Application of High–resolution Reflection Seismic Attributes for Researching 3D Shallow Marine Geology Structures

Cuong Van Anh LE[*1), 2)]*, Man Ba DUONG*[3)]*, Thuan Van NGUYEN*[1), 2)]*, Truong Ngoc NGUYEN*[1),2)]

[1)] University of Science, Ho Chi Minh City, Vietnam; email: lvacuong@hcmus.edu.vn
[2)] Vietnam National University Ho Chi Minh city, Ho Chi Minh City, Vietnam
[3)] Ho Chi Minh City Institute of Resources Geography, VAST, Vietnam
* Corresponding author: lvacuong@hcmus.edu.vn

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Abstract

In river sedimentology and bathymetry study, high–resolution seismic approach equipped with a sub–bottom profiler is necessary. Difference of acoustic impedances resulted by varies of sediment stratigraphy layers can be visualized through dynamic seismic vibration. In marine environments, detection of young sediment as sand dunes or mud, mixtures of sand and clay, and clay formations can help policy makers to launch policies or regulations in safety of water transportation as well as civil building infrastructure. We have measured, analyzed, and interpreted an enormous collection of 2D seismic sub-bottom profiles in Can Gio offshore, Ho Chi Minh City, Vietnam for understanding its shallow subsurface young deposits. Our approach is to combine three key seismic textural attributes (i.e., Correlation, Variance, and Homogeneity) in the representation of color-blended attribute for picking distinguished geological features. In our result, 2D seismic horizons representing boundaries of diverse types of sediments can provide a great input for modeling 3D seabed and distribution of sand, sand-clay mixture, and clay sediments within the interest area. The sand layer useful for mining in this area is strongly affected by channels stemming from Soai Rap river.

Keywords: *high-resolution seismic, textural attribute, bathymetry, color-blend*

1. Introduction

Reflection seismic method is useful in imaging geology boundaries when using exploiting interactions between seismic waves and difference of acoustic impedances (Ianniruberto et al., 2012, Bui Viet et al., 2013, Novak and Björck, 2002). Physics laws (i.e., Snell and Diffraction laws) can guide knowledge of seismic waves responding from the boundaries with underground structures. High resolution seismic reflection is especially compatible with research works for shallow marine sedimentology. Seismic waves emitted from a sub-bottom profiler can propagate downward to seabed, meet sediment formations, and bounce back to its fixed receiver. Smaller energy source comparing to the explosion seismic source, the high-resolution seismic method can only cover quite shallow depth investigations/ scale just around several tens of meters from the seabed.

The reflection signals reveal boundaries of sedimentary matters as mud, sand dunes, clay mixtures, Holocene structures, seabed, river channel sedimentation processes or even seagrass meadow distribution (Ianniruberto et al., 2012, Bui Viet et al., 2013, Le et al., 2020, Laws et al., 2019, Monnier et al., 2021). For improving the reflection seismic interpretation, computation of seismic attributes can be used for revealing many valuable structures or features hidden in abundant information raw seismic data. Overlay image of two attributes (i.e., seismic amplitude and its cosine of phase) can really help to interpret seismic horizons, faults, and channels (Le et al., 2016, Chopra and Marfurt, 2007, Zhao et al., 2015, Le et al., 2019).

We have applied seismic attributes to research sand dunes, young Holocene sediment and seabed by applying their different combinations. The interest area locates in Can Gio offshore, Ho Chi Minh City, Vietnam.

Research projects applied in Can Gio offshore, Ho Chi Minh City, Vietnam focus on seabed, young Holocene sediment and sand layers using high resolution seismic method (Le et al., 2020, Bui Viet et al., 2013, Le Ngoc Thanh et al., 2018). In our research, a workflow of processing seismic attributes from conventionally processed data is applied to 3D modelling sand dunes in Can Gio offshore, Ho Chi Minh City, Vietnam. Moreover, the attributes are color-blended to represent hidden features of each sediment features.

2. Study area

Can Gio District location is important in the socioeconomic development of Ho Chi Minh City because of its natural resources habitat (i.e., big rivers, mangrove Biosphere) (Bao Tuoi Tre, 2020). Can Gio as the southmost isolated island of Ho Chi Minh City has its area as 71,361 ha, containing one third of Ho Chi Minh City area and its 70% area is mangroves and rivers including Long Tau and Soai Rap ones and Its shoreline length is 20 km (People's Committee of District Can Gio Ho Chi Minh City, 2018). The data collection area is the extended southern area, in Can Gio district, Ho Chi Minh City, Vietnam (Fig. 1).

