AVO feasibility and signature of a Taglu reservoir in Mackenzie Delta

Yong Xu - Scott Pickford

CSEG Geophysics 2002

Summary

The work in this paper is a part of a comprehensive study to investigate the AVO feasibility and AVO signature of the reservoirs in Mackenzie Delta. Based on one production well in this area, petrophysics and rock physics of the reservoir sandstones are studied and AVO responses are modeled. The work exhibits the feasibility of application of AVO to discriminate lithologies (sandstone-shale) and pore fluids (gas-brine) for the Taglu formation.

Introduction

In Beaufort-Mackenzie basin, the onshore delta underwent an early reconnaissance phase of exploration, which resulted in large gas discoveries and some minor associated oil discoveries. The Geological Survey of Canada using probabilistic play analysis has recently evaluated the potential of the basin. The analysis identified large potential resources of current interest in plays in the outer delta and shallow offshore environments, and in the offshore delta, principally in the Taglu and Kugmallit sequences. The potential for more substantial oil discoveries and supplementary gas discoveries is high and will be realized with a better understanding of structural complexity and depositional architecture, aided by new seismic exploration techniques.

As AVO technology has been applied successfully on seismic exploration in Alberta basin, it will become a significant tool to assist the exploration and drilling in Mackenzie delta area. In the AVO application, rock physics and petrophysics play important roles to process and interpret the seismic exploration. However, there is not much such kind of information to be referred to because exploration plays in Mackenzie Delta are relatively new. The petrophysical and rock physical details are rarely shown in the publications. Fortunately, a geophysical and well database has been built up since the first discovery (1971) and it is publicly available. Based on this database, an AVO feasibility study for this area is conducting. which focuses on rock physics, petrophysics, AVO modeling with simple and complex structures. The work in the paper is the part of this study and it investigates the rock physics, petrophysics, and AVO signature of the Taglu reservoir sandstone based on one production well.

Well log data

To perform AVO feasibility study two different steps must be done. First, study the elastic response of the reservoir rocks to changes in the interest reservoir properties (rock physics and petrophysics). Second, study the effects introduced by the wave propagation phenomena (modeling). Well Ya Ya A28 is a production well with reservoirs in Taglu formation. Its log curves are available from the database from International Datashare Corporation. Figure 1 shows the acoustic and petrophysical logs curves. In the half-transparent zone, the neutron and density porosity curves are crossed over in multi interbeds, which indicate the gas saturation. Two wells can be found in the database with shear sonic logs, one is well I43, and another is L38-2. L38-2 is only about 1000meters deep. The reasonable shear sonic curves from well I43 are plotted in Figure 2 (a). In Figure 2 (b), P and S wave velocities are cross-plotted and the mud-rock line is obtained from Vp and Vs. The gamma ray value of 60 is used as a separator between shaly and sandy rocks. In the cross-plot of Vp and Vs, the sandy samples shows subtle shift from shaly rock to the upper-left corner. In Figure 2 (c), while the sandy rocks shows subtle separation from shaly rocks in terms of Vp/Vs ratio, the density shows promising differentiation between two kinds of lithologies.

Rock physics and petrophysics

Based on well A28, the rock physics analysis consists of the following steps: model the shear sonic, pore fluid replacements. In general, this involves the use of petrophysical information and Gassmann fluid substitution to compute rock properties with different pore fluids (e.g. Mavko et al., 1998). In this study, the shear sonic prediction follows the chart in Figure 3. Reservoirs of Eocene and older sequences tend to have higher percentages of volcanic fragments than the younger sequences, are better cemented and exhibit lower porosity, in the range of 12 to 20%. Attention was paid to the estimation of porosity which is crucial to use Biot-Gassmann. The gamma ray, neutron and density porosity, and resistivity curves are used to specify gas bearing sandstone interbeds. Figure 4 shows the analysis results. The following observations can be made based on the analysis:

1. The estimated porosity is between 10%-20%, generally fitting other studies (National Energy Board).
2. LMR attributes are sensitive parameters to differentiate gas and brine saturated reservoir rocks. Gas sand should low lambda*rho, low lambda/mu and low difference between lambda*rho and mu*rho (see Figure (4) (d),(e), and (f)).
3. As the porosity in the reservoir rocks increases, the gaps of these sensitive parameters for gas and brine saturations also increase, and this means the probability to differentiate these two fluids increase.
4. Gas bearing rocks exhibit Vp/Vs ratio of 1.58-1.68 (see Figure 4(j)). This value is higher than that of ideal gas sand, which is about 1.5. One possible reason is the rock is not clean, and pore is partially occupied by shale or other cementations.
5. The cross-plot of Vp and Vs does not show great separation between brine saturated reservoir rocks and non-reservoir rocks. Lambda*rho shows better ability to separate these two lithologies because the density of wet reservoir rock is usually lower than non-reservoir rock within similar burial interval. This observation is consistent with the analysis from the well I43 in Figure 2.

