

가스하이드레이트 탄성파 자료의 복소분석

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Complex Analyses for Gas Hydrate Seismic Reflection Data

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Abstract : Gas hydrate has been paid attention to study for because: 1) it can be considered as a new energy resources; 2) one of reasons causing the instability of sea floor slope and 3) a factor to the climate change. Bottom simulating reflector (BSR) defined as seismic boundary between the gas hydrate and free gas zone has been considered as the most common evidence in the seismic reflection data for the gas hydrate exploration. BSR has several characteristics such as parallel to the sea bottom, high amplitude, reducing interval velocity between above and below BSR and reversing phase to the sea bottom. Moreover, instantaneous attribute properties such as amplitude envelop, instantaneous frequency, phase and first derivative of amplitude of seismic data from the complex analysis could be used to analyze properties of BSR those would be added to the certain properties of BSR in order to effectively find out the existence of BSR of the gas hydrate stability zone. The output of conventional seismic data processing for gas hydrate data set in Ulleung basin in the East sea of Korea will be used for complex analyses to indicate better BSR in the seismic reflection data. This result of this analysis implies that the BSR of the analyzed seismic profile is clearly located at the two ways time (TWT) of around 3.1 seconds.

1. Introduction

Gas hydrate, the solid-like substance, is composed of methane molecule at the center and number of water molecules surrounding. It became of major interest during the last 20 years because: i) it may represent a future energy; ii) it may play a role in global climate change and iii) it may represent a potential geological hazard. The gas hydrate is formed under low temperature, high pressure and proper natural gas concentration. Seismic reflection method has been the most powerful method in oil and gas exploration in general and gas hydrate exploration in particular. In seismic reflection data of gas hydrate exploration, the BSR is considered as the most common indicator however it does not mean that the existence of gas hydrate must require the BSR in its seismic section. In some cases, the gas hydrate exists without occurrence of the BSR. The specific characteristics of the BSR consist of high amplitude, parallel to sea bottom, reflection

polarity reversed to the sea bottom reflector and reducing the interval velocity those are used to identify the BSR locations. Many researches on velocity estimation of gas hydrate bearing sediment (Lee et al., 1996, Wood, 1941, Willye et al., 1958 and Kuster & Toksoz, 1974) showed that the velocity increases significantly with the amount of gas hydrate concentration while the density does not change much. So, the acoustic impedance of gas hydrate bearing sediment is much higher than of free gas zone

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that create strong reflecting plain in the seismic data. Further more, the other component of seismic such as acoustic impedance, reflectivity, frequency and phase will change accordingly to the changing of velocity.

Gas hydrate research has been carried out in Korea since 1997 by Korea Institute of Geosciences and Mineral Resources (KIGAM). Seismic exploration survey was performed in the Ulleung basin, East Sea of Korea to qualify the potential and distribution of gas hydrate. According to the result of survey, KIGAM has mapped the location of BSR in Ulleung basin. However, in the areas examined so far, their occurrences are patchy and, for the most occurrences, the BSR amplitude is low (there are several location exceptions) (Ryu et al., 2003 and Lee et al., 2005). The line of the seismic reflection data in 2000 was used for multiple analyses. The following scopes are proposed: i) to briefly review on the complex analysis; ii) to present the result of seismic data processing by Geobit seismic data processing tools including the complex analysis tools developed by KIGAM seismic data processing team (Suh, 2005).

2. Complex analysis

Instantaneous attributes are products of complex signal theory whose original application was the mathematical treatment of amplitude modulated and frequency modulated transmissions whole bandwidth was a fraction of their center frequency. The seismic trace attributes such as real part, imaginary part, amplitude envelop, frequency, phase instantaneous and so on are used to present in the color density section in order to verify the abnormally for better locating the boundary between two different physical properties of subsurface layers as introduced by commercially licensed software namely ATRIB3D (Taner, et al., 1979; Taner et al., 2000). Among of them, phase, frequency instantaneous and amplitude envelop are most effectively used. Further more, the first and second derivative of amplitude envelop could be usefully interpreted because they indicate the energy variation of the reflected events and the sharp changes of lithology, reflector interfaces of the bandwidth seismic data, reflectively.