Late Cenozoic (KZ) sediments are widely distributed in Ho Chi Minh City. It is divided into strata, including Pliocene sediments, Early Pleistocene, Middle-Late Pleistocene, Late Pleistocene, and Holocene. The thickness of the late KZ deposits varies depending on the morphology of the rock foundation, ranging from a few tens to several hundred meters

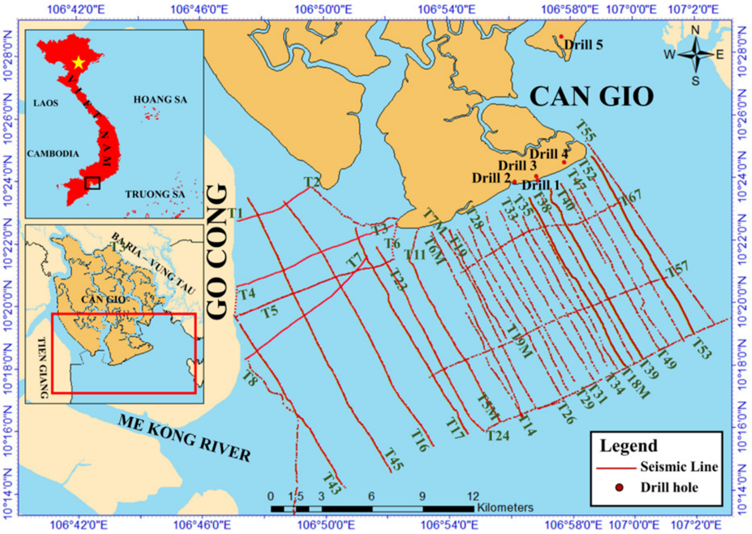

Fig. 1. Location of the survey area for research sediment structures in Can Gio, Ho Chi Minh City, Vietnam (Vietnam Department of Survey)

Rys. 1. Lokalizacja obszaru badawczego do badań struktur osadowych w Can Gio, Ho Chi Minh City, Wietnam (Wietnamski Departament Geodezyjny)

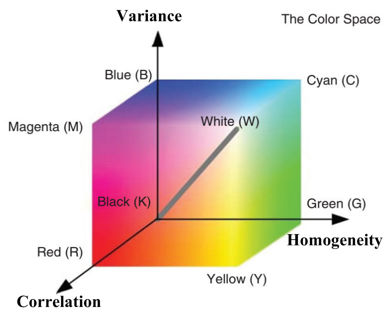

Fig. 2. A representation of three seismic texture attributes (Variance, Homogeneity, and Correlation) compatible with three axes (blue, green, red) of 3D subspace normalized color cube modified from the work of Al-Shuhail et al. (2017). The corners of the cube are shown as red, green, blue, cyan, magenta, yellow, black, and white

Rys. 2. Reprezentacja trzech atrybutów tekstury sejsmicznej (wariancja, jednorodność i korelacja) zgodnych z trzema osiami (niebieska, zielona, czerwona) trójwymiarowego znormalizowanego sześcianu kolorów podprzestrzeni zmodyfikowanego na podstawie prac Al-Shuhaila i in. (2017). Rogi sześcianu są pokazane jako czerwony, zielony, niebieski, cyjan, magenta, żółty, czarny i biały

(Nguyễn Xuân Bao et al., 1994, Hồ Chín et al., 2008, Le Ngoc Thanh et al., 2018, Kitazawa et al., 2006, Kitazawa, 2007).

In Can Gio, bedrock is characterized by old alluvium (Pleistocene sediments) (Nguyễn Xuân Bao et al., 1994, Hồ Chín et al., 2008, Le Ngoc Thanh et al., 2018, Kitazawa et al., 2006, Kitazawa, 2007). It has only a single outcrop at Giong Chua mountain, Thanh An commune. The ancient alluviums are not exposed to the surface, often locating at depths around tens of meters below the Holocene sediments. This ancient alluvial surface is basin-shaped having the great depth more than 40 m in the center of the district and shallower when moving to the sea (at the 30/4 Beach, its surface depth as about 18–20 m). Holocene sediments known as new alluvium are mostly dominant in the ground surface in Can Gio. The new Holocene alluvium includes middle Holocene marine sediments, intertidal sediments, wind-Giong sediments, marine-swamp sediments, river-sea sediments or tidal sediments (Le Ngoc Thanh et al., 2018).

