



Methods for Identifying and Quantifying Gas-Hydrates – An Alternate Source of Energy

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Summary

To meet the rising demand of energy and to keep pace with the economic growth for country like ours, we are desperately looking for an alternate source of energy. Bathymetry, seafloor temperature, sedimentary thicknesses, rate of sedimentation and total organic carbon content indicate good prospects of gas-hydrates in the vast offshore regions of India. As the energy content in gas-hydrates is estimated to be double the amount of total fossil fuel energy reserve, gas-hydrates seem to be a viable source of energy for India. Gas-hydrates are mainly recognized by BSR on remote seismic data and have been identified in the Kerala-Konkan, Saurashtra, Krishna-Godavari, Mahanadi offshore basins and the Andaman region. Recent drilling (NGHP – Expedition 1) have validated the ground truth and we are interested now to delineate the lateral/areal extent and evaluate the resource potential of gas-hydrates. Various organizations like DGH, ONGC, OIL, GAIL, NGRI and NIO along with Reliance Pvt. Co. are actively involved in identifying gas-hydrates based on geophysical, geochemical, geological and microbial data. At NGRI, we have built expertise in various seismic methods such as travelttime tomography; waveform inversion; AVO inversion; AVO attributes; quality factors and seismic attributes with a view to identifying and quantifying gas-hydrates from marine seismic data. As seismic velocity of gas-hydrates is very high compared to host sediments, presence of gas-hydrates increases the velocity that again depends on the nature of distribution of gas-hydrates. Underlying free-gas reduces the seismic velocity considerably. Thus estimating accurate velocities using AVO and waveform inversion followed by rock physics or effective medium theory provides an excellent tool for quantifying gas-hydrates and free-gas. We will present the application of all these methods to the real data for the detection and assessment of gas-hydrates.

Introduction

Gas-hydrates are crystalline substance of water and light hydrocarbons (mainly methane), and are found in the permafrost and outer continental margins of the world where methane concentration is sufficient (Sloan, 1990; Kvenvolden, 1998). Gas-hydrates are gaining importance due to their natural occurrences in permafrost and outer continental margins; potential as future energy resources and role in environmental hazards. The most commonly used marker for gas-hydrates is the BSR (bottom simulating reflector), which can be identified based on certain characteristic features of mimicking the shape of seafloor; opposite polarity w.r.t. the seafloor reflection event and cutting across the dipping strata etc. Since the main constituent of gas-hydrates is methane – a greenhouse

gas, release of the same to the atmosphere causes climate change or global warming. Gas-hydrates are stable only at high pressure and cool temperature and mostly occur within few hundred meters of submarine sediments when methane concentration exceeds the solubility limit and water depth becomes at least 300 meter. Destabilization of gas-hydrates reduces the strength of the seafloor causing slope failure or geohazard. Therefore, identification and quantification of gas-hydrates is essential for evaluating the resource potential and hazard assessment.

Several factors such as bathymetry (pressure,) seafloor temperature, organic carbon content, sediments, rate of sedimentation etc. indicate favorable environment for the occurrences of gas-hydrates in the vast offshore



region of India (Gupta and Sain, 2002). A total volume of 1894 TCM of gas is predicted from the gas-hydrates reserve (http://www.dghindia.org/site/dgh_gas_hydrates.aspx) from the Indian offshore, and it is necessary to map the prospective zones along the margins of India. Analysis of available seismic data shows prominent Bottom Simulating Reflectors (BSRs) in the Kerala-Konkon, Krishna-Godavari (K-G), Mahanadi offshore basins and the Andaman regions.

