Improvement of Seismic Research for Petroleum and Gas Hydrate Exploration in Vietnam

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Abstract

Located in Southeast Asia, Vietnam has a diverse and complex geology. Seismic methods have solved many different geological tasks such as interpreting geological structure, petroleum and mineral exploration, research gas hydrate, etc.
In this report, we present some achievements using Seismic methods for petroleum exploration to find not only structural traps but also stratigraphic traps in sedimentary basins, in non-traditional fractured granite basement reservoirs, and in the initial stage of gas -hydrate exploration. Seismic acquisition methods such as 3D / 4C have been applied effectively. Advanced seismic processing and interpretation methods have been used, such as applying seismic filters (T-P, Radon, SRMA…), seismic imaging (Pre-stack Migration/ PSTM, Control Beam Migration/CBM), Seismic Inversion (SI), Amplitude Versus Offset Analysis (AVO), Seismic Sequence Stratigraphy, Seismic Attributies, Artificial Neural Network (ANN), etc. The results seismic interpretation, thereby which lead to enhansed effectiveness of oil and gas exploration programs.

Keywords: processing and interpretation of seismic data in Vietnam, stratigraphic traps, seismic attributes, fractured granite reservoir, gas hydrates

1. Introduction

The continental shelf of Vietnam comprises a structural unit of the continental crust called the Kontum - Borneo plate. This was consolidated from the end of Mesozoic, the beginning of Pre-Tertiary during the opening of the Vietnamese East Sea. The formation of transitional oceanic crust thus formed comprises the basic tectonic framework of South East Asia. The geological evolution resulted in the formation of sedimentary basins with both petroleum, gas hydrate potential on the continental shelf and Vietnamese East Sea region (Gwang, et al, 2001). The distribution of sedimentary basins in the continental shelf of Vietnam is shown in figure 1.

On the continental shelf of Vietnam, oil and gas have been produced from Eocene, Oligocene, and Miocene complexes and from Pre-Cenozoic fractured basement rocks. New technology has been applied to improve the efficiency of seismic processing and interpretation for oil and gas exploration focusing on complex stratigraphic traps, fractured granite basement reservoirs, gas hydrates in deep waters (Al-sadi, 2016; Nanda, 2016).

2. Enhancement of seismic data analysis for stratigraphic traps

Many dome shaped structural traps exist in the sedimentary basins of the Vietnamese. However, more complex stratigraphic traps exist in flank pin¬ch-out and/or onlap. Stratigraphic traps are related to sediment depositional, environmental changes, or erosion, which are then covered by low permeability layers. They are usually small, and the geological data needed to recognize this type of play is often of limited extent and quality. To solve this problem, the application of seismic sequence stratigraphy and seismic attributes has proven to be effective (Tan et al, 2018).

Seismic sequence stratigraphy is based on analysis of patterns of seismic reflectors and of sequences and system tracts using a depositional sequence model as the main interpretation framework (Catuneanu, 2006). By analyzing reflection patterns, seismic reflection terminations, and seismic facies, etc., once can apply seismic sequence stratigraphy to discriminate stratigraphic units. This includes identifying stratigraphic types such as pinch-outs, and alluvial fans and predicting lithology distribution. The results obtained from analyzing seismic data in the flank of Southeast Cuu Long Basin clarify the presence, distribution and sedimentary facies of stratigraphic traps (Chuc et al, 2018). Typical stratigraphic pinch-out trap in the Southern margin of Cuu Long basin is shown in figure 2.

A seismic section interpreted by seismic stratigraphy with sedimentary sequence, system tracts and stratigraphic traps is shown in figure 3. The facies pattern and its external form in figure 4 reveal that the sediments were deposited during regression of water level at a time of high depositional energy. Out traps were formed due to the tapering of sand layers landward or toward the horst, which these sand layers were overlaid by finer-grained sediment deposited in the high stand stage of water level. These formed lateral and top seals for the traps.