Can Gio formation age is around 8000 to 7000 BP (David et al., 2018, Fujimoto et al., 2011) with the sediment supply of Saigon-Dong Nai River. Marine sediments in the study area were formed by the middle Holocene maximal transgression period (Le Ngoc Thanh et al., 2018). At that time, the sea covered most of the areas, except for the highlands of the ancient alluvium. The material left behind by the advancing sea is quite regular, continuous, and distributed under the receding marine sediments or younger sediments. Many shallow drillholes as the depth a few meters can meet the sediments. The marine sediments have layers of gray-green mud rich in biological remains.

Sand in Can Gio consists of two types, Giong sand and tidal sand (Le Ngoc Thanh et al., 2018). The Giong sand type includes continuous dunes located behind the shoreline. Material of the shore carried by the action of waves and other factors can form Giong sand type. Its heigh is ranging from 1 to 3 m over the surface. Giong sand can be active or inactive. The inactive ones are inland while the active one is set along the shoreline known as the new Giong field. New Giong runs from Dong Tranh cape to Ganh Rai cape and extends for more than 10 km, and its thickness is about 3.5–6.5 m. The other sand type is dependent on the tidal activity. The tidal beach with the lowest height includes sediment stripes around the fork, sea, especially bend of tide rivers. In the Can Gio shoreline, the tidal beach whose maximum thickness is around 3 m is upper soft clay zone (Le Ngoc Thanh et al., 2018).

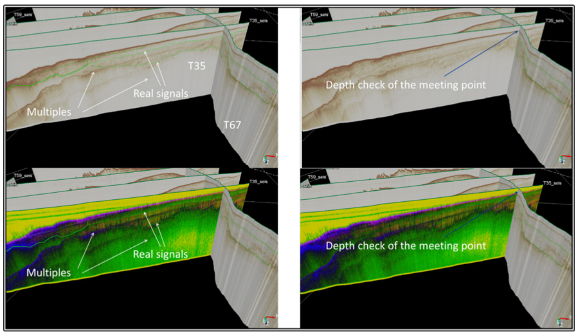

Fig. 3. Quality check of seismic data and 2D seismic interpretation. White arrows represent real signals that help formation of 2D horizons while similar depths are detected proving the excellent quality of the high-resolution seismic data

Rys. 3. Kontrola jakości danych sejsmicznych i interpretacji danych sejsmicznych 2D. Białe strzałki reprezentują rzeczywiste sygnały, które pomagają w tworzeniu horyzontów 2D, podczas gdy wykrywane są podobne głębokości, co dowodzi doskonałej jakości danych sejsmicznych o wysokiej rozdzielczości

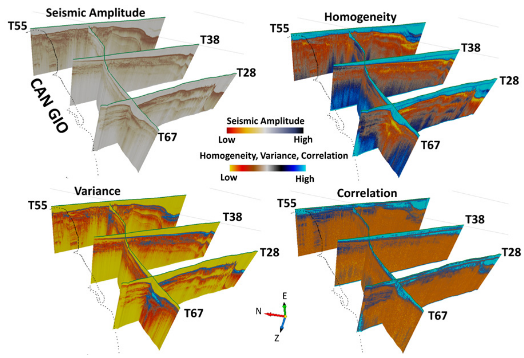

Fig. 4. Representation of 2D conventionally processed seismic amplitude and its seismic texture attributes as Homogeneity, Variance, and Correlation for the 2D seismic profiles T55, T38, T28, and T67

Rys. 4. Reprezentacja 2D konwencjonalnie przetworzonej amplitudy sejsmicznej i jej atrybutów tekstury sejsmicznej, takich jak jednorodność, wariancja i korelacja dla profili sejsmicznych 2D T55, T38, T28 i T67

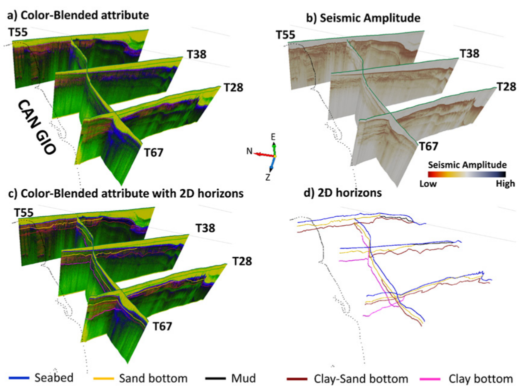

Fig. 5. Representation of 2D interpreted horizons overlaid with the color-blended representation of three seismic texture attributes as Homogeneity, Variance, and Correlation (a, c, d) and the conventionally processed seismic amplitude (b) for the 2D seismic profiles T55, T38, T28, and T67. Sand layer can be bounded by two 2D horizon top and bottom as seabed (blue) and sand bottom (yellow) lines

