Gas Hydrate Detection Based on High Resolution Seismic Data in the Southeastern Offshore of Vietnam

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Abstract

Gas hydrates are the accumulations of methane (natural gas) trapped in ice-like structures with water. Gas hydrates represent an immense energy resource underlying large portions of the world's marine continental shelves. Vietnam has a large continental shelf area, in the deep water zone with suitable low temperatures and high pressure, which is suitable for the formation and existence of potential energy source of Gas Hydrate (GH).

The application of High-Resolution Seismic method (HRS) plays an important role in exploring for Gas Hydrate. The enhancement of HRS research such as optimal short - reception conditions and advanced data processing suitable for Gas Hydrate in shallow layers below the seafloor, allows for determining the geological factors related to Gas Hydrate's existence in the deep water area. Advancements in data processing technology, such as noise filters (Radon, F-K, SRMA, Tau-P..), seismic attributes analysis, seismic migration, AVO, seismic inversion, pre-stack seismic data and AI technology … allow to identify of the signs of Gas Hydrate presence, such as Bottom Simulated Reflector (BSR), Gas Hydrate Stability Zone (GHSZ), Pockmark, Chimney, etc.

This paper presents some of the results obtained from applying High-Resolution Seismic method to predict the distribution of Gas hydrate in the Southeastern offshore of Vietnam.

Keywords: *gas hydrate, high resolution seismic, Gas Hydrate Stability Zones/GHSZ, Bottom Simulated Reflector/BSR*

1. Features of the east sea area related to the existence of gas hydrate

Gas hydrates are formed under high pressure and low temperature conditions, so they exist only in shallow layers of the seabed in deep waters with natural gas potential and favorable geological factors.

a. Geological features

The documents obtained in many areas in the Southeastern offshore of Vietnam Sea and adjacent areas have demonstrated the existence of gas hydrates in areas between and below the continental slope with seabed depths of about 700 - 2500m.

The tectonic features, the operation of fault zones, especially young fault systems, volcanic activity have important implications for the formation and existence of Gas hydrate (Huaishan, 2002; Thakur, 2016; Tan, 2019). The tectonic feature of the East Vietnam Sea is the result of the impact of the Indian, Australian and Pacific plates on the Southeast edge of the Eurasian continent, combined with the spreading and development of the East Sea.

Newly developed young faults or reactivated older faults cut through Pliocene - Quaternary mainly in the NE-SW and N-S directions. The system of young faults is the favorable structural elements for leading gas from the deep up to accumulate into gas hydrate. Along the western slopes of the East Sea is where young volcanoes thrive, including young mud volcanoes, which relate to the sources forming gas hydrates.

The deep water area in the East Sea has a sea level depth of about 300-3500m. Most of the seabed topography has structural directions NE-SW and sub-latitudes, coinciding with the East Sea spreading direction, which is favorable for the formation of underground plateaus, uplift zones, turbidite sediments, mud diapirs and wedge encroachment. In the continental slope, the topography has a sudden change, creating quite steep terrains favorable for the formation of turbulent flow structures; the bottom sediment fan is related to the characteristics of the existing areas gas hydrate. Figure 1 is a seismic section of deep water areas associated with lightning diapir and volcanic activity possibly related to gas hydrates. The map of the Gas Hydrate forecast location in the East Vetnam Sea and study area is shown in Figure 2.

b. Temperature and pressure characteristics

With the characteristics of temperature, pressure and mineralization of seawater in the Vietnam East Sea, the top gas hydrate zone (TGHZ) at a depth of 500m from the seabed has a temperature of about 7.8°C. The thickness of the gas hydrate stability zone increases gradually from the shelf slope (0–120m) towards the center of the East Sea (up to 200m or thicker). With a depth of about 100–200m, the temperature changes from 13-20°C, at a depth of 300–500m, the temperature of the seabed changes in the range of 10.5–7.5°C, at a depth of 1000–3000m the temperature changes in the range of 5.0–2.5°C. In the deeper depressions of the East Sea, the temperature can drop below 2°C. With the characteristics of temperature, pressure and mineralization of seawater in the East Sea, the gas hydrate stability zone at a depth of 500m from the seabed has a temperature of about 7.68°C. Figure 3 is a section temperature forecasting model of Pliocene – Qua-

