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Lithology prediction and fluid discrimination in Block A6 offshore Myanmar

Hanumantha Rao. Y *, Loic Michel, Hampson-Russell,
Kyaw Myint, Ko Ko, Hay Man Ye Lwin, MPRL E&P

Summary

Integrated reservoir characterization studies are key to successful exploration. This paper presents such studies carried out in Block A6 offshore Myanmar which helps us to identify the potential prospective zones and reduce the risk at exploration stage. A feasibility study based on well logs showed that reservoir facies can be discriminated from elastic properties of logs. The Fluid Replacement Modeling (FRM) modeling studies on well logs and its pre- stack synthetic seismic shows synthetic AVO attributes i.e. product stack can discriminate hydrocarbons sands and brine sands. This encourages us to go ahead with simultaneous inversion studies by integrating the seismic data with available two wells data in A6 survey area. Bayesian litho classification studies were carried out to map the reservoir facies from inversion volumes. Further studies on quantitative interpretation of these attributes will be helpful to map the potential prospective zones and to improve the success rate of exploration.

Keywords*: Rakhine Basin, Myanmar, AVO Modeling, Simultaneous Inversion, Bayesian Lithology classification*

Introduction

During mid-seventies several international oil companies carried out exploration along Rakhine offshore basin, but with no significant discovery. Exploratory drillings of Daewoo E&P confirmed the hydro carbon potential of North West Rakhine Basin along Myanmar offshore (Yang et al., 2006). The recent hydrocarbon discoveries by MPRL E&P established the hydrocarbon potential of southern Rakhine offshore basins.

The present study area block A6 is located in Southern Rakhine basin, offshore Myanmar and comprises 550 sq km. of 3D seismic data with 5 angle stacks and 2 exploration wells (Fig. 1). The Rakhine-Yoma fold belt formed between tectonic ridges consists of proven gas plays (Shwe) in Pliocene and Miocene mass flow deposits. The geology is complex with the presence of shallow channel cuts and complex structures with steep slopes due to translation movement of the India plate against the Eurasian plate. Sand depositions are guided by tectonic ridges through time. The main lithology is sand-shale alterations in the shallower horizons and potential limestone and mass transport complex in older strata. On the basis of log quality, both the wells are considered for inversion studies. The zone of interest is around Pleistocene-Miocene sands bounded by 7 horizons with the main reservoir around top seal south fan and base fan horizons.

The given well logs were first conditioned for petro-physical studies. Cross plot analysis of elastic logs shows good discrimination of facies. Fluid Replacement Modeling (FRM) studies were carried out to understand the elastic properties of reservoir rocks for fluids (brine and hydrocarbon) and its saturation changes (Fig. 2b). In continuation to that, wavelet has been extracted to carry out synthetic-seismic well ties. A good synthetic-seismic well tie was obtained in the reservoir interval at both the wells. Pre-stack synthetic seismic of FRM logs shows an increase in AVO response for gas sands and a decrease in AVO response for water sands. The modeled synthetic seismic AVO product stack (fig. 2c) and seismic AVO product stack (fig. 2a) shows that AVO attributes are dependable to discriminate hydrocarbon sands from water sands in the study area.

9 Serangoon North, Avenue 5, Singapore-554531,
E-mail: RaoYandapalli.Hanumantha@cgg.com

Simultaneous inversion is the process of integrating the well data and seismic data by inverting the angle stacks in terms of absolute elastic properties of the reservoir. A layered initial earth model has been created using horizons and low pass filtered logs (Vp, Vs and Density) where low pass filtered Vp logs are calibrated with seismic interval velocities. During inversion process, initial model is iteratively perturbed using simulated annealing techniques to minimize the differences between synthetics and angle stacks, and generate the final earth model.

Transforming the inverted elastic attributes in terms of reservoir facies is the next key step in the reservoir characterization studies. Generally the cut off identified from either histograms analysis of elastic properties or cross plots can be used to map the inversion results in terms of reservoir facies. Though popular, these techniques are subjective to the cut off used or polygons defined for mapping process. Also the above mentioned techniques are not also able to quantify the uncertainty associated with mapping process. Bayesian litho-classification is an advanced mapping method where uncertainty associated with mapping process can be quantified. From the given set of well logs, appropriate elastic attributes are identified to generate a training set of probability density functions color coded by litho facies. Guided by these training sets, final inversion volumes are classified in terms of reservoir facies probability volumes. With further work on quantitative interpretational studies can be carried out on these volumes to map appraisal and development targets for drilling and reduce the exploration risk.

