Identification of New Seismic Evidence Regarding Gas Hydrate Occurrence and Gas Migration Pathways Offshore Uruguay*

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Abstract

Natural gas hydrates are crystalline solids formed by natural gas (mostly methane) and water that are stable at thermobaric conditions of high pressure and low temperatures that are found in nature in areas of permafrost and in offshore basins of continental margins. Besides the various applications related to the study of this subject, international interest in natural gas hydrate has grown in recent years mainly due to the estimations of large amounts of carbon stored in this form and its potential as an energy resource. An increasing number of countries have established research programs regarding hydrates.

In the Uruguayan offshore, seismic evidence for the occurrence of gas hydrate has been identified based on the presence of BSRs (bottom simulating reflectors) in 2D seismic reflection sections. Initial determinations concerning the presence of BSRs indicated an area of 5,000 km^2 (de Santa Ana et al., 2004) according to information from seismic surveys performed offshore Uruguay between 1970 and 2002, which were available so far in non-digital media (paper and acetate).

In order to reach a better understanding of the extent of gas hydrate-bearing sediments offshore Uruguay, we interpreted more than 10,000 km of regional and semi-detailed 2D reflection seismic sections from surveys shot in 2007 and 2008, using the Kingdom Suite© seismic interpretation software. Special seismic processing was also performed on some of these new seismic sections using multi-attribute and neural networks focused on the identification of gas chimneys.

In this paper we present recent results regarding the identification of BSRs in 2D seismic data acquired in the years 2007 and 2008, which indicate the presence of BSRs in areas that were not previously identified. The BSRs extend over an area of approximately 22,000 km^2 and show that the potential for this non-conventional resource offshore Uruguay is higher than thought.

We also show seismic evidence suggesting the existence of free gas below the hydrate stability zone (sub-hydrates prospects) through the presence of increased amplitudes below the BSR. Additionally, we present the results of the processing for identifying chimneys, which suggest a thermogenic origin of the gases that reach the hydrate-bearing layers.

Introduction

The study area for this work is located in the western South Atlantic on the continental margin of Uruguay. Here we found three sedimentary basins: Punta del Este, Pelotas, and Oriental del Plata (Figure 1). In the Uruguayan territorial sea, seismic evidence for the occurrence of gas hydrate has been identified based on the presence of BSRs in 2D seismic reflection sections.

BSRs are frequently used in the indirect diagnosis of gas hydrate accumulations (Sloan, 1998; Pecher and Holbrook, 2000) as geophysical indicators of the base of the GHSZ (gas hydrate stability zone). Because the BSR occurs at a contact between higher acoustic impedance above and lower acoustic impedance below (a negative acoustic impedance contrast), it produces a phase reversal in a reflected acoustic wave compared to the reflection from the seafloor (Max et al., 2006). The base of the GHSZ can have different seismic expressions such as continuous BSRs, segmented BSRs, and high-relief BSRs (Shedd et al., 2009) depending on the geological, fluid and geothermal setting.

Offshore Uruguay, initial determinations concerning the presence of BSRs indicated an area of 5,000 km^2 according to information from seismic surveys performed offshore Uruguay between 1970 and 2002, which were available at that moment in non-digital media (paper and acetate) (de Santa Ana et al., 2004). In several of these seismic lines, associated with post-Miocenic sequences, the presence of several BSRs were identified. In this work we present recent results regarding the identification of BSRs in 2D seismic data acquired in the years 2007 and 2008 as well as the results of the chimney processing analysis performed in some of these seismic sections.