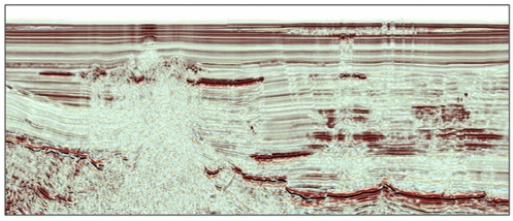

Fig. 1. Seismic section of deep water areas associated with lightning diapir and volcanic activity possibly related to gas hydrates

Fig. 2. The map of Gas Hydrates forecast location and study area in the East Sea of Vietnam

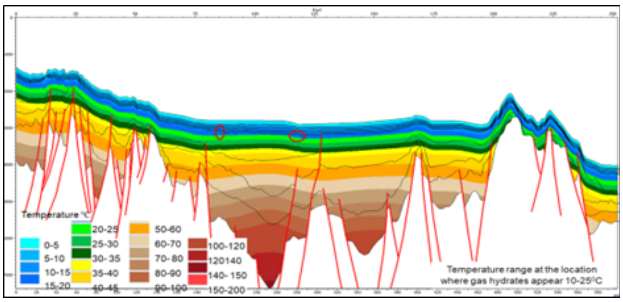

Fig. 3. The secton temperature forecasting model of Pliocene – Quaternary sediments in Phu Khanh marine at the present time

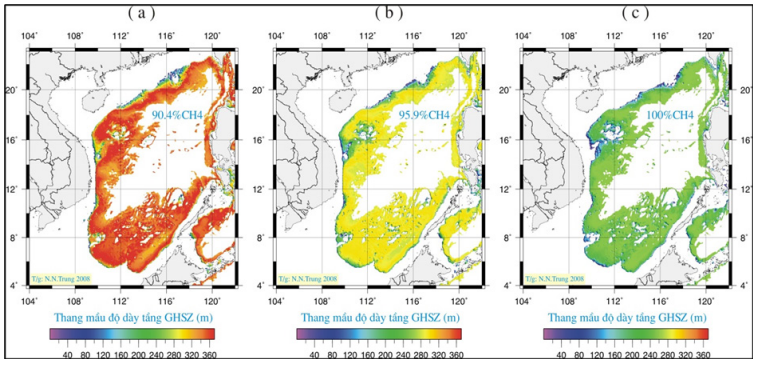

Fig. 4. Thickness map of gas hydrate stable layer (GHSZ) calculated for gas hydrates formed from natural gas. a. Content 90.4% CH4, b. Content 95.9% CH4, c. 100% CH4

ternary sediments on a line in Phu Khanh basin and Figure 4 is a thickness map of gas hydrate stable layer (GHSZ) calculated for gas hydrates formed from natural gas (Trung, 2012).

2. Highresolution seismic exploration for gas hydrate in Vietnam

In Vietnam today, initially conducting research, survey and search for Gas Hydrates in deep sea areas. The geophysical methods used include High Resolution Seismic (HRS), Multibeam Echo Sounding, Hydro Acoustic, Gravity Corer, etc. in which Multichannels High-Resolution Seismic methods (MHRS) play a dominant role (Hyndman, 1992; Thakur, 2010).

The GH is located in the shallow layers of the seabed in deep waters, in the gas hydrate survey, the source needs to generate short wavelength, high frequency pulses. The seismic source system uses a GI Airgun with a source pressure of 2000psi, the distance between two consecutive explosion points is 25m, the depth of the source is 3m. The receiver system has a length of 1200m, with 96 channels, the distance between the channels is 12.5m, the depth of the receiving band is 4m. The recording time is 5s, sampling step is 1ms.

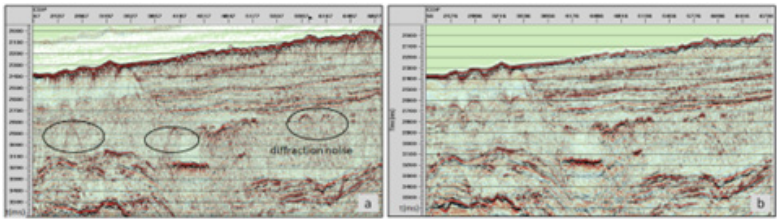

Fig. 5. Comparison of seismic section before (a) and after (b) applying Seismic Migration