Seismic attribute can be used to interpret the depositional environment as well as to identify internal patterns in stratigraphic units. Many seismic attributes (RMS amplitude, spectral - decomposition, seismic inversion, average instantaneous phase, etc.) have been applied in this area (Chopra

Fig. 1. The sedimentary basins in the continental shelf of Vietnam
Rys. 1. Baseny sedymentacyjne na kontynentalnym szelfie Wietnamu

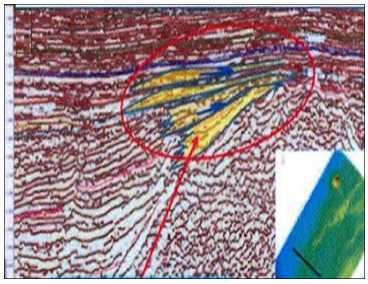

Fig. 2. Seismic image of stratigraphic pinch-out trap in the southern margin of Cuu Long Basin
Rys .2. Obraz sejsmiczny stratygraficznej pułapki typu pinch-out na południowym brzegu Basenu Cuu Long

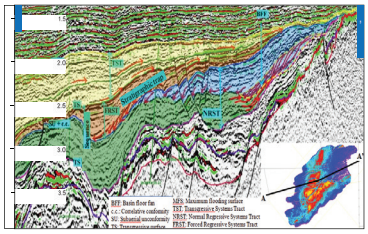

Fig. 3. Seismic section interpreted by seismic stratigraphy showing sedimentary sequence, system tracts and stratigraphic traps in NE Cuu Long Basin
Rys. 3. Sejsmostratygraficzna interpretacja sekcji sejsmicznej pokazująca sekwencję sedymentacyjną, system komunikacyjny oraz pułapki stratygraficzne w NE części Basenu Cuu Long

and Marfurt, 2008; Tan et al, 2018). RMS amplitude in the study area shows facies changing from delta plain to delta front, and delta slope. These deltaic sand body stratigraphics traps developed, an extensive fan – during the low stand stage of water level (Fig. 5a). The average instantaneous phase attribute (Fig. 5b) zone of seismic phase change which occurs at the approximate boundary of the upper part of the Oligocene fan. The fan-shaped amplitude anomalies are interpreted to be the sand distribution that coincides approximately with the highest thickness area observed on the isochore map. The Spectral Decomposition map in 25 Hz of Lowstand System Tract/LST of the upper part of the Upper Oligocene is shown in figure 6. Note the seismic at the approximate boundary of the upper part of the Oligocene fan.

3. Study of reservoirs in fractured zones of granite basement

In Vietnam, oil and gas are not only found in sedimentary environments, but also in fractured zones of granite basement rocks. Oil and gas migrated from the source rock in sedimentary environment through faults and accumulated in the fractured zones of the uplifted zone of granite basement (Fig.7).

The unique characteristics of basement reservoirs require a careful evaluation and unique processing and interpretation methods. Identifying fracture zone distribution is important for extrapolation of favorable exploration targets. However, because of the absence of stratified, coherent reflectors, illumination of basement faults is more problematic than illumination of faults within the sedimentary sections. With complex interference, patterns, related to non-layered and steeply dipping faults and fractures, it is important to enhance seismic data processing, reducing noise and multiple reflections (Ha et al, 2009; Tan et al, 2016). To solve the above problems, the following data processing methods were implemented and found to be effective:

– Applied seismic filters for removing multiple reflections from strong reflection surfaces in sediments and revealing the weaker seismic signals inside basement.

Seismic signals from fractured granitic basement are of very low quality, and contain a lot of noise and multiples.

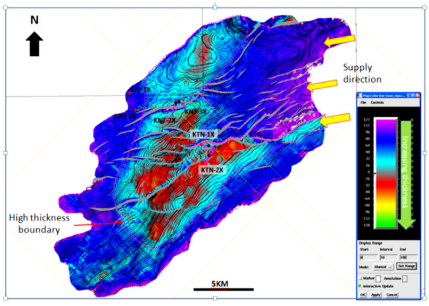

Fig. 4. Isochore map showing thickness changing of fan-shaped distribution
Rys. 4. Mapa izochor ilustrująca zmiany miąższości stożka rozprowadzającego w kształcie wachlarza

