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Estimation of Gas Hydrate Saturation along a Seismic line in the Andaman Offshore using Acoustic Impedance and Resistivity

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Summary

Gas Hydrates have been inferred by identifying an anomalous reflector, known as the bottom simulating reflector (BSR) on multi-channel seismic (MCS) data in the Andaman offshore. Seismic attributes like the blanking, enhanced reflections, absorption of higher frequencies also indicate presence of gas hydrates. The drilling/coring have confirmed their occurrences in volcanic ash. A prominent BSR coupled with reverse polarity is observed on seismic data around 600 m below sea floor (mbsf) along a line. The BSR has been established at 595 mbsf from the log data. An increase in seismic amplitudes with offsets from BSR imply free gas below the BSR. Using the resistivity log data at site NGHP-01-17B, we have computed the hydrate saturation as 10-20% of pore spaces. Here we have estimated the saturation of gas-hydrates along the seismic line using the input from log data. The relationships between acoustic impedance (product of sonic and density logs) and porosity (from density log) have been determined by a linear regression for hydrate- and non-hydrate-bearing sediments. By employing the Archie's law, we have determined the saturation of gas hydrates from resistivity log at the well location. Then we derive the acoustic impedance from the MCS data along the line. By employing this approach, we have derived the saturation of gas hydrates at every seismic trace. A simple interpolation of the saturations, thus obtained, results in lateral and vertical variation of hydrate saturation varying between 5 to 15% along the seismic line.

Keywords: *BSR, Acoustic Impedance, Resistivity, Hydrate saturation.*

Introduction

Gas hydrates are ice-like crystalline solids formed at high pressure and low temperature with adequate concentration of gas, mainly the methane, trapped inside cages of water molecules. These compounds are recognized as a potential source of energy since dissociation of 1 m3 of gas hydrate is believed to release about 164 m3 of methane. The identification of these deposits is usually done by seismic methods, where a prominent reflector that mimics the shape of seafloor and crosscuts the local dipping strata is noticed on seismic section. This reflector is called as the bottom simulating reflector (BSR) and it marks the base of the gas hydrate stability zone (GHSZ) and is associated with a prominent polarity and velocity reversal caused due to the strong acoustic impedance contrast between sediment containing gas hydrate above and underlying sediments with free gas. The estimation of gas hydrate and associated free gas is generally carried out using multi-channel seismic data. The saturation of gas hydrate is often estimated using the chloride anomalies (if cores are available), resistivity or sonic logs when wireline logs are available and by seismic velocities in absence of log or core data.

A combination of density and sonic logs is used to develop an empirical relation to estimate water-filled porosity from acoustic impedance and then to estimate gas hydrate saturation by applying Archie equation to the resistivity log. This approach is very practical as it inverts the acoustic impedance instead of seismic velocity alone, thus accounting for the lithology and seismic velocity at the same time. Given a seismic data, we can derive acoustic impedance at every trace and obtain a pseudo impedance log at every location. The hydrate saturation estimation is carried out at every trace, resulting in hydrate saturation along the profile. This simple extrapolation of the method is fairly accurate, provided the well location is not very far from the seismic line. This approach was effectively used for estimation of gas hydrate saturations in Blake Ridge (Liu and McMechan, 2002), South China Sea (Xiujuan, 2006; 2011), and is used here to obtain gas hydrate saturations along a 2D seismic line (Fig.1) using the well log data from drill site NGHP-17B.

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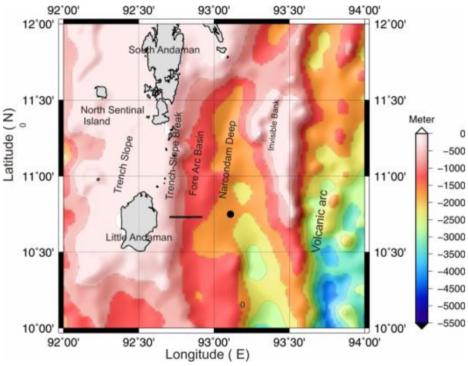

Fig 1: The map of the Andaman offshore region showing the multi-channel seismic line (solid line) and the bathymetry. Solid circle shows the drill location of NGHP- 01 Expedition.

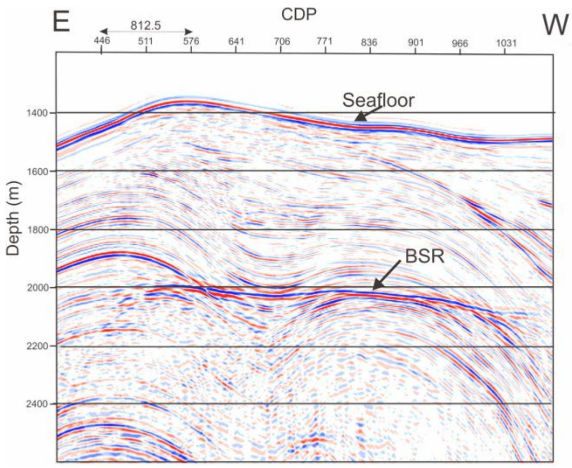

Fig2: The seismic stack section obtained along the profile.