Recent drilling and coring using the “JOIDES Resolution” drill-ship by the Indian National Gas Hydrates Program (Expedition-01) have proved the occurrences of gas-hydrates in the K-G and Mahanadi basin and the Andaman region. It has become all the more important to demarcate the lateral/areal extent of gas-hydrates and/free-gas occurrences and assess their true potential. For this, we have built expertise in processing/modeling/inverting seismic data using various tools such as traveltimes tomography; waveform inversion; AVO inversion; AB crossplots of AVO attributes; quality factors etc. We will demonstrate the application of various seismic tools to the multi-channel marine seismic reflection data with a view to identifying and quantifying gas-hydrates and/or free-gas across the BSR. We will also show the usefulness of various seismic attributes like reflection strength, blanking, instantaneous frequency and attenuation or quality factor for identification of gas-hydrates at places where identification of BSR becomes a suspect. As gas-hydrates increase the seismic velocities and underlying free-gas reduces the P wave velocity, estimating accurate velocities using AVO or Waveform inversion coupled with rock physics modeling or effective medium theory serves as an excellent tool for quantitative assessment of gas-hydrates and/or free-gas.

Results and discussion

As the sophisticated waveform inversion is a powerful method for delineating small-scale features and resolving tuning effects, the method has been employed to determine the fine structure across a BSR at two CDP locations (Fig.1) in the Makran accretionary prism (Sain et al., 2000). The result of full waveform inversion reveals unusually thick ‘free-gas’ zone (~200-350 m) below ~160 m thick hydrates-bearing sediments.

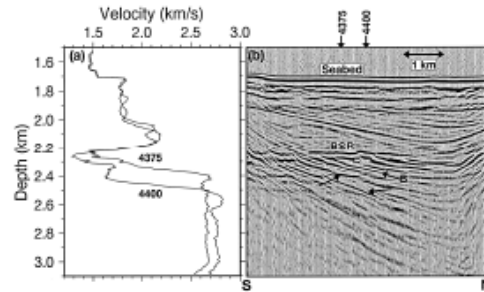


Figure 1: (a) Full waveform inversion results at CDPs 4375 and 4400, (b) Seismic section in the Makran accretionary prism.

Recently, Ojha and Sain (2007a) have performed the attribute analysis and show the blanking or reduction in amplitudes above the BSR; high reflectivity below the BSR (Fig. 2) that has been attributed to the presence of gas-rich and gas-poor sedimentary strata; and absorption of high frequencies below the BSR, observed as shadows in instantaneous frequency plot, indicating ‘gas accumulations’.

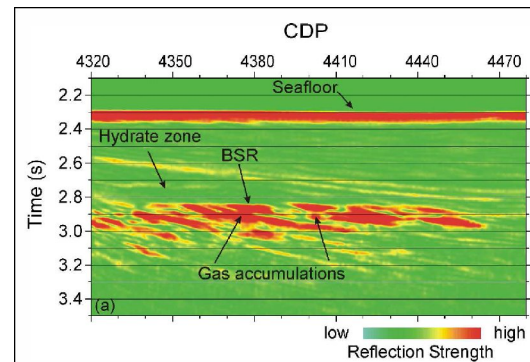


Figure 2: Reflection strength in the CDP range between 4320 to 4480.

Based on the AVO A-B crossplot (Ojha and Sain, 2007b), we estimate the gas-hydrates as 10-15% and free-gas as 2.5-4.5% (Fig.3) in the Makran accretionary prism. To complement the estimation, we also perform the AVO modeling (Ojha and Sain, 2007c) by cooperative traveltimes inversion followed by amplitude modeling (Fig.4) and the result based on the V_P/V_S ratio shows 12-14.5% gashydrate and 4-5% free-gas of the pore volume of the sediments.