AVO Modeling

Based on the log curves obtained from rock physics analysis, AVO responses are modeled based on Zoeppritz equations. The AVO response CDP gathers for the gas and brine saturated cases are shown in Figure 5. The frequency band for the synthetic gather is used as 5/10 – 50/60 Hz, which is common observed on the seismic data at this reservoir depth. The gas saturated reservoir show amplitude increasing with offsets at a few time levels (indicated by the arrows in Figure 5). The general dimming with offset is obvious in the brine-saturated case.

Conclusions and discussions

Based on the rock physics analysis and AVO response modeling, promising potentials of AVO as direct hydrocarbon indicator are shown up. The gas saturation sensitive parameters, such as Vp/Vs, lambda*rho, and lambda/mu, present the good ability to differentiate gas and brine saturations. Amplitude increasing with offsets is shown in multi beds inside the reservoir zone with gas saturation. The brine-saturated reservoir generally exhibits amplitude dimming with offsets.

Although the study in this paper shows positive aspects, study is conducting on some other issues:

1. Interbed effect. The reservoirs are usually stacked sandstones separated by shales, over a large vertical interval. AVO ability to characterize net pay is to be investigated.
2. AVO to be recovered in the complex structure. AVO friendly imaging and dip correction techniques are being studied.

References

Marvko, G., Mukerji, T., and Dvorkin, J., The rock physics handbook: 1998, Cambridge University Press.

Northern Oil and Gas Directorate, Petroleum exploration in northern Canada – A guide to oil and gas exploration and potential: 1995, Indian and Northern Affairs Canada.

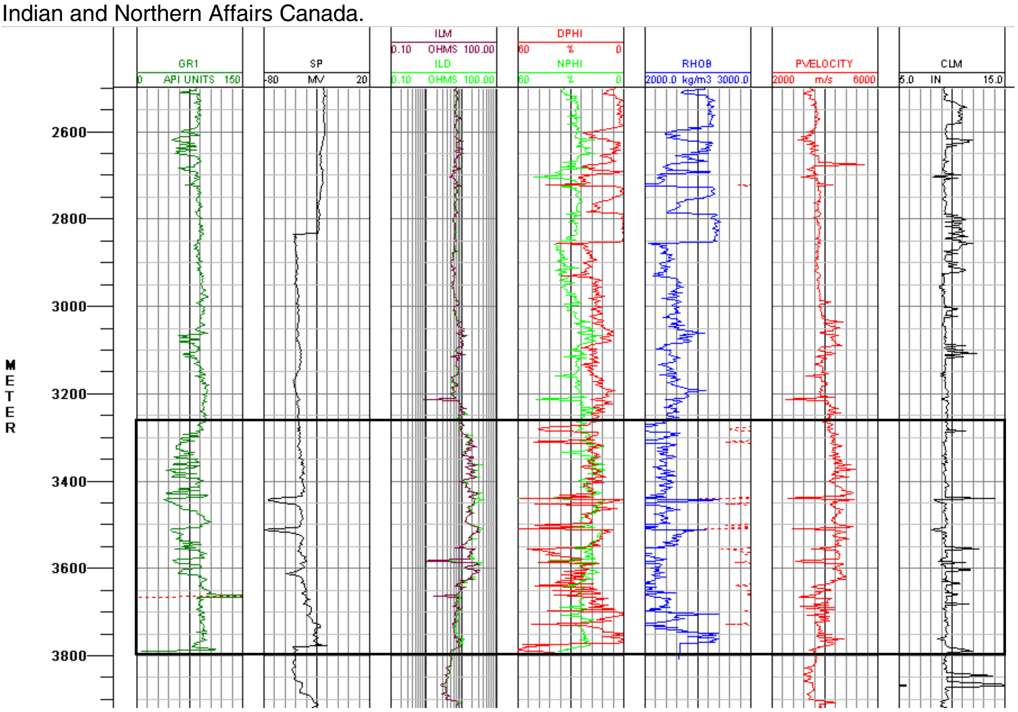

Figure 1. Log curves from well A28 in Ya Ya area in Mackenzie Delta.