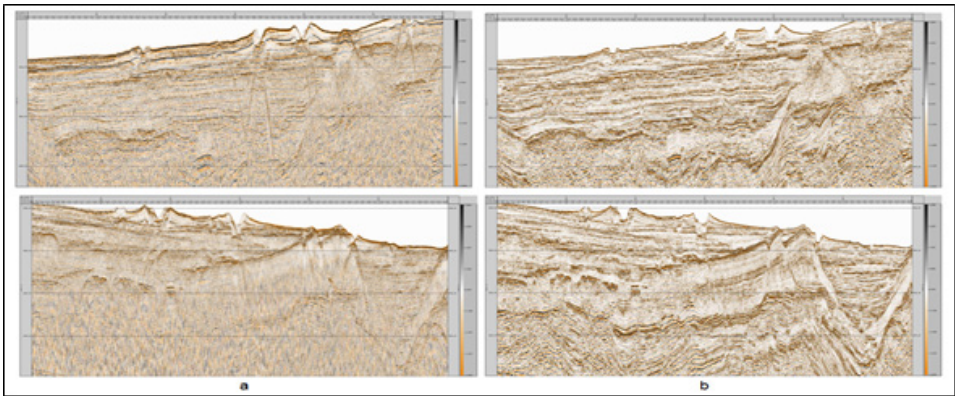

Fig. 6. Example of seismic sections comparison before (a) and after (b) data processing

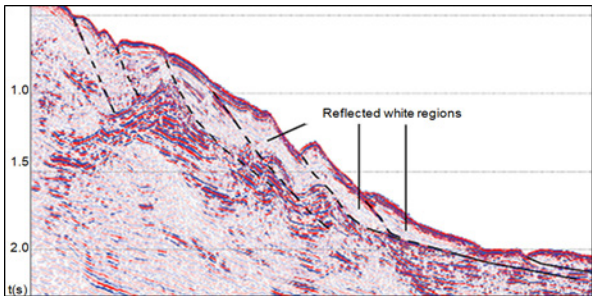

Fig. 7. A reflected white area on a seismic slice

Because gas hydrates have distinct characteristics from petroleum and other mineral objects, it is imperative to improve treatment efficiency with appropriate processes, software, and process parameters (Huaishan, 2002; Deng, 2006). Advanced processing methods are applied to improve the quality of data and directly determine the nature of Gas Hydrates such as detailed velocity analysis, using technologies to remove strong disturbances near the seabed that affect the detection of gas hydrate signatures (Predictive Deconvolution,SRMA, Randon, Tau-P,...), increase simulation reliability (CBM, DMS..), Seismic Migrations, use seismic attributes (SA), studying Amplitude Versus Offset (AVO), Seismic Inverse transform (SI) and using Artificial Intelligence Network (ANN).

Figure 5 is an example comparing the high resolution seismic section in study areas before and after seismic migration. Figure 6 is another example showing the improved seismic section quality after seismic data processing.

3. Direct signs of gas hydrate on seismic data

The process of improving the efficiency of processing and interpreting High Resolution Seismic data in the Southeastern offshore of Vietnam Sea allows studying upper sedimentary cover structure, marking out fracture zones and faults, serving pathways for gas - saturated fluids, migrating upwards (Tan, 2019). The achieved results detected the signs of the existence of Gas Hydrate such as Gas Hydrate Stability Zones (GHSZ), Bottom Simulated Reflector (BSR), Blank Zones (BZ), pores (Pockmark), gas column (Chimney)...(Wang, 2011; Taylor, 2004)

Gas Hydrate Stable Zones

In the East Sea area, with the relationship between sea water depth, geothermal gradient and gas hydrate type, the GHSZ zone can be formed at water depth from 600m to 1,500–2,200m with thickness from 0–225m to 0–365m. High-resolution seismic data have shown reflected white regions associated with this GHSZ. An example of a reflected white area on a seismic slice is shown in Figures 7.