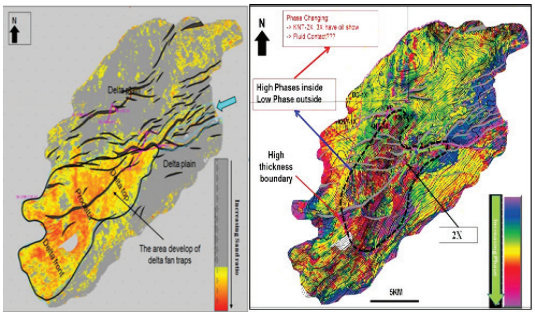

Fig. 5. RMS amplitude map (a) and Average Instantaneous Phase map (b) of the Upper part of Oligocene in the study area
Rys. 5. Mapa amplitudy RMS (a) i Średniej Fazy Chwilowej (b) górnego oligocenu na obszarze badań

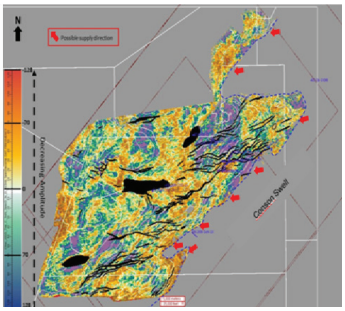

Fig. 6. Spectral Decomposition map in LST (Sequence C) of the Upper Oligocene
Rys. 6. Mapa Dekompozycji Spektralnej LST (sekwencja C) górnego oligocenu

Multiples are related to strong reflection surfaces of the Miocene, Oligocene sediments, and top of basement. Multiple suppression methods can be used based on either prediction criteria or normal move-out differential to improve the weak primary reflections. Using seismic filters enhances the signal-to-noise ratio and improves seismic signals significantly. In the Cuu Long, using filters such as f-k, Tau-p and Radon transform for multiple attenuation is not only successful in improvement of seismic signals for sedimentary units but also works well in fractured, non-layered and structural complex basement. Comparison of a seismic section before and after reprocessing with applying seismic filters shows images of fault and fractured in the basement more clearly (Fig.8),

– Enhanced efficiency of seismic migration for imaging steeply dipping fault and fracture plane events and using of seismic attributes for further delineate and map out fractures.

Migration of seismic data corrects reflection from dipping surface to their true positions, collapses diffractions, increases spatial resolution and resolves areas of complex geology. Kirchhoff Migration is a seismic migration methods that id used extensively in both layered environments and non-layered fractured basement by summing the energy along diffraction curves. The advantage of this type of migration is that it can enhance signals of steeply dipping objects and moderate lateral velocity variations. In a single-arrival migration algorithm, only one arrival is imaged, depending on certain predefined criteria. In order to reduce this disadvantage, Controlled Beam Migration (CBM) can handle multi-arrival ray paths, and preserve steeply dipping reflections, resulting in a cleaner image. Figure 9 shows that improved imaging by CBM is allows a better understanding of the orientation, spacing and potential connectivity of the fracture zones within basement.

For further identification of fault signature, beside dynamic attributes (amplitude, frequency, spectrum). Geometrical attributes have been applied to well-established vector attributes including structural dip and azimuth and amplitude energy gradients to provide greater interpreter interaction.

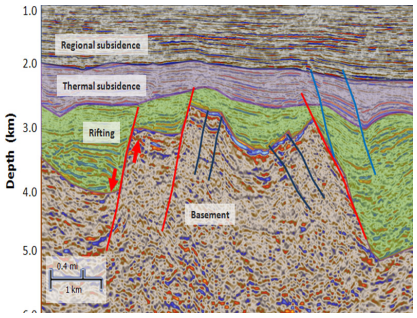

Fig. 7. The fractured granite basement traps in Cuu Long Basin
Rys. 7. Pułapki w spękanym granitowym podłożu w Basenie Cuu Long

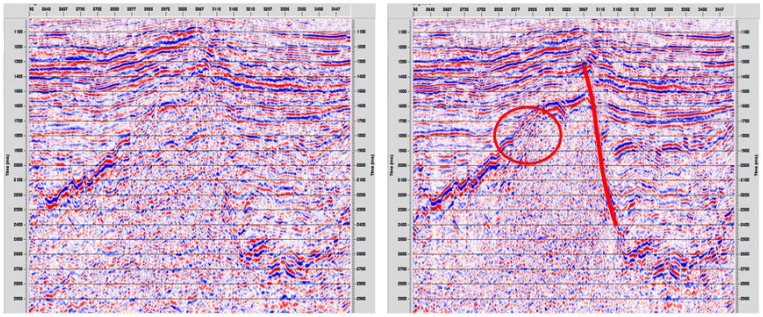

Fig. 8. Seismic section before (a) and after (b) reprocessing with applying seismic filters
Rys. 8. Sekcja sejsmiczna przed (a) i po reprocessingu z wykorzystaniem filtrów