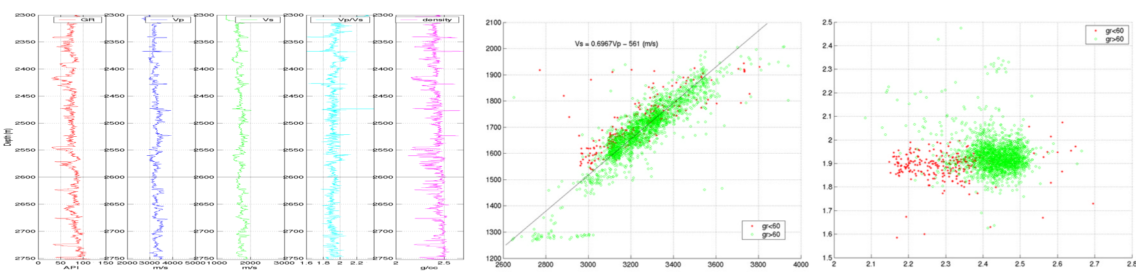

Figure 2. (a) Log curves form well I43 in Mackenzie Delta. (b) cross plot of Vp and Vs and mudrock line. (c) density versus Vp/Vs cross-plots.

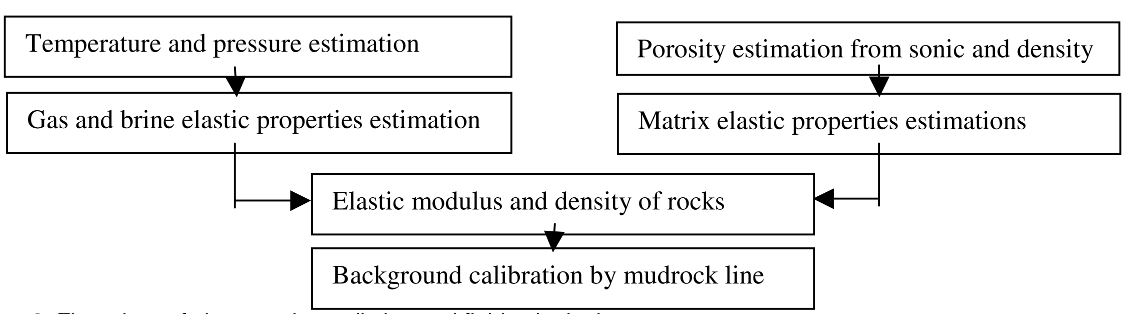

Figure 3. Flow chart of shear sonic prediction and fluid substitutions.