The analytic trace is given as follows:

$$F(t) = f(t) + ig(t), \quad (1)$$

where $f(t)$ is real part corresponding to the recoded seismic data and $g(t)$, the imaginary part of the complex trace, is the Hilbert transform of $f(t)$ that is defined as:

$$g(t) = \frac{1}{\pi} \int_{-\infty}^{+\infty} \frac{f(\tau-t)}{\tau-t} d\tau$$

Further more, let define $E(t)$, $\Theta(t)$ and $\omega(t)$ is amplitude envelop, instantaneous phase and frequency, respectively. The total instantaneous energy or amplitude envelope is computed as:

$$E(t) = \sqrt{f^2(t) + g^2(t)}. \quad (2)$$

As given in eq. (2), the envelop is dependent of phase and it relates to the acoustic impedance contrasts or reflectivity. This attribute can be used as an effective discriminator for the several characteristics such as possible gas accumulation, major changes of lithology and depositional environments and so on.

First derivative of amplitude envelop is represent for variation of the energy of the reflected events. It is also representative for the energy absorption. The lower rise indicates larger absorption effects. The first derivative of amplitude envelop is calculated as:

$$\frac{dE(t)}{dt} = E(t) * \text{dif}(f(t)) \quad (3)$$

where * denotes for convolution and $\text{dif}(f(t))$ is differentiation operator.

Second derivative of envelope ($\frac{d^2E(t)}{dt}$) gives the measure of the sharpness of the envelop peak and it could be used as principle attribute to indicate the sharp changes of lithology as well as the change of depositional environment even when the corresponding envelop amplitude may be low.

The instantaneous phase is determined from the complex form of seismic trace given in eq. (1) as follows:

$$\Theta(x, t) = \arctan\left(\frac{g(x, t)}{f(x, t)}\right). \quad (4)$$

The information of instantaneous phase is dependent to the amplitude and it relates to the propagation phase of the seismic wave front. The phase attribute can be effectively used as a discriminator for geometrical shape classification.

Instantaneous frequency is defined as

$$\begin{aligned} \omega(x, t) &= \frac{d\Theta}{dt} = \frac{d}{dt} \left[\arctan\left(\frac{g(x, t)}{f(x, t)}\right) \right] \\ &= \frac{g(x, t) \frac{df(x, t)}{dt} - f(x, t) \frac{dg(x, t)}{dt}}{f^2(x, t) + g^2(x, t)}. \end{aligned} \quad (5)$$

This equation shows the natural of instantaneous frequency is phase variation with time, which is different to the frequency in Fourier transform. As seen in eq. (5)

we may see the instantaneous frequency is negative whenever $g(x,t) \frac{df(x,t)}{dt} - f(x,t) \frac{dg(x,t)}{dt}$ is negative. The instantaneous frequency could relate to the wave propagation and depositional environment as well as hydrocarbon indicator by low frequency anomaly, hence they are physical attribute.

3. Application of complex analysis to the gas hydrate seismic data

The seismic data were acquired in 2000 by KIGAM. The receiver interval was 6.25 m with 8400 shot gathers and total length about 60km from East to West. Each shot gather consists of 96 channels or traces. The preprocessing steps included: muting, bandpass filter, multiple rejections by deconvolution. The shot gather No. 4874 and its preprocessed result are shown in Fig. 1. After CDP sorting, velocity spectrum analysis and applying the NMO correction, the stack section will be made by gathering up all the seismic trace of one CDP gather. The stack section, known as the product of seismic processing, of this analyzed data is shown in Fig. 2. As seen in Fig. 2 we may see the pull up structures at shot point # 5700 and 5200. Additionally, the acoustic blanking zone is also seen between around 3-3.2 second. Several strong reflected events occurring at the TWT position of around 3, 3.1 and 3.2 seconds could indicate the existence of BSR. Thus, this criterion can not be used to identify the BSR and the complex analysis as mentioned above could be applied for this data set for getting clearer the position of BSR. The result of complex analysis including amplitude envelop, instantaneous frequency, instantaneous phase and first derivative of amplitude are shown in Fig. 3, 4, 5 and 6, respectively. The chimney structures and blanking zone are all seen in these sections that are concise with the stack image. By picking trace by trace of these sections for considering the behavior of those analyses to the characteristic of BSR, we could see clearer location of BSR than those of original seismic trace from the stack image. The representative of this work is shown in Fig. 7 where the seismic trace is picked up at the position of 7.2 km on the survey line. As seen in Fig. 7, we may see high anomalies that look similar to the sea bottom in the amplitude envelop (Fig. 7a), instantaneous frequency (Fig. 7b) and first derivative amplitude (Fig. 7d), is located at the TWT of 3.1 second. At this position in the instantaneous phase trace (Fig. 7c), the phase term is reverse to the sea bottom reflector. Gathering all information above, we could conclude that the BSR is located at the TWT of a round 3.1 second.