Rys. 5. Reprezentacja zinterpretowanych horyzontów 2D nałożona na mieszaną kolorystycznie reprezentację trzech atrybutów tekstury sejsmicznej, takich jak jednorodność, wariancja i korelacja (a, c, d) oraz konwencjonalnie przetworzonej amplitudy sejsmicznej (b) dla profili sejsmicznych 2D T55 , T38, T28 i T67. Warstwa piasku może być ograniczona przez dwie górne i dolne linie horyzontu 2D jako dno morskie (niebieskie) i dno piasku (żółte)

3. Methodology

Application of the high-resolution seismic method is well known for researching shallow subsurface marine structures (Bui Viet et al., 2013, Yutsis et al., 2014, Aiello et al., 2014, Le et al., 2020). Physics laws such as reflection, refraction, and diffraction have controlled the seismic wave propagation through the Earth environments.

For researching the shallow marine depth, the Sub-bottom profiler, namely SB-216 (EdgeTech, 2005) installed in a ship is used to measure the seismic vibration data. Data collection is conducted with 38 2D profiles covering the area up to 300 km square in 2017. The underground marine structures are imaged through researching characteristics of wavefield propagation (i.e., traveltime and amplitude) with the sources of frequency modulation having its length from 5 ms to 200 ms and frequency band from 2 to 16 kHz (EdgeTech, 2005). Going deep down to the earth, the seismic echoes from the reflectors are measured by specialized recording system (i.e., hydrophone) (Iannniruberto et al., 2012, Bui Viet et al., 2013, Novak and Björck, 2002).

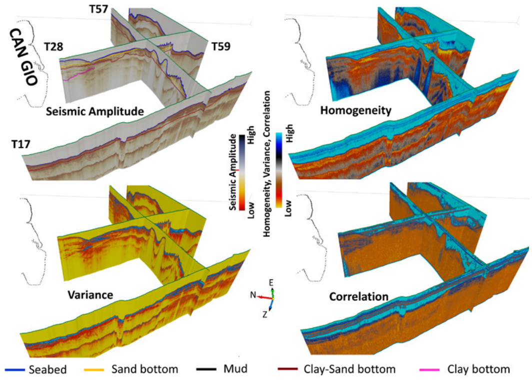

Fig. 6. Representation of 2D conventionally processed seismic amplitude and its seismic texture attributes as Homogeneity, Variance, and Correlation for the 2D seismic profiles T57, T59, T28, and T17

Rys. 6. Reprezentacja 2D konwencjonalnie przetworzonej amplitudy sejsmicznej i jej atrybutów tekstury sejsmicznej, takich jak jednorodność, wariancja i korelacja dla profili sejsmicznych 2D T57, T59, T28 i T17

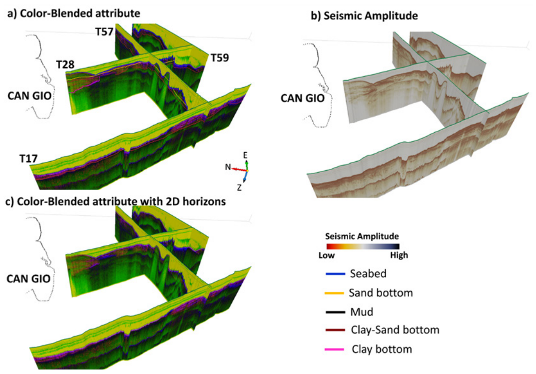

Fig. 7. Representation of 2D interpreted horizons overlaid with the color-blended representation of three seismic texture attributes as Homogeneity, Variance, and Correlation (a, c, d) and the conventionally processed seismic amplitude (b) for the 2D seismic profiles T57, T59, T28, and T17. Sand layer can be bounded by two 2D horizon top and bottom as seabed (blue) and sand bottom (yellow) lines

Rys. 7. Reprezentacja zinterpretowanych horyzontów 2D nałożona na mieszaną kolorystycznie reprezentację trzech atrybutów tekstury sejsmicznej, takich jak jednorodność, wariancja i korelacja (a, c, d) oraz konwencjonalnie przetworzonej amplitudy sejsmicznej (b) dla profili sejsmicznych 2D T57 , T59, T28 i T17. Warstwa piasku może być ograniczona przez dwie górne i dolne linie horyzontu 2D jako dno morskie (niebieskie) i dno piasku (żółte)

Prior data interpretation, two analysis stages are applied as processing and seismic attributes computing:

In data processing, transformation of raw data to interpretable data in 2D visualization is done with the help of the professional software packages, Reflexw (Sandmeier, 2020). Conventional routines such as Substract – DC – Shift and Divergent (div.) Compensation Gain are applied to all the 2D seismic profiles (Le et al., 2020, Sandmeier, 2020). The Compensation Gain filter helps to increase the weak amplitude of seismic signals in deeper part when the waves lose their energy because of spherical energy dissipation (Sandmeier, 2020).