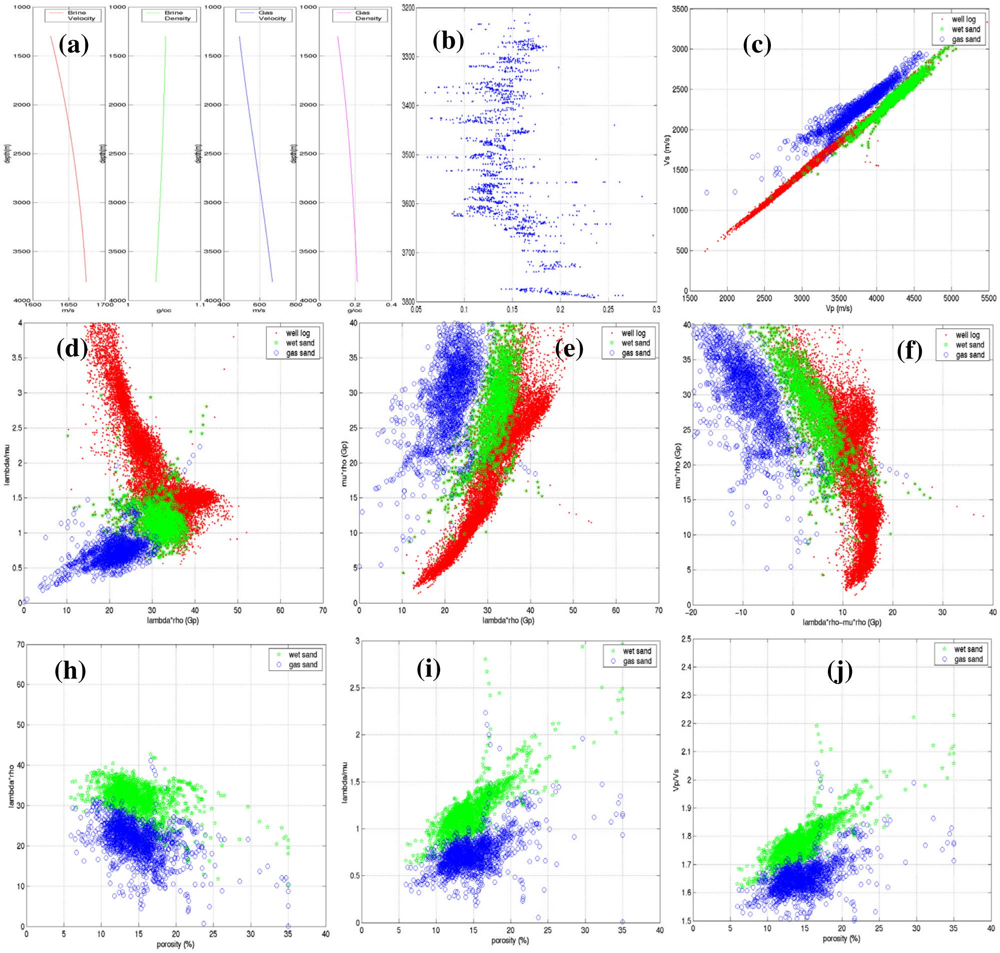

Figure 4. Rock physics analysis for well YaYa A28. (a) Estimates of P wave velocity and density variation with burial depth in gas and brine. (b) The estimates of porosity of the gas bearing interbeds in the reservoir zone (shaded in Figure 1). (c) Vp and Vs cross-plots. Blue and green samples are the gas and brine substitutions in the reservoir sandstone. The red are other samples from non-reservoir rocks. (d), (e), and (f) show the differentiation abilities of gas / brine reservoir sand and non-reservoir rocks in different cross-plot domains usually applied in AVO analysis. (h), (i), and (j) show the variation of three AVO sensitive parameters, lambda*rho, lambda/mu, and Vp/Vs, with the porosity; and also indicate the separation abilities of gas/brine saturation for different pore porosities.

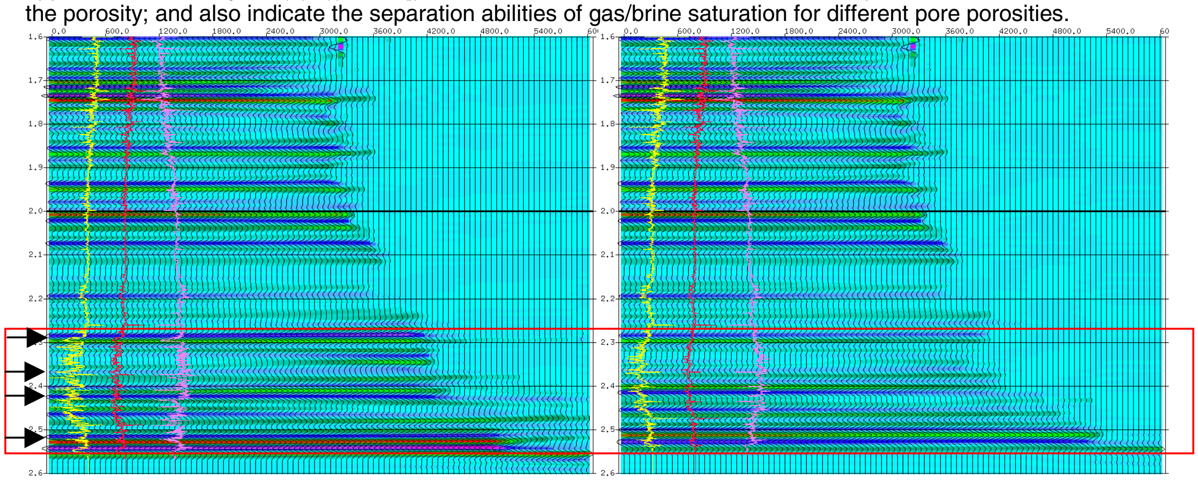

Figure 5. The AVO responses for gas and brine saturations in the reservoir zone. The yellow curves are Poisson's ratio; the red curves are gamma ray; and purple curves are P wave velocity.