Petro physical studies on well data

The given logs at two wells from the study area are subjected to basic log editing and petro physical curves (Vclay, Porosity, Sw) were generated using industry standard practices. Consistency between petro physical logs and elastic logs has been verified through Rock Physics Modelling studies (RPM) and is observed to be good. The histograms and cross plot analysis of elastic properties shows good separation of litho facies (brine sands, gas sands and shale). Followed by Fluid Replacement Modelling studies were carried out on insitu logs for 4 scenarios i.e. the insitu, 100%water, 10% Gas and 80% Gas. The cross plot QC and 1D QC of FRM logs shows that elastic attributes are sensitive to fluids (brine and hydro carbon) as well as its saturation changes (Fig. 2b). From FRM logs we can also observe that for given saturation changes, change in Vs is minimal because shear wave is insensitive to fluids. However change in Vp and Density (Rho) are significant. We can also notice that Vp drops quickly as we move from from 100% water case to 10% gas case after which it increases slightly even for higher gas saturation. Density consistently decreases as we move from 100% water to 80% gas case, which indicates the density is a good saturation indicator.

In continuation to this, pre-stack synthetic response of modelled FRM logs, shows a clear difference in AVO response for brine sands and hydrocarbon sands (Fig. 2c). Model response of synthetic seismic AVO product stack (Fig. 2b) and seismic AVO product stack (Fig. 2a) shows that AVO attributes are dependable to discriminate hydrocarbon sands from water sandsand in the study area.

Simultaneous Inversion

Simultaneous inversion is a tool that integrates the seismic data and log data to generate the absolute elastic properties of earth model. The CGG proprietary inversion scheme StratiSI begins with layered initial earth model of elastic properties. During inversion the initial model is iteratively perturbed using simulated annealing technique to find a global solution that optimizes the match between angle stacks and respective synthetics. In addition to data mismatch term, objective function contains 3D spatial continuity constraints that are used to attenuate random noise. In case if the number of angle stacks and data quality are not sufficient enough link between Vp-Density is used to estimate density variations. As the seismic data is band limited in nature, an initial low frequency model should be created encompassing the missing low frequencies. Also note that the low frequency initial model is key to convert the relative inversion results into absolute final model. For the current study area a 0-6 Hz initial low frequency model is built by krigging the low pass filtered logs guided by seismic velocities as secondary property. The initial model building process is controlled by stratigraphic frame work of horizons in time and layer thickness for initial is determined from the width of central lobe of the wavelet.

The inversion is carried out in 3D sense that many bins are inverted simultaneously which preserves the lateral continuity and leads to more stable results. However, the choice of final elastic parameters and inverted results depends on the data quality and the available angle range. In the majority of cases, only Vp and Vs elastic parameters are estimated and density (ρ) is internally constrained by the algorithm. When inversion of the density is not possible this attribute can be either frozen during the inversion process or estimated using given Vp-Density relationships between well logs. Fig. 3a shows the 1D QC of inversion results with up-scaled logs, which shows good match between up-scaled logs and inversion results. Fig. 3b shows an arbitrary section of the inverted VpVs section passing through wells shows potential hydrocarbon zones with relatively low VpVs values.

Bayesian Litho classification

Further step in the reservoir characterization is mapping the final earth model of elastic properties in terms of the litho facies probability model. Popular and commonly used techniques for this transformation process are a) Histograms b) Cross plots of elastic properties. However these techniques are subjective in terms of range of cut offs or polygon applied and cannot quantify the uncertainty associated with the classification process. Bayesian litho-classification techniques are advanced techniques to overcome the above limitations. An improved classification can be obtained with Bayesian techniques which can also quantify the uncertainty associated with classification. Bayesian litho classification technique also provides the probability volume of each litho class as well as volume of the most probable facies.

In order to carry out lithology classification, firstly we need to have target log of desired litho facies at each well. This can be generated by applying appropriate cut offs on petro physical logs at each well. The probability density function (Bi-variate or Tri-variate pairs) may be generated for the best combination of elastic attributes color coded by litho facies. For the present study VpVs and Poisson impedance attributes seems to be a better choice for the prediction of litho facies volumes (Fig 4a). On the basis of these PDF's inverted Poisson impedance and VpVs volumes are classified to generate probability volume of each litho facies (Shale/Gas sand/Water sand) and also the most probable litho facies volume. Fig. 4b shows an arbitrary section of most probable litho facies section through wells. We can see good match in predicted facies at well locations.