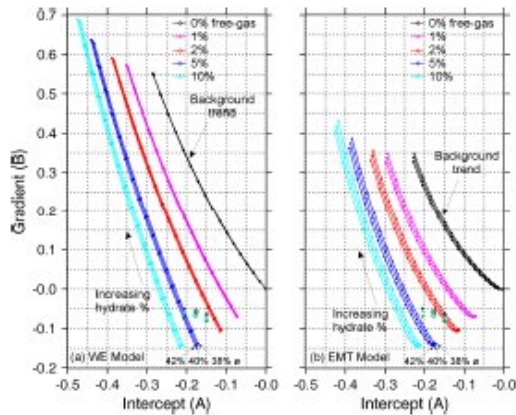


Figure 3: Theoretical crossplots between intercept (A) and gradient (B) for various gas-hydrates models at 40±2% porosity using the (a) WE and (b) EMT modeling respectively. The crosses, circles and triangles represent the A-B values for lower bound, best fit (average) and upper bound lines corresponding to the $R(\theta) \approx A + B\sin^2\theta$ curves respectively for various CDP ranges.

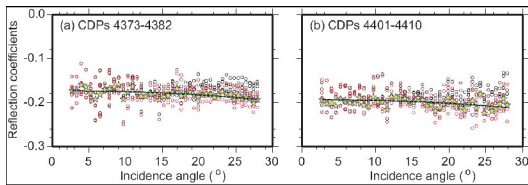


Figure 4: The reflection coefficients of BSR plotted against the incidence angles for CDPs (a) 4373-4382 and (b) 4401-4410 in the Makran accretionary prism. Red and black open circles represent the directivity corrected and non-corrected reflections coefficients. The black line is the best fit model response (calculated using the Zoeppritz equation) through the average (blue stars) of directivity corrected reflection coefficients.

Using the log spectral ratio method, we show that the region with BSR shows large quality-factor than that of the region without BSR (Sain et al., 2007). This implies that the hydrates-laden sediments have less attenuation or associated with more quality factor and can thus be used as an indicator for gas-hydrates in absence of BSR. The quality factor can also be used as a proxy to ascertain whether a BSR is caused by gas-hydrates or generated by diagenetic property. By employing the effective medium theory (Ghosh et al., 2007), we have quantified the amount of gas-hydrates as 22% for contact and 31% for noncontact models respectively in the Cascadia margin, and the study shows that nature of distribution of gas-hydrates within sediments should be known for evaluating the

true potential of gas-hydrates. We demonstrate that BSR can be used to determine the heat-flow (Vohat et al., 2003) and other physical parameters (Ghosh et al., 2006) without related probes and the case study has been employed to the Makran and the Cascadia margins. Gas-hydrates can also be identified based on several other proxies (Uma Shankar and Sain, 2007) like pockmarks, faulting through the seabed, gas-escape feature etc, and we have brought out specific character of BSR near the mud diapir.

Conclusions

Application of various seismic tools helps in identifying and quantifying gas-hydrates by measuring physical properties and relating the same to the hydrates saturation. The resource estimate is very much required for further research with regard to exploitation of gas-hydrates. Much of the deep-water regions within the Indian exclusive economic zone (EEZ) are yet to be explored. We are in the process of acquiring large-offset MCS and OBS data from the prospective zones in the eastern offshore. The traveltome tomography of large-offset MCS data would assist in demarcating the lateral and areal extent of gashydrates/ free-gas' saturated sediments by imaging the 'velocity build-up' and 'velocity drop' in the velocity tomogram. Independent P- and S-wave velocity information from the OBS data would help to know the nature of distribution of gas-hydrates within the sediments. Again the study of Poisson ratio is an important aspect for true assessment of gas-hydrates. Pre-stack depth migration of large-offset MCS and OBS data using the derived velocity tomogram would provide an improved structural image of BSR and base of free-gas saturated sediments. This may delineate faults or fractures acting as migration path for fluid flow to understand the genesis of gashydrates. Lot of scientific efforts is on for the exploration of gas-hydrates. However, the exploitation technology needs to be developed. It is expected that gas from below gas-hydrates will be produced soon and it will take a decade or so for viable production of gas from gashydrates. Depressurization, thermal stimulation, chemical injection, combination of these or molecular substitution (methane by carbon dioxide) can be considered for exploitation of gas-hydrates.

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