Methodology

We interpreted more than 10,000 km of regional and semi-detailed 2D reflection seismic sections from surveys shot in 2007 and 2008, using the Kingdom Suite© seismic interpretation software looking for reflectors attributable to the base of the GHSZ based on the known characteristics of the BSRs. The acquisition parameters of these surveys are showed in Figures 2 and 3 (CGG Veritas).
From these surveys some lines have been selected for special processing aiming to identify gas chimneys. Gas chimneys are visible in seismic data as columnar disturbances, where the continuity of reflectors is missing, and reflection amplitudes are weaker than in the surroundings areas (Heggland, 2005). The processing for gas chimney identification was performed by Geoinfo-Argentina and dGB-USA, and was accomplished through seismic attribute analysis by training a neural network to recognize chimneys that have been

identified in a seed interpretation (Heggland, 2005). The network transforms all attributes into one new attribute, which indicates the probability of chimney at the seismic position. The resulting chimney-probability section can be further enhanced by image processing techniques and iterating the process (Meldahl, 2001). The processing is based on the following workflow:

1) Data analysis and attribute selection.
2) Select representative train locations.
3) Calculate seismic attributes.
4) Feed calculated data to neural network and train.

In this work we studied some of the results of the gas chimney identification processing in the surroundings of the BSRs in order to find a link between gas hydrate occurrence and gas chimney presence.

Discussion

The interpretation of the base of the GHSZ on the 2007 and 2008 surveys show a widespread occurrence of the gas hydrate bearing sediments as showed in the Figure 4. As shown in Figure 4, the BSR is present in water depths greater than 500 m and has high continuity in the northern area (Pelotas Basin), but is more discontinuous at Punta del Este Basin and southern part of Oriental del Plata Basin.

The presence of BSR at the southern part of Offshore Uruguay represents a new discovery regarding gas hydrates in this area since previous seismic surveys have not reached these areas so there was no information regarding gas hydrate occurrence. In Figure 5 we present a seismic section from the southern area showing a clear example of BSR and enhanced amplitudes suggesting the presence of free gas below the base of the GHSZ.

Regarding the gas chimney identification, Figure 6 shows the results for the processing in the surroundings of an interpreted BSR. Here we can observe the presence of enhanced amplitudes below the BSR and high probability of gas chimneys (shown in green colour) associated with a recent fault system. In Figure 7 we present results of gas chimney identification showing possible gas chimneys ending at the BSR. One explanation of this is that the hydrate bearing sediments are acting as a stratigraphic seal. The deep source of the gas chimneys present in this section suggests thermogenic origin.

Conclusions

The BSRs extend over an area of approximately 22,000 km^2 and show that the potential for this non-conventional resource offshore Uruguay is higher than thought. We also found seismic evidence suggesting the existence of free gas below the GHSZ (sub-hydrates prospects) through the presence of increased amplitudes below the BSR. Additionally, the results of the processing for identifying chimneys are consistent with the BSR interpretation suggesting in some cases thermogenic origin of the gases that reach the hydrate-bearing layers.

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Website

CGG Veritas website, Marine Data Library Offshore Uruguay, http://www.cggveritas.com/default.aspx?cid=1744&lang=1