4. Conclusions and recommendation

Seismic data processing for gas hydrate and its complex analyses have been adopted successfully by using Geobit seismic processing package. The result of processing implies very clearly the position of chimney structure and acoustic impedance blanking zone but not clearly indicate the position of BSR. The complex analyses of the stack section have been added to the seismic reflection data for better the position of BSR in the seismic section. By using these analyses, the seismic characteristic of gas hydrate data set (blanking zone and pull up structure) are still kept remain in all the sections and the BSR location can be distinguished by picking up trace by trace. The result shows that BSR is located at the TWT of around 3.1 second.

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6. References

- [1] Kuster, G. T., and Toksoz, M. N., 1974, Velocity and attenuation of seismic waves in two phase media, 1, Theoretical formulation. *Geophysics*, V. 39, 587-606.
- [2] Lee, J. H., Baek, Y. S., Ryu, B. J., and Riedel, R., 2005, A seismic survey to detect gas hydrate in the East Sea of Korea. *Marine Geophysical Research*, Vol. 26, 51-59.
- [3] Lee, M. W., Hutchinson, R. D., Collett, T. S., and Dillon, W. P., 1996, Seismic velocity for hydrate-bearing sediments using weight equation. *Journal of Geophysical Research*, Vol. 101, 347-358.
- [4] Ryu, B. et. al., 2003, Study on gas hydrate exploration and development, KR-0300-09, KIGAM.
- [5] Suh, S., 2005, Geobit 2.10.4 The seismic processing tools, KIGAM
- [6] Taner, M. T., Koehler, F., and Sheriff, R. R., 1979, Complex analysis. *Geophysics*, Vol. 44, 1041-1063
- [7] Taner, M. T., 2000, Attributes revisited, Technical paper in rock solid images.

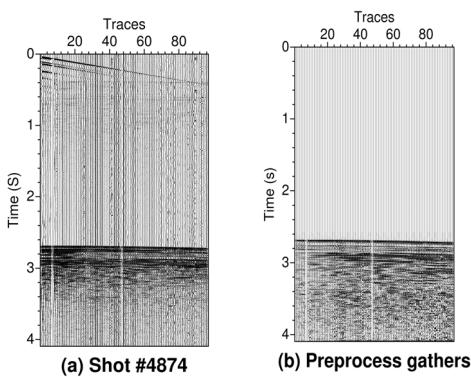


Fig. 1 A shot gathers and preprocessed result.

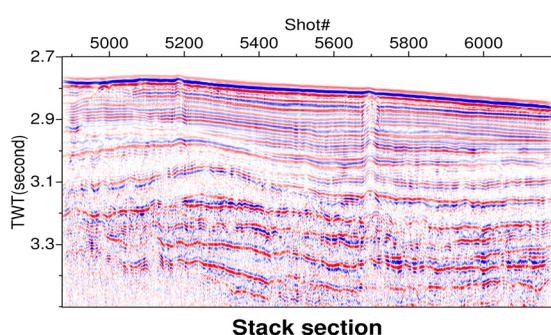


Fig. 2 Stack image of line 00-10.

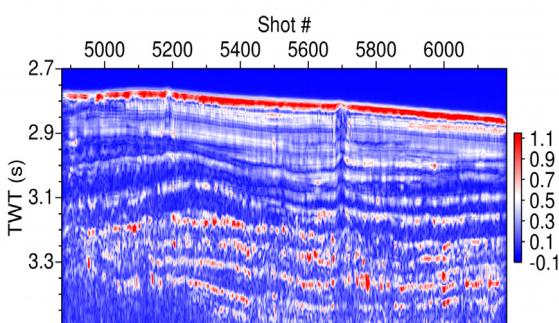


Fig. 3 Amplitude envelope.