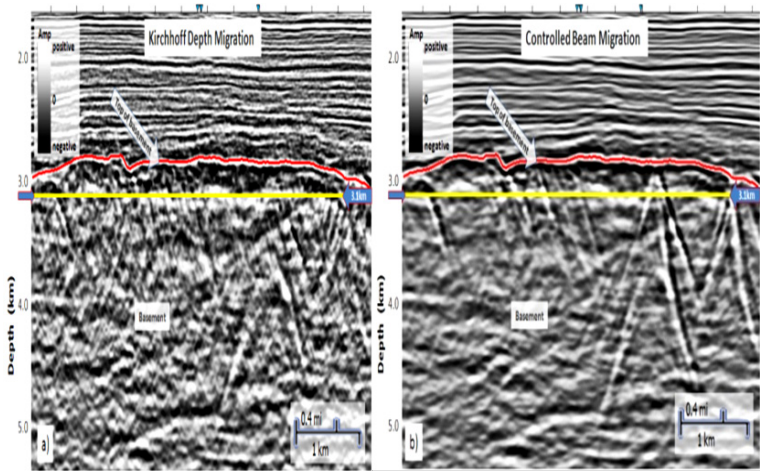

Fig. 9. Seismic section with Kirchhoff Migration (a) and CBM (b)
Rys. 9. Sekcja sejsmiczna po migracji Kirchhoffa (a) oraz CBM (b)

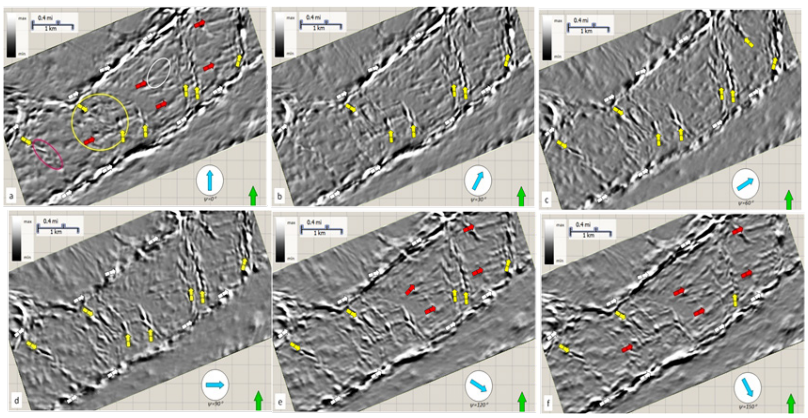

Fig. 10. Improving image fault and fractured basement by using Geometrical Attributes
Rys. 10. Poprawa obrazu uskoku i spękanego podłoża przez zastosowanie Atrybutów Geometrycznych

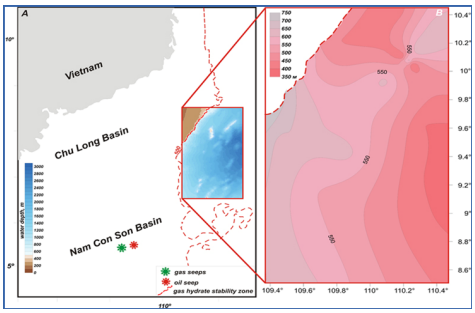

Fig. 11. Methane Hydrate Stability Zone in Vietnam
Rys. 11. Strefa stabilizacji hydratów metanu w Wietnamie