OpendTect (dGB Earth Sciences, 2015) provides tools for computation of seismic attributes. The processed seismic data and its seismic attributes are mutual support for seismic horizons interpretation. In our research, representation of seismic textures attributes and their combination via color-blending are used to to reveal distinguished seismic patterns that reflect marine sediments (i.e., sand or mixtures of sand clay). The attributes are Variance, Homogeneity and Correlation.

3.1 Seismic Texture Attributes

2D horizons can be picked from strong seismic reflection amplitudes (Yilmaz, 2001, Le et al., 2020, Le et al., 2019, Le et al., 2016, Chopra and Marfurt, 2007). However, its seismic texture attributes play important roles in depicting many hidden geological features that the conventional seismic amplitude can miss. In our works, three texture attributes as Variance, Homogeneity, and Correlation (Le et al., 2019, Haralick et al., 1973, dGB Earth Sciences, 2015) are used for data interpretation. To process the texture attributes, two stages are following included:

(i) Calculation of the grey – level – occurrence Matrix (GLCM) (Hall-Beyer, 2007, Haralick et al., 1973, Wang, 2018). In this paper, the true seismic data (i.e., 2D matrix) can be rescaled into a new 32-bit integer data whose values range from 0 to (2^{32}-1). From equation 1, the new 32-bit data is namely matrix G(x,y) and GLCM matrix is $P_{i,j}$.

$$P_{i,j} = \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} \begin{cases} 1, & G(x,y) = i \text{ and } G(x+\Delta x, y+\Delta y) = j, \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

where x, y are spatial positions and Δx, Δy are offsets in x and y directions, respectively.

(ii) Specific equations for their texture definitions (Le et al., 2019, Haralick et al., 1973, dGB Earth Sciences, 2015):

$$\text{Variance} = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} (i-\mu_i)^2 P_{i,j} \tag{2}$$

$$\text{Homogeneity} = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} \frac{P_{i,j}}{1+|i-j|} \tag{3}$$

$$\text{Correlation} = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} \frac{ijP_{i,j}-\mu_x\mu_y}{\sigma_x\sigma_y} \tag{4},$$

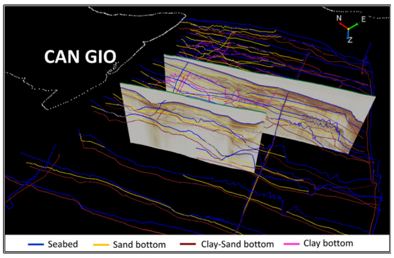

Fig. 8. Representation of 2D seismic horizons interpreted from the seismic sections. Blue lines represent seabed, yellow for bottom of sand layer, magenta for bottom of clay, and red for bottom of clay-sand mixture

Rys. 8. Reprezentacja poziomów sejsmicznych 2D zinterpretowanych na podstawie przekrojów sejsmicznych. Niebieskie linie reprezentują dno morskie, żółte dno warstwy piasku, karmazynowe dno gliny, a czerwone dno mieszanki gliny i piasku

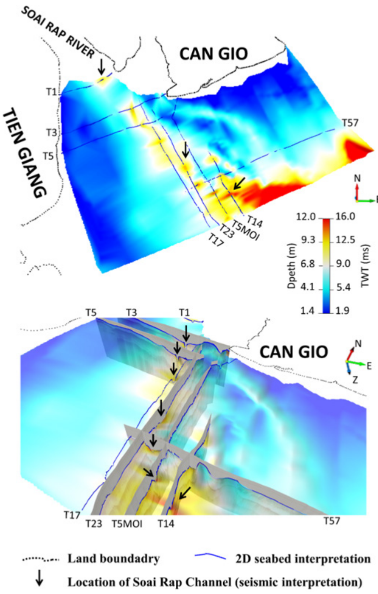

Fig. 9. 3D seabed represents geometry of Soai Rap channel (top and bottom images). The red color zones show its distinguished depth. For clarity, its positions can be detected through positions of black arrows

Rys. 9. Trójwymiarowe dno morskie przedstawia geometrię kanału Soai Rap (zdjęcia górne i dolne). Strefy koloru czerwonego pokazują jego wyróżniającą się głębię. Dla jasności jego pozycje można wykryć za pomocą pozycji czarnych strzałek

where $\mu_i = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} iP_{i,j}$; μ_x, μ_y, σ_x, and σ_y are the means and standard deviations for p_x and p_y (Haralick et al., 1973). p_x and p_y are sums of each row or column from the GLCM matrix $P_{i,j}$, respectively.