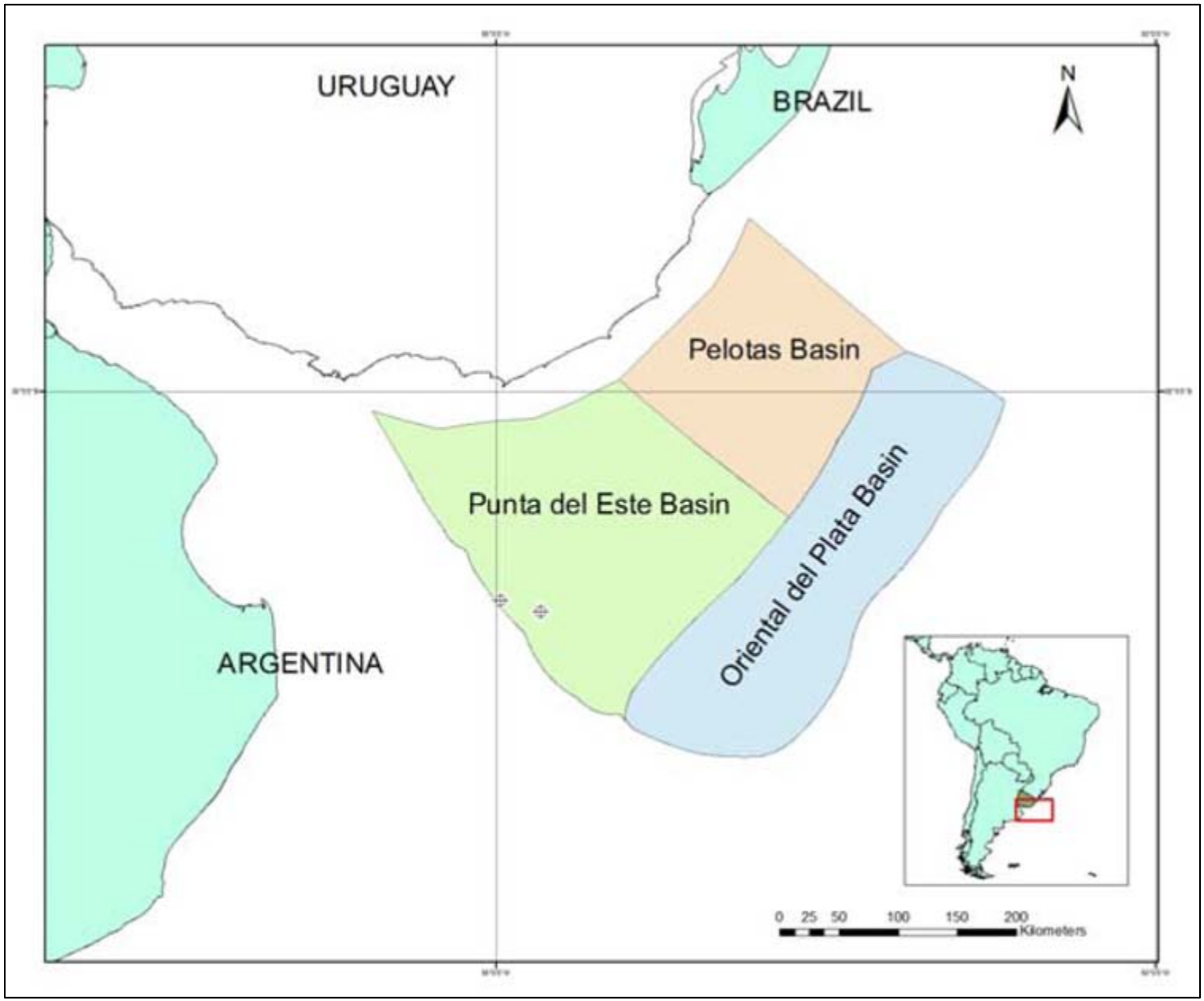

Figure 1. Offshore basins of Uruguay.

Contractor	Wavefield-Inseis
Vessel	M/V Bergen Surveyor
Date(s)	2007
Program Size	7,125 km
Source Type	Bolt Long-Life Airgun
Group Interval	12.5 m
Streamer Length	8,000 m
Source Depth	6 m
Shot Interval	25 m / 37.5 m
Sample Rate	2 ms
Processing contractor	Geotrace

Table 1. Acquisition parameters UR07 [6]

Figure 2. Acquisition parameters UR07 (CGG Veritas).

Contractor	Sevmorneftegeofizika (SMNG)
Vessel	M/V Akademik Shatskiy
Date(s):	2008
Program Size	2,909 km
Source Type	Bolt Long-Life Airgun
Group Interval	12.5 m
Streamer Length	8,100 m
Source Depth	6 +/- 1 m
Shot Interval	25 m
Sample Rate	2 ms
Processing Contractor	Geotrace

Table 2. Acquisition parameters UR08 [6]

Figure 3. Acquisition parameters UR08 (CGG Veritas).