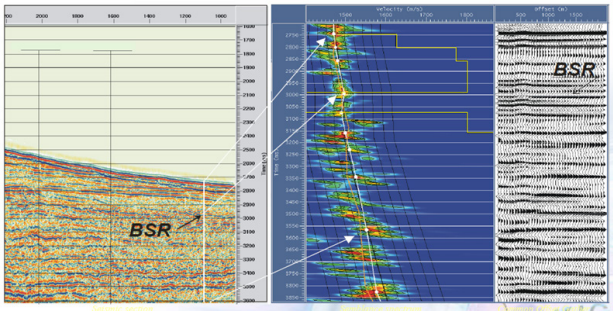

Fig. 12. Velocity analysis related to the Bottom Simulating Reflector (BSR)
Rys. 12. Analiza prędkości w odniesieniu do spągowego poziomu odbijającego (BSR)

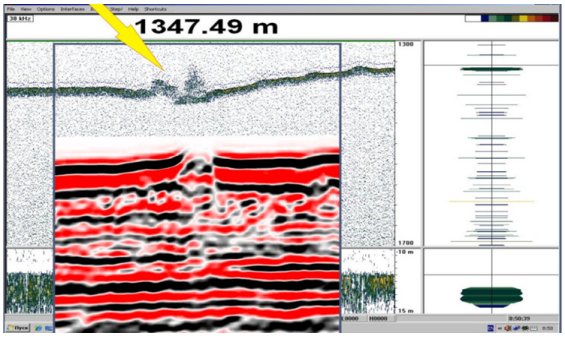

Fig. 13. Echo-sounder and seismic data correlations
Rys. 13. Korelacja danych sejsmicznych i zapisu echo-sondy

By mathematically generating simple axis rotations and projecting the two orthogonal dip or energy gradient components along the surfaces can be clearly illuminated. Figure 10 shows that using Geometrical Attributes clearly two main fault directions inside the basement and permite imaging of fracture zones between the faults.

4. Introductory Study of Gas Hydrates in Vietnam

Gas hydrates are the accumulations of methane (natural gas) trapped in ice-like structures with water. They represent an immense energy resource underlying large portions of the world's marine continental shelves and Arctic continental areas (Collet, 2002; Yuri, 2010). Figure 11 shows the area with favorable conditions for formation and existence of gas hydrate in the Vietnamese East Sea.

Gas hydrate has very different characteristics compared to traditional exploration objects. They are formed under high pressure and low temperature conditions, so they exist only in shallow layers of the seabed in deep waters, with complicated geological conditions. In recent years, much research has been conducted to ident ify the signs of gas hydrate potential within Vietnam economic water area, with surveys using a combination of methods (Westbrook et al, 2008) such as High Resolution Seismic (HRS), Multibeam Echo Sounding, Hydro Acoustic, Gravity Corer, Water Sampling, and so on. Seismic data is processed based on algorithms that use SRMA, Tau-P, Radon, FX filters, Pre-stack migration, and seismic attribute analyses (Ojha and Sain, 2009) the hydrates only exist in the shallow layers of the seabed in deep waters high frequency seismic is very effective. The features associated with gas hydrates that these methods reveale include Bottom Simulated Reflected (BSR), Gas Hydrate Stability Zone (GHSZ), blank zones (BZ), channels, pockmark, upper sedimentary cover structures, and fracture zones and faults, serving as pathways for gas-saturated fluids to migrate upwards. example of velocity analysis related to the Bottom Simulating Reflector (BSR). The correlation of Echo-sounder and seismic data documents shows the signal typical of pockmarks at a depth

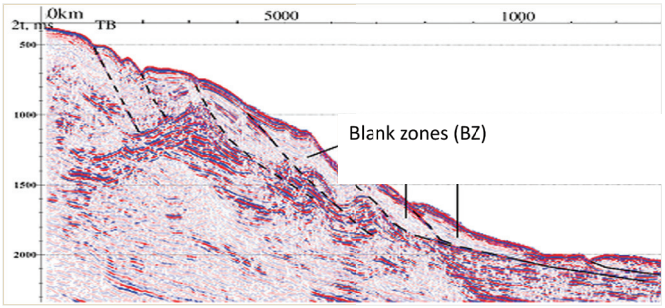

Fig. 14. Blank zones in the seismic section in the continental shelf of Vietnam
Rys. 14. Puste strefy na sekcji sejsmicznej na kontynentalnym szelfie Wietnamu