3.2 Color-blended Approach

The color-blended display technique is to form a color – blended representation that provides significantly clear detailed features (dGB Earth Sciences, 2015, Al-Shuhail et al., 2017, Chopra and Marfurt, 2007). Three seismic attributes as Variance, Homogeneity, and Correlation are rendered with specific color bands as red, green, and blue, respectively (Fig. 2).

The RGB model is commonly used on many visualization applications. The three attributes with each color are put into a RGB interface (Al-Shuhail et al., 2017). Each attribute is defined in the range of [0, 255] for 8-bit integer value. In other word, each RGB pixel have a scale of 24 bits. Then, each RGB value composed of three RGB elements can have $(2^8)^3$ = 16777216 colors that are shown in the Fig. 2.

3.3 Interpretation of 2D/3D Seismic Horizons

Interpretation of 2D seismic horizons for each type of sediment plays a key role in forming its 3D horizon. Understanding a sediment layer needs interpretation of its top and bottom 2D horizons.

A 2D seismic horizon is chosen from conformity of seismic waveforms in its seismic data or its similar seismic pattern (Le et al., 2016, Le et al., 2019, Yilmaz, 2001, Le et al., 2020). The similar seismic pattern can be extracted from the representation of seismic attributes as conventional seismic amplitude, texture attribute or even combination of two/three simultaneous attributes (i.e., color-blend attribute). Besides, multiple noises (i.e., Fig. 3) are cumbersome for interpreting seismic horizons, and they should be firstly detected before further interpretation.

The workflow for building a 3D surface consists of (i) a set-up of 2D interpreted seismic horizons and (ii) an interpolation algorithm. For the interpolation process, the Matlab built-in function, scatteredInterpolant.m (MathWorks, 2019) is used with linear approach. For converting two-way travel time (TWT) to depth domain, sound velocities are assumed to be 1500 m/s and 1550 m/s for sea water and shallow sediment environments, respectively (Le et al., 2020).

Data validity checking is important in deciding whether a 2D seismic line is good or not. For example, similar depths of two or three 2D seismic lines in their meeting points should be confirmed (Le et al., 2020) (see Fig. 3).

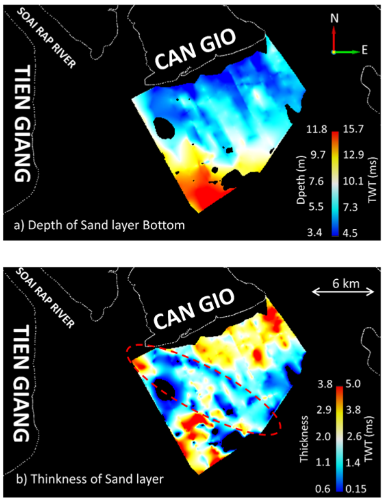

Fig. 10. Representation of the sand depth bottom (a) and its thickness (b). Note that existence of Soai Rap channel (stemming from Soai Rap river) can wipe out sand layer in the interest area. The red dashed ellipse refers to the sand zone with the smallest thickness

Rys. 10. Reprezentacja głębokości dna piasku (a) i jego miąższości (b). Należy zauważyć, że istnienie kanału Soai Rap (wynikającego z rzeki Soai Rap) może zniweczyć warstwę piasku w obszarze zainteresowania. Czerwona przerywana elipsa odnosi się do strefy piasku o najmniejszej miąższości