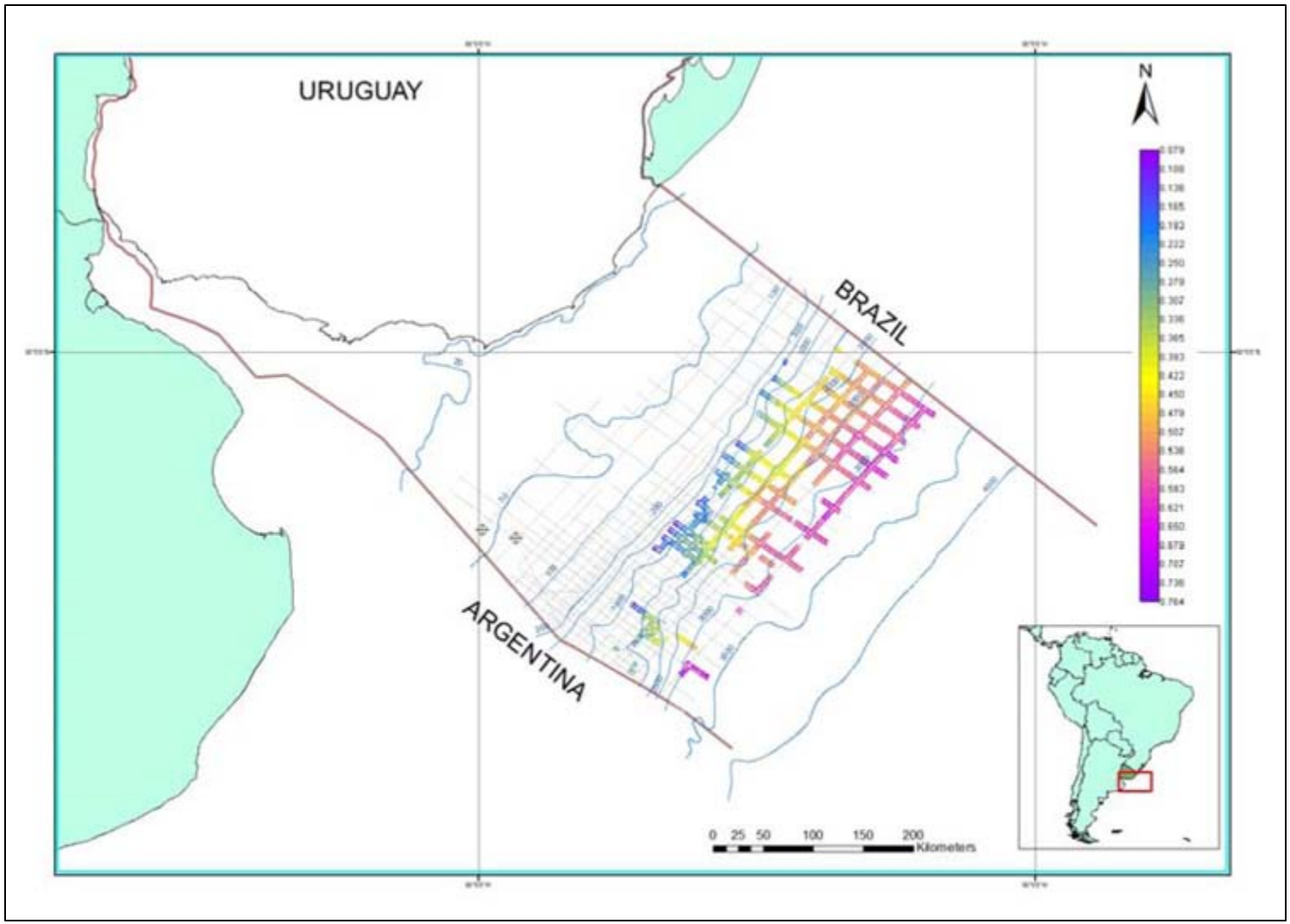

Figure 4. Distribution of the BSR and bathymetry offshore Uruguay. The color scale shows the depth of the base of the GHSZ from the seafloor in seconds (TWT).