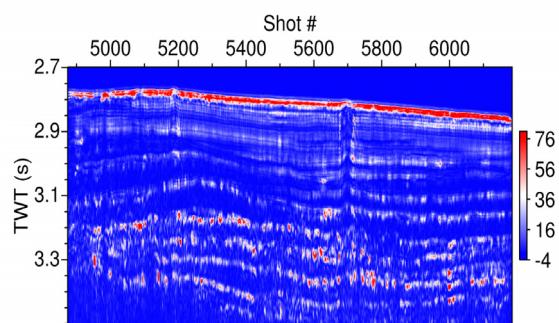


Fig. 4 The instantaneous frequency section.

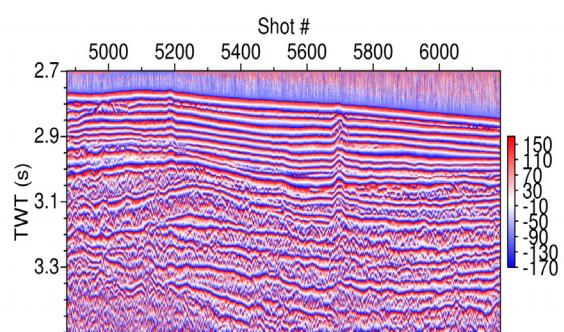


Fig. 5 The instantaneous phase section.

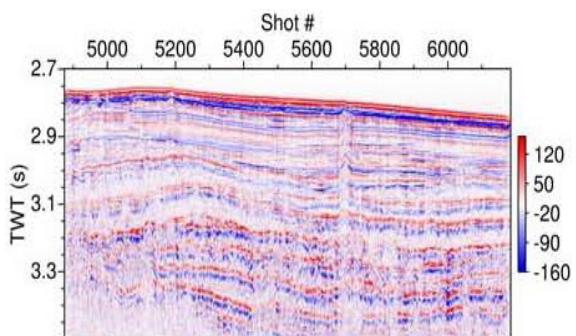


Fig. 6. The first derivative amplitude section.

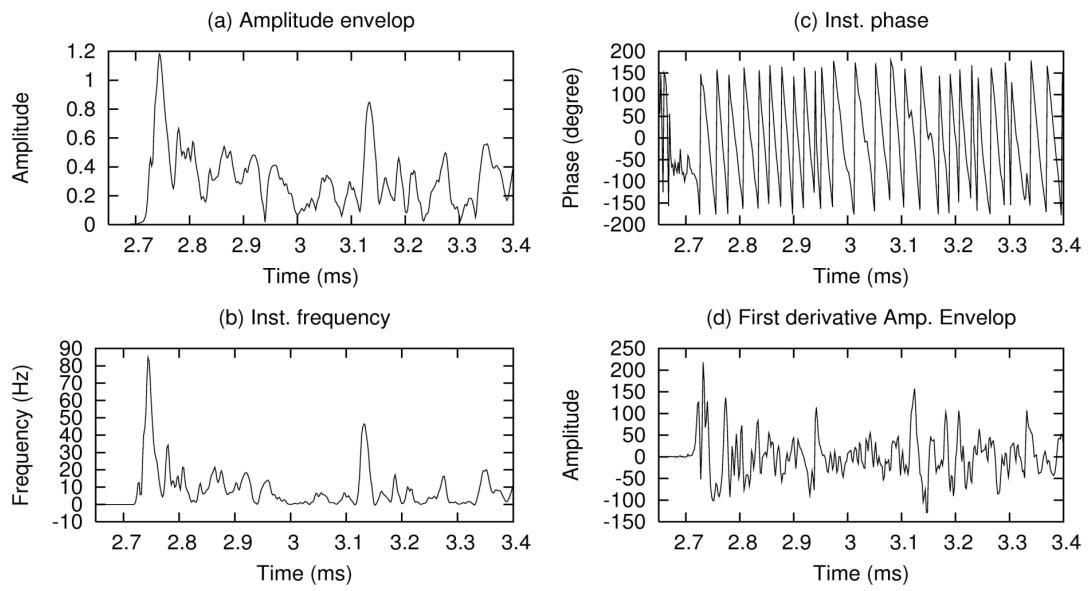


Fig. 7 Picking up single trace at the position of 7.2km on the survey line.