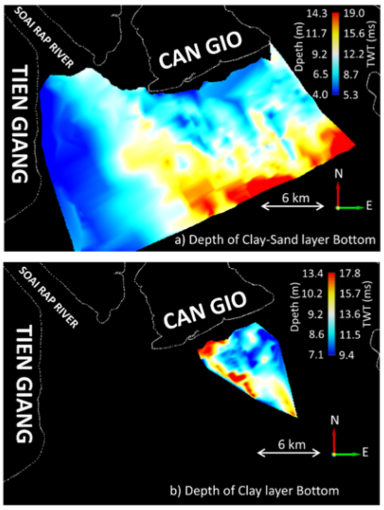

Fig. 11. 3D Horizons of the clay-sand mixture and clay bottom

Rys. 11. Horyzonty 3D mieszaniny iłowo-piaskowej i dna ilastego

4. Results and discussion

Seabed interface is the easiest to pick because of its visible reflection seismic amplitude. There does not need big effort to interpret the 2D horizons and 3D interpolation can be straightforward calculated from the 2D results. 2D horizons for seabed shown can represent boundaries of water volume and marine sediments. The seismic amplitude, its seismic attributes as textures or color blend can quickly show the 2D horizons for each seabed in any 2D seismic line (i.e., See Figs. 4 and 5). The water volume is visualized through the first prominent white zones from water level in seismic amplitude section, the cyan ones in Homogeneity and Correlation sections, the first yellow zone in Variance section and Color-blend sections (Figs. 4, 5 and 6).

For interpretation of other horizons relating to different sediments, we have calculated different seismic attributes. Figs. 5 to 8 are used to represent images of seismic amplitude input and the seismic textures as Homogeneity, Variance, and Correlation. The interpreted information are horizons of seabed, sand Bottom, clay-sand mixture (Mixture of Sand and Clay components), mud, and clay.

We have used different seismic attributes for specifying the bottom of each sediment type. Color-blended attribute and seismic amplitude are very useful in categorizing them. One example shown in Fig. 8 can show the different pattern of sand and clay type in both seismic and color blended images. Then, all 2D horizons of the sediments can be shown in Fig. 9, that would be input for 3D interpolation.

4.1 Seabed interpretation

3D interface interpolated from the 2D horizons (Fig. 9) can reflect bigger view of Soai Rap channel that was indicated in Thuan Nguyen et al 's work (2022). Overall, the sea depth looks gradually increasing from 2 m to 16 m when going far from the Can Gio shoreline although there're some channels wandering near the shoreline. According to the 3D seabed interpretation (see black arrows in Fig. 9), the direction of the Soai Rap channel is strongly influenced by the Soai Rap river.

4.2. Sand and other sediments' interpretation

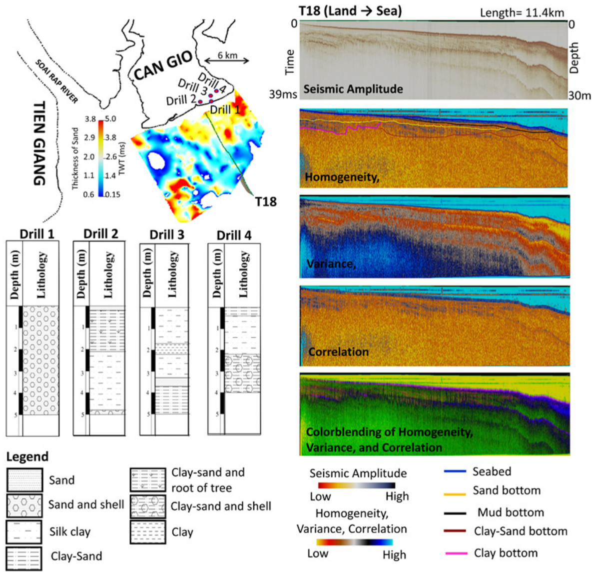

Fig. 12. Representation of 3D Horizons of the Sand thickness, the seismic data for the 2D profile T18, and information in the four drills (Drill 1, 2, 3, and 4). Note sediment types in Drills 1, 2, 3, and 4 are extracted from documents of Ho Chi Minh City Institute of Resources Geography, VAST, Vietnam (Le Ngoc Thanh et al., 2018)

Rys. 12. Reprezentacja horyzontów 3D miąższości piasku, dane sejsmiczne dla profilu 2D T18 oraz informacje z czterech odwiertów (wiertło 1, 2, 3 i 4). Uwaga typy osadów w wiertarkach 1, 2, 3 i 4 pochodzą z dokumentów Ho Chi Minh City Institute of Resource Geography, VAST, Wietnam (Le Ngoc Thanh et al., 2018)

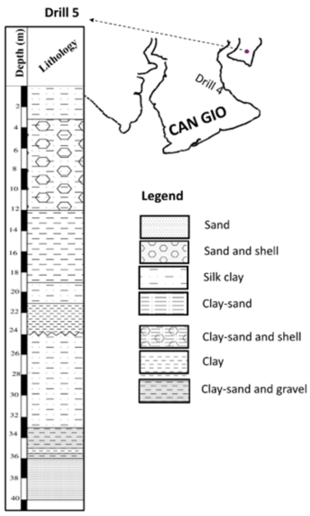

Fig. 13. Sediment information extracted from Drill 5. Note that information of sediment types are extracted from documents of Ho Chi Minh City Institute of Resources Geography, VAST, Vietnam (Le Ngoc Thanh et al., 2018)