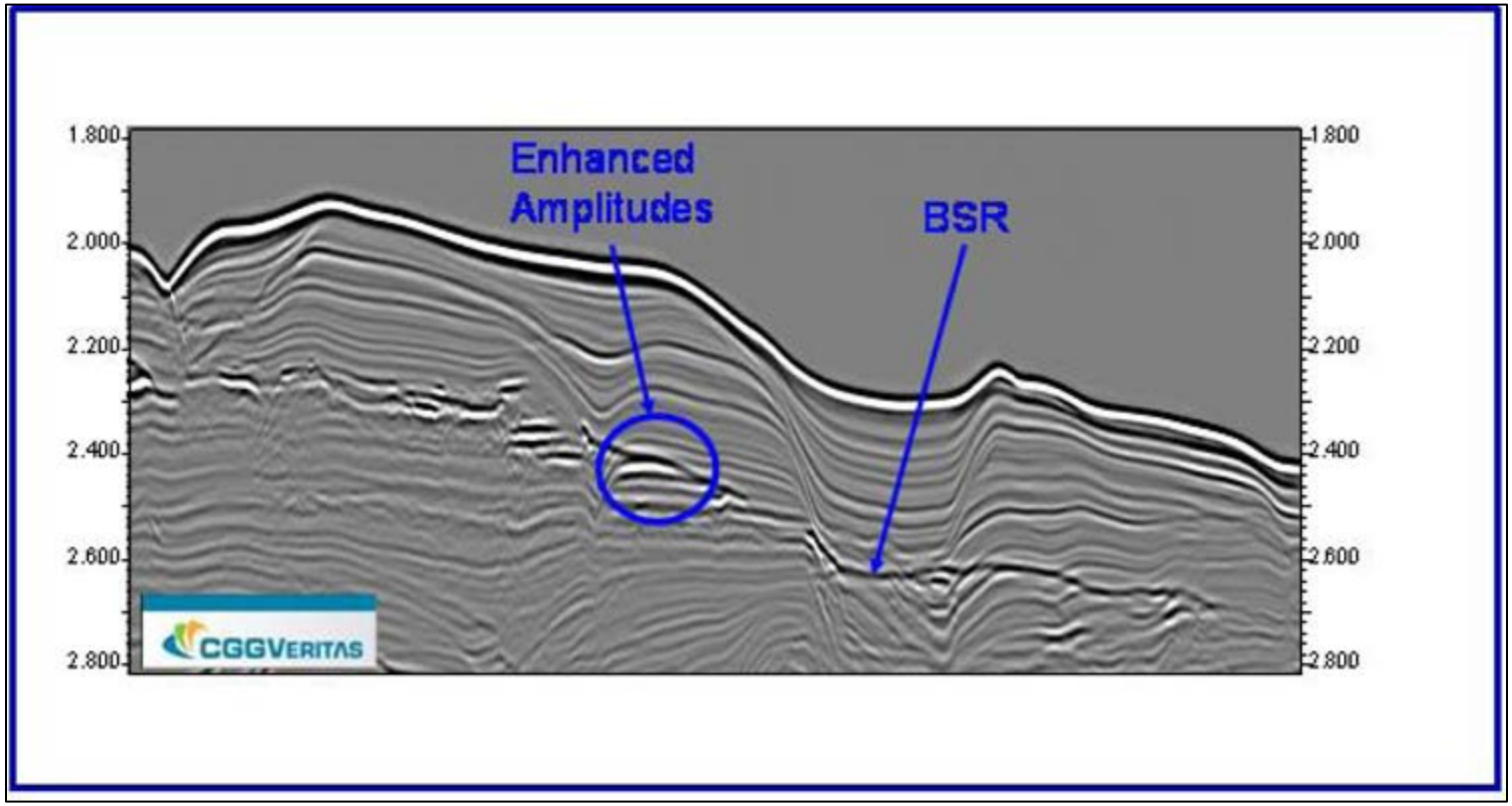

Figure 5. Seismic line from the southern area showing a BSR at 0.330 sec TWT from the seafloor and enhanced amplitudes below the GHSZ.