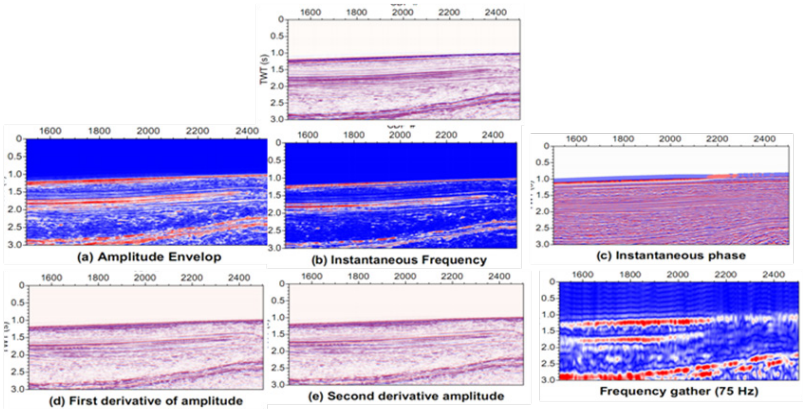

Fig. 15. Seismic attributes for high potential of location of BSR
Rys. 15. Atrybuty sejsmiczne ilustrujące strefy o wysokim potencjale BSR

of 1347.54 m (Fig. 13). The blank zone in the seismic section in the eastern slope of the continental shelf of Vietnam is shown in figure 14. The result of seismic attribute analyses (Amplitude Envelope, Instantaneous Frequency, Instantaneous phase, first derivative of amplitude, second derivative of amplitude and frequency gathered at 75Hz) shows high potential of location of BSR at 1.8s TWT. This result needs to be integrated with geochemistry, geothermal and sea-bottom temperature data (Fig. 15).

5. Conclusions

The Vietnamese East Sea has many sedimentary basins with petroleum and gas hydrate potential. In addition to common targets such as structural traps, there are also non-traditional targets such as stratigraphic traps, fractured basement traps, and gas hydrates in the deep sea. With the application of seismic sequence stratigraphic and seismic attributes analysis, we can identify the existence, distribution and characteristics of stratigraphic traps in the sedimentary basins' margin, contributing to increased accuracy in the assessment of oil and gas potential. Efficiency improvements in 3D seismic data processing using Radon, Tau-P filters, PSTM, CBM, and applying seismic attributes reveals zones of faults and fracture inside basement related to oil and gas traps. The initial survey results in Vietnam's deep sea waters reveal the existence of Gas Hydrate resources (BSR, GHSZ, pockmarks, etc.) and further research is needed.

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Poprawa badań sejsmicznych w poszukiwaniu ropy naftowej i hydratów gazu w Wietnamie

Położony w Azji Południowo-Wschodniej Wietnam ma różnorodną i złożoną geologię. Metodami sejsmicznymi rozwiązano wiele różnych zadań geologicznych, takich jak interpretacja struktury geologicznej, poszukiwania ropy naftowej i minerałów, hydratów gazu itp.

W niniejszym artykule przedstawiono niektóre osiągnięcia w których wykorzystano metody sejsmiczne do poszukiwań ropy naftowej, w celu określenia zaburzeń strukturalnych, a także stratygraficznych w basenach osadowych, w nietradycyjnych zbiornikach granitowych oraz w początkowej fazie eksploracji gazu i hydratów. Skutecznie zastosowano metody akwizycji sejsmicznej 3D/4C. Zastosowano zaawansowane metody przetwarzania i interpretacji danych sejsmicznych, takie jak stosowanie filtrów sejsmicznych (TP, Radon, SRMA), obrazowanie sejsmiczne (Migracja / PSTM, Migracja wiązki kontrolnej / CBM), Inwersja sejsmiczna (SI), Amplituda kontra przesunięcie (AVO), stratygrafia sekwencji sejsmicznych, atrybuty sejsmiczne, sztuczna sieć neuronowa (ANN) itp. Wyniki interpretacji sejsmicznej pozwalają na osiągnięcie zwiększonej skuteczności programów poszukiwania ropy i gazu.

Słowa kluczowe: przetwarzanie i interpretacja danych sejsmicznych w Wietnamie, pułapki stratygraficzne, atrybuty sejsmiczne, spękany granit – skała zbiornikowa, hydraty gazowe