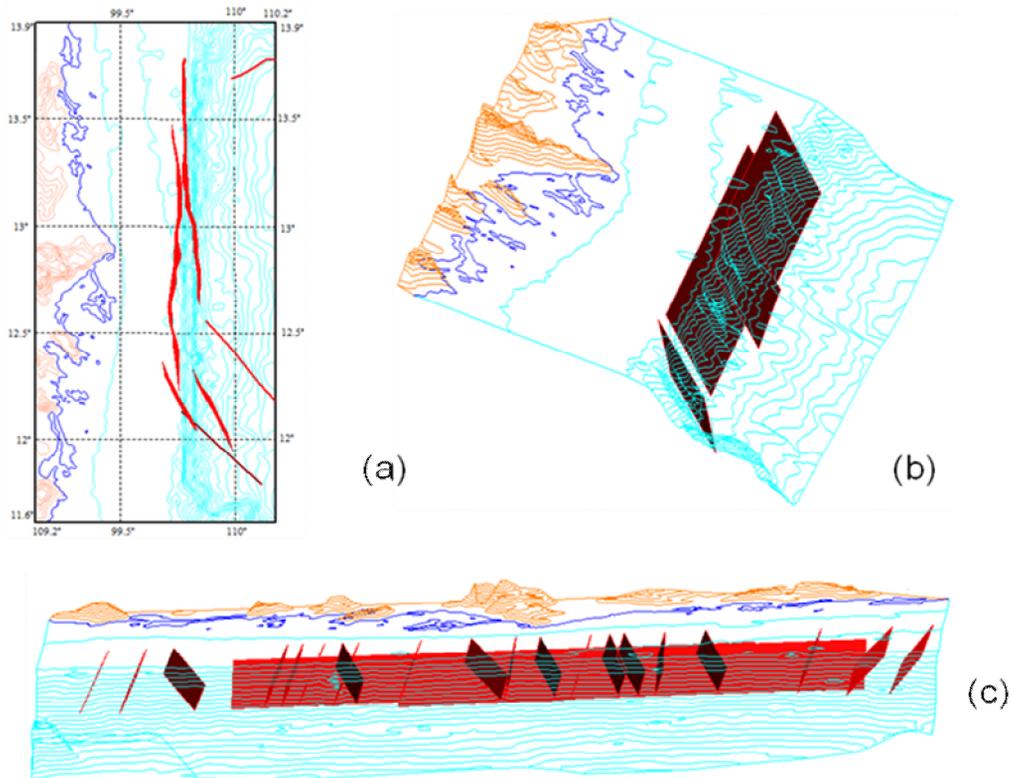
The analytical results in detail of slope and aspect in this study enrich existing data as a base for correcting the necessary parameters in assessing landslide risk in this area.



**Fig. 10.** Evidences of subsidence and landslide on the seismic profiles: VOR-93-102, VOR-93-103, VOR-93-104, VOR-93-105, 83-61, VOR-93-112 [2]



**Fig. 11.** 3D model of the base surface of landslide block which is interpreted from figure 10 [2]



**Fig. 12.** Map of Quaternary faults (a); 3D model of faults (b) and (c) [5]

## CONCLUSIONS

The analytical results of bathymetric data in three maps: Three dimensions (3D), slope, aspect on the continental slope and shelf area in the central part of Vietnam within  $11.7 - 14.0^{\circ}$  and  $109.5 - 110.2^{\circ}$  reflected clearly the characteristics of topography and morphology in detail. Particularly, on the topographic map, the continental slope exists three steps at the depths of 500 - 700 m, 1,250 m and 1,500 - 1,700 m, running along the meridian  $109.7^{\circ}$ , about 250 km long; On the slope map, from the depth of about 250 m to the first step base, the slope angle varies within  $5 - 20^{\circ}$  and from the first step base to second step base, the slope angle varies within  $5 - 10^{\circ}$ ; In the remaining part, the slope angle varies within  $2 - 8^{\circ}$ ; On the aspect map, the direction of slope surface changes from  $50^{\circ}$  to  $100^{\circ}$ , towards the east, where is abyssal plain. The existence of Pliocene-Quaternary sedimentary along with steep continental slope caused landslide phenomenon in this area.

The studied results of this paper are important prerequisite for other studies on the continental slope and shelf area in the central part of Vietnam in the future.

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## NHỮNG KẾT QUẢ PHÂN TÍCH ĐỊNH LƯỢNG VỀ ĐẶC ĐIỂM ĐỊA HÌNH TRÊN THỀM LỤC ĐỊA VIỆT NAM TRONG PHẠM VI TỌA ĐỘ 11,7 - 14,0<sup>0</sup> VÀ 109,5 - 110,2<sup>0</sup>

**Phí Trường Thành**

*Trường Đại học Tài nguyên và Môi trường Hà Nội*

**TÓM TẮT:** Bài báo này trình bày một số kết quả phân tích tài liệu đo sâu theo ba mô hình: Ba chiều (3D), độ dốc, hướng sườn trên thềm và sườn lục địa Nam Trung Bộ trong phạm vi tọa độ: 11,7 - 14,0<sup>0</sup> và 109,5 - 110,2<sup>0</sup>. Các kết quả thu được đã phản ánh chi tiết những nét đặc trưng riêng về đặc điểm địa hình - địa mạo ở đây. Cụ thể là, trên mô hình số ba chiều, địa hình sườn lục địa tồn tại các bậc thềm ở những khoảng độ sâu 500 - 700 m, 1.250 m và 1.500 - 1.700 m, chạy theo phương kinh tuyến 109,7<sup>0</sup>, dài khoảng 250 km. Kết quả này cũng được chỉ ra trên mô hình số độ dốc và hướng sườn. Trên mô hình hướng sườn, từ bề mặt thềm ở độ sâu khoảng 250 m đến bậc thứ nhất, góc dốc của địa hình thay đổi trong khoảng 5 - 20<sup>0</sup> và từ bậc thềm thứ nhất đến bậc thềm thứ hai, góc dốc của sườn địa hình thay đổi trong khoảng 5 - 10<sup>0</sup>; Phần còn lại, góc dốc chỉ thay đổi trong khoảng 2 - 8<sup>0</sup>. Các kết quả phân tích khác từ mô hình số hướng sườn cũng còn chỉ rõ thêm góc của hướng sườn ở hai phần chuyển tiếp giữa các bậc thay đổi từ 50<sup>0</sup> đến 100<sup>0</sup>, thể hiện rõ hướng sườn nghiêng về phía đông, nơi trũng sâu Biển Đông. Sự gắn kết yếu của các trầm tích Pliocen-Đệ tứ cùng với địa hình sườn dốc đã gây nên hiện tượng trượt lở, sụt bậc rất rõ trong khu vực này.

**Từ khóa:** Bản đồ ba chiều, bản đồ độ dốc, bản đồ hướng sườn, sườn lục địa, góc dốc.