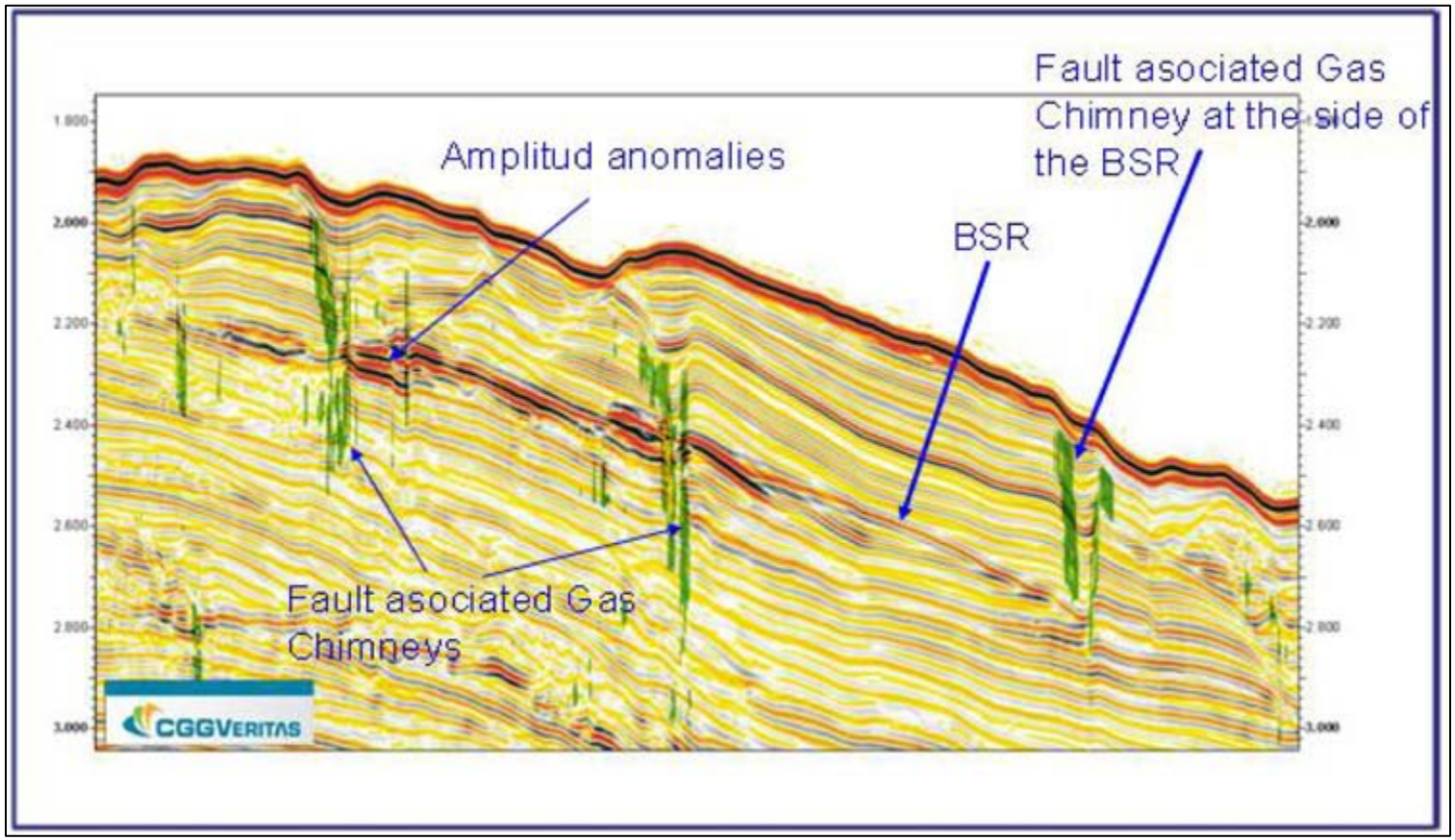

Figure 6. Seismic line showing the results of gas chimney identification.