Seismic and well log data

The 384-channel seismic data used in the present study was collected in 1999 with a GI gun of 2,250 cubic inches at an interval of 12.5m. The source interval is 25 m and the fold is 96. The near trace offset is 206 m, while the far offset is 4,987.5 m. The data processing scheme consists of band pass filtering (8-10-80-90 Hz); true amplitude recovery (6db/s); predictive deconvolution (2 ms, prediction distance and operator length of 160 ms); velocity analysis (1 km); Normal Move Out Correction (NMO with 30% stretch mute), followed by stacking and post-stack migration (Fig.2). The seismic data shows a clear BSR at a depth of ~600 m below seafloor (mbsf), that predominantly cross-cuts the local stratigraphy and is associated with negative polarity. The unusual depth of BSR has raised concerns about its association with gas hydrates and paved way for further research to ascertaining gas hydrates. The computation of seismic attributes from surface seismic data has demonstrated that the deep BSR is due to gas hydrates underlain by free gas (Satyavani et al, 2008), which was corroborated by drilling and coring of Indian National Gas Hydrate Program (Collett et al., 2008). The seismic data showing an increase in amplitudes with offsets imply free gas below BSR.

Well log data

Site 17B is one among 21 log locations that were drilled during the NGHP -01 expedition. This site is located in the Andaman convergent margin and a suite of logging studies were carried out (Fig.3). Gas hydrate play can be identified at around 590 mbsf, wherein a high P-wave velocity is observed, while there is a lowering of density. Some high P-wave velocities are also seen in the log data, but they are associated with an increase in density and it is felt that these may not be related to hydrate shows.

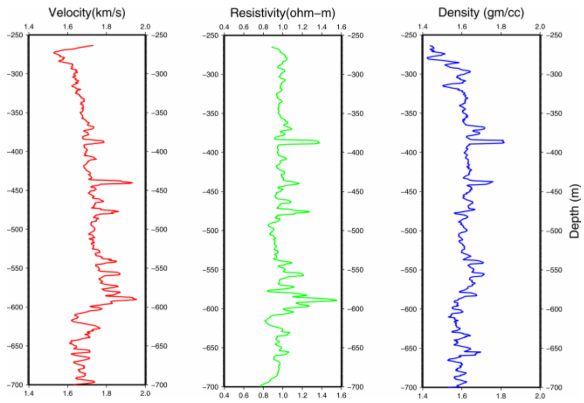

Fig.3: The 30 point average plot of density, sonic and resistivity log data obtained at Site 17.

Estimation of Hydrate Saturation

The saturation of gas hydrate can be estimated in two steps, First of all, the resistivity, density and velocity logs obtained from the NGHP drill site 17B are used to develop an empirical relation to estimate the water filled porosity from acoustic impedance for the hydrate and non-hydrate intervals. Next, the water filled porosity, thus obtained, is used to estimate the hydrate saturation at well locations using the Archie's equations. The methodology is applied to the data from site-17 and the hydrate saturation that is computed is shown in Fig. 4, which is in good agreement with the core-derived hydrate saturations (shown in red).

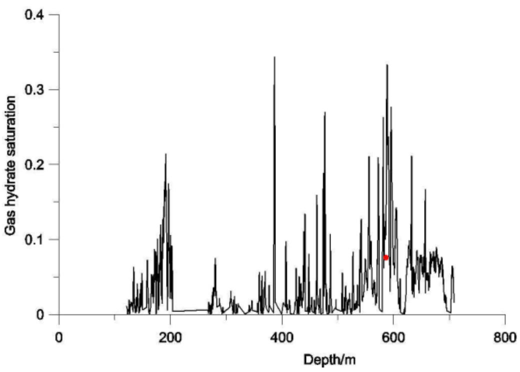

Fig4: Gas Hydrate saturation estimated at Site 17. The red dot shows the gas hydrate saturation derived from the core.

However, the well log data provide information at well location only and to understand the variation of hydrate distribution along a 2D seismic line we need to spatially extend the well information. The technique applicable to the well log as described above can also be used to the seismic data, since each trace can be visualized as a log location. The seismic data along the profile can be inverted to obtain the acoustic impedance along the profile and effectively a pseudo impedance log can be obtained at every seismic trace. The gas hydrate saturation can then be estimated along the profile using the same procedure as explained above. Using this technique, we first invert the seismic velocity and obtain the acoustic impedance by employing the method of constrained sparse spike inversion (CSSI) using ProMAX, the commercial seismic data processing software, and the water filled porosity can be obtained by employing the empirical equations derived in step 1 at every trace. Now the estimation of saturation can be done using step 2 for every trace and then an interpolation gives the hydrate saturation along the profile. This methodology is applied to the seismic data in the Andaman offshore and the results, thus obtained (Fig.5), show a hydrate saturation varying from 5-15% of the pore space along the line.

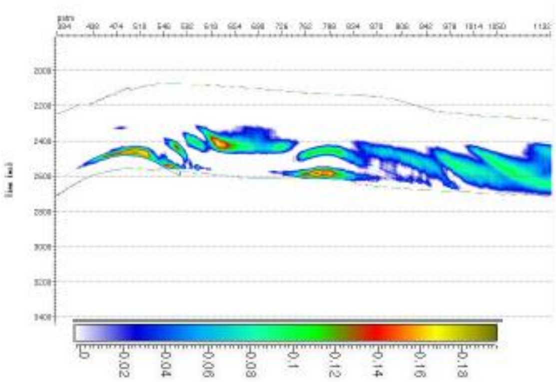

Fig.5: Gas Hydrate saturations estimated along the seismic line.

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