Rys. 13. Informacje o osadach pobrane z wiertła 5. Należy zauważyć, że informacje o typach osadów pochodzą z dokumentów Instytutu Geografii Zasobów Miasta Ho Chi Minh, VAST, Wietnam (Le Ngoc Thanh i in., 2018)

We focused on sand, clay, clay-sand mixture signatures where we could build 3D horizons (Figs. 10 and 11). The sediment information for the seismic layer interpretation can be extracted from near drill holes in the shoreline (Le Ngoc Thanh et al., 2018) (Figs. 12 and 13).

From the interpretation of the drill holes (Figs. 12 and 13), clay layer is upper the Clay-sand Mixture layer. Imaging sand distribution is important because of its value. The near shoreline drill hole in Can Gio peninsula can confirm the sand existence in the shallow depth that is compatible with seismic data. For the deepest drill hole 5 with 40 m in Thanh An commune (Fig. 13), the sand, clay, clay-sand mixture are existed that can be used for interpreting the seismic data.

According to sediment interpretation from the color-blend attribute (i.e., Figs 3, 4, 5, and 12), sand looks like respond to green components, clay looks mix of all three colors (green, red, and blue), and clay-sand are seen mostly blue. Note that picking all horizons needs to visualize different pattern of seismic attributes including the conventionally processed seismic and seismic attributes.

For the sand distribution (Fig. 10), the sand erosions may exist because of the water flows of Soai Rap River and Soai Rap channel. That is, two different zones of sand are separated by the zone of the smaller thickness (See dashed red ellipse in Fig. 10) which shares the similar location of Soai Rap channel (See black arrows in Fig. 9).

The clay-sand mixture sediment has tendency to exist in the entire interest area while the clay layer just appears in the margin of Can Gio Peninsula (Fig. 11).

4. Conclusion

3D image of seabed and sand sedimentation in area of Can Gio district, Ho Chi Minh city, Vietnam can be presented using application of 2D high resolution seismic data. We have applied different seismic attributes for imaging sediment types, especially sand zone. 2D seismic horizons are the input for building 3D horizons. Distinguished Soai Rap channel can be further expressed in the bigger picture. We can notice that seismic interpretation of the sand, clay, and clay-sand mixture layers is compatible to information of drill holes in Can Gio.

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6. Conflicts of Interest

The authors declare no conflict of interest.

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Zastosowanie atrybutów sejsmicznych odbić o wysokiej rozdzielczości do badania struktur 3D płytkiej geologii morskiej

W badaniach sedymentologicznych i batymetrycznych rzek konieczne jest podejście sejsmiczne o wysokiej rozdzielczości wyposażone w profiler poddenny. Różnicę impedancji akustycznych wynikającą ze zmienności warstw stratygraficznych osadów można zwizualizować za pomocą dynamicznych drgań sejsmicznych. W środowiskach morskich wykrywanie młodych osadów, takich jak wydmy lub błoto, mieszanki piasku i gliny oraz formacje gliny, może pomóc decydentom we wprowadzaniu polityk lub przepisów dotyczących bezpieczeństwa transportu wodnego, a także infrastruktury budynków cywilnych. Zmierzyliśmy, przeanalizowaliśmy i zinterpretowaliśmy ogromny zbiór profili sejsmicznych 2D pod dnem w Can Gio na morzu w mieście Ho Chi Minh w Wietnamie, aby zrozumieć jego płytkie, podpowierzchniowe młode złoża. Nasze podejście polega na połączeniu trzech kluczowych atrybutów tekstury sejsmicznej (tj. Korelacji, Wariancji i Jednorodności) w reprezentacji atrybutu mieszania kolorów w celu wybrania wyróżniających się cech geologicznych. W naszym wyniku, poziomy sejsmiczne 2D reprezentujące granice różnych typów osadów mogą stanowić doskonały materiał wejściowy do modelowania 3D dna morskiego i rozmieszczenia piasku, mieszanki piaskowo-gliniastej i osadów gliniastych w obszarze zainteresowania. Na warstwę piasku przydatnego do wydobycia na tym obszarze duży wpływ mają kanały wychodzące z rzeki Soai Rap..

Słowa kluczowe: *sejsmika wysokiej rozdzielczości, atrybut tekstury, batymetria, mieszanie kolorów*