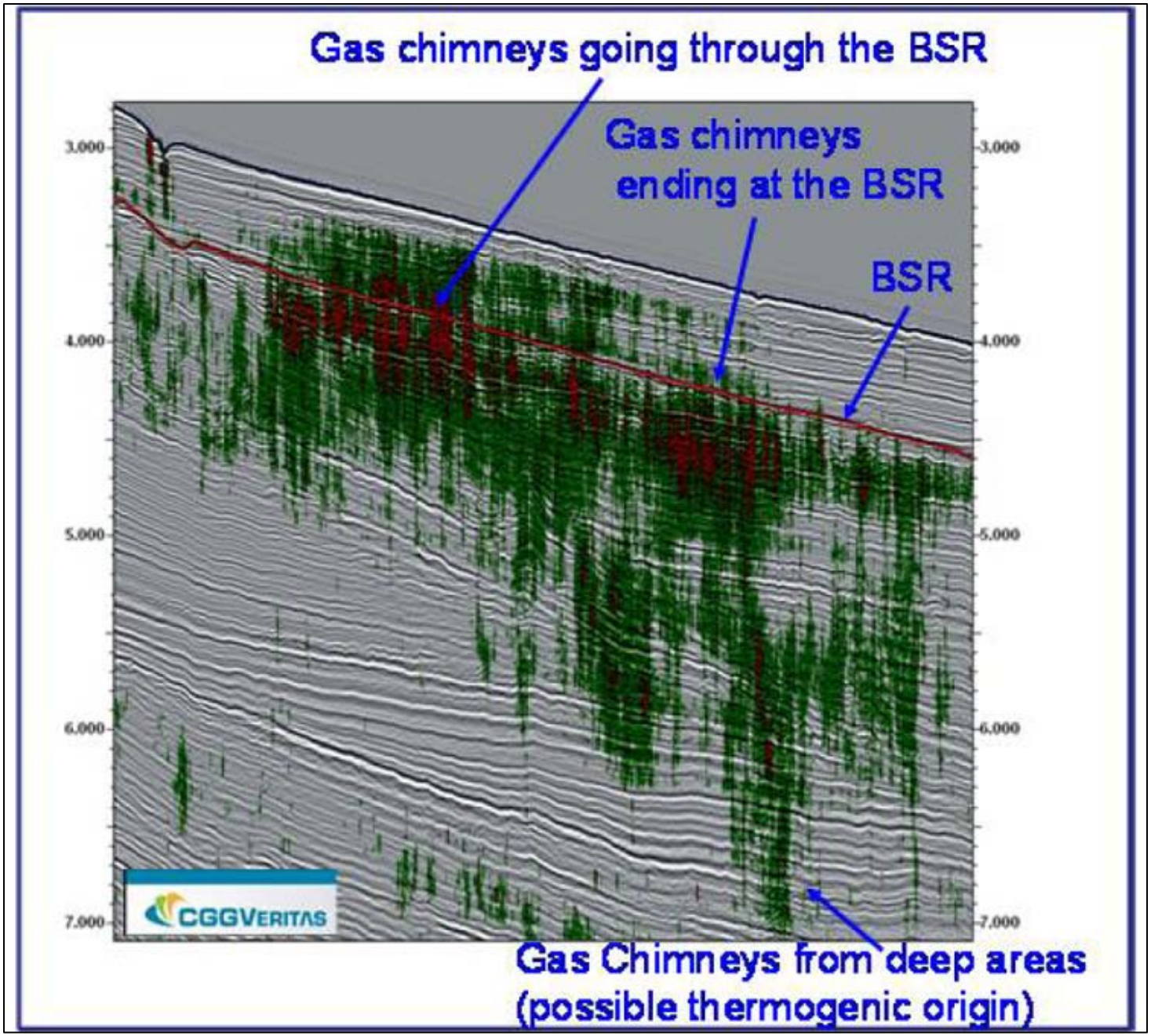

Figure 7. Gas chimney identification suggesting thermogenic origin of the gases that reach the hydrate bearing sediments.