Bottom Simulated Reflector (BSR)

The bottom surface of the gas hydrate stable zone is the boundary between the zone containing gas hydrate and free gas, so there is a difference in speed and high reflection amplitude. Because the bottom surface of the gas hydrate stability zone has a shape similar to that of the seabed but has a phase reversal compared to the seafloor, it is called a simulated seafloor reflector (BSR) (Le, 2005; Ojha,2009). In the East Sea, the stability of the gas stability zone is not as high as in other

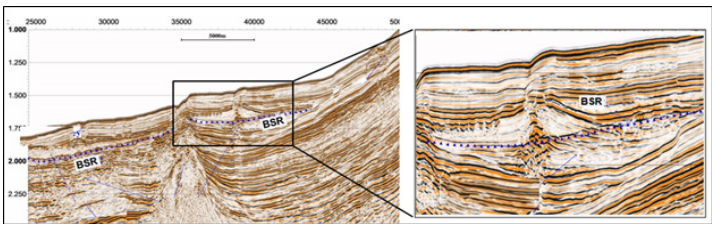

Fig. 8. Seismic slice showing BSR (Tu Chinh Vung May area).

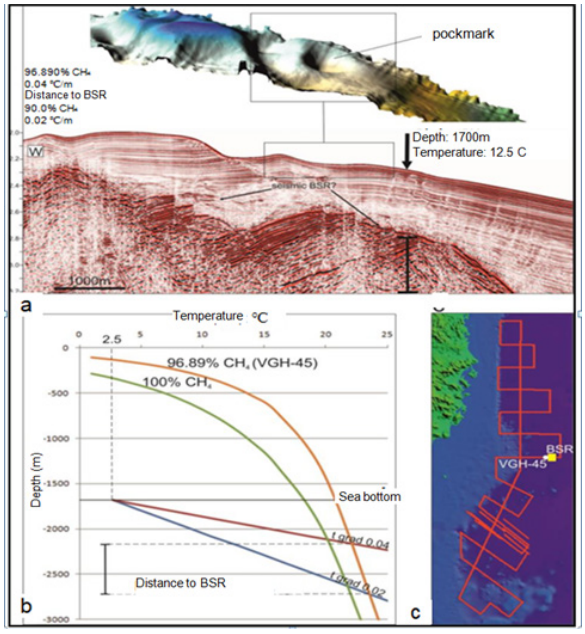

Fig. 9. Seismic section and gas hydrate stability curve. a. The seismic line shows the BSR, b. Gas Hydrate stability curve, c. Location of seismic section and of sampling station

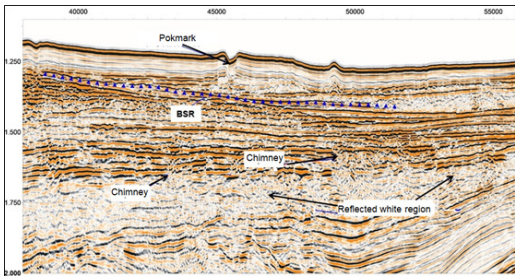

Fig. 10. Representation of pockmark, chimney, reflected white region and BSR on seismic section

regions, so identifying them requires improving the efficiency of document processing. Figure 9 is a seismic slice showing BSR (Vung May Tu Chinh area). Figure 9 shows the section with seabed depth of 1700m, and seabed temperature of 12.50°C. Here, there is a high-amplitude reflector lying gently parallel to the sea floor, covered with fine sediment. Below the gas hydrate stability zone, the seismic wave field represents a saturated gas region. Vertical cracks can be a path for saturated gas to escape to the seafloor. On hydroacoustic data, a pockmark ~800m in diameter is observed, possibly created above the gas hydrate accumulation area.

Pockmark and Gas chimney

In the marginal uplift zones, the central uplift often has depressions, where mud, liquid and gas from the seabed push into the aquatic environment to form Pocmarks. These pits may be buried in association with Gas chimneys which are likely related to gas hydrates. In the seismic and hydroacoustic literature, some signs of saturated gas in the upper sediments along the pore structures have been identified that may be related to the gas hydrate stability zone (GHSZ). Figure 10 is representation of pockmark, chimney, reflected white region and BSR on seismic section

Conclusions

Gas hydrate is a potential energy source of Vietnam in the deep sea with low temperature and high pressure. The application of the high-resolution seismic method has a very important role, which is used effectively not only to determine the geological factors related to the gas hydrate existence, but also allows to identify the signs of development and present them as gas hydrate stability zone (GHSZ), bottom simulated reflector (BSR), pores (pockmark), gas column (Chimney)...

The research results have allowed to determine the applicability of the high-resolution seismic method to search for gas hydrate in Vietnam, a feature that exists in the study area in the Southeast of Vietnam's waters.

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