The next step in reservoir characterization includes quantitative interpretation studies. The objective of quantitative interpretation is to predict lithology and fluid content away from well. Geo-body volumes can be generated using facies volumes and its voxel connectivity analysis. These geo-bodies can be used in volumetric interpretation like estimating HCPV and NTG of reservoir for development studies.

Conclusions

The well log studies established the feasibility to classify reservoir sands from non-reservoir sands from elastic properties of block A6 survey area. The FRM studies on well logs and its pre-stack synthetic seismic AVO studies show the ability to discriminate water sands from hydro carbon sands from AVO studies. Integration of well data and seismic data through simultaneous inversion gives the final earth properties of earth model. By using the Bayesian litho classification techniques we could map the final earth model as probability volume for each litho facies and the most probable litho facies volume. These facies volumes can be used to map potential prospective zones in the A6 survey area and reduce the risk in exploration wells. Quantitative interpretation of facies volumes coupled with rendering voxel geo-bodies are beneficial for successful exploration as well as field development studies.

Acknowledgments

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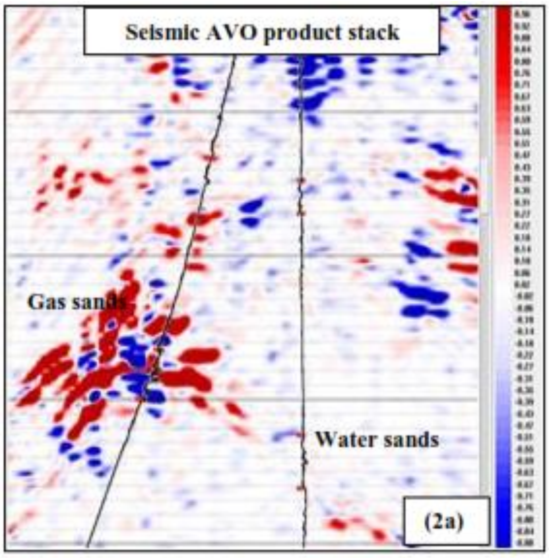
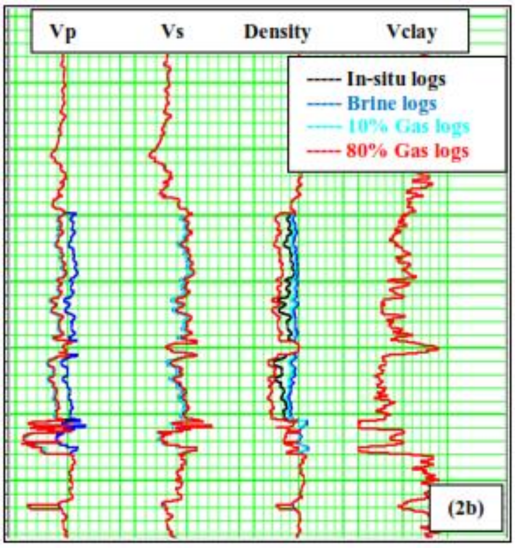
Fig. 1 The Base map of study area





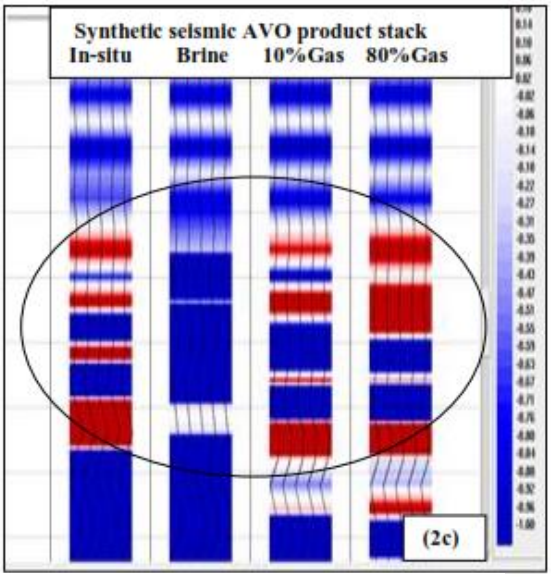


Fig. 2 (a) AVO Product stack passing through wells (b) Fluid Replacement Modeled logs for various scenarios (c) Synthetic-Sesimic AVO product stack (Intercept*Gradient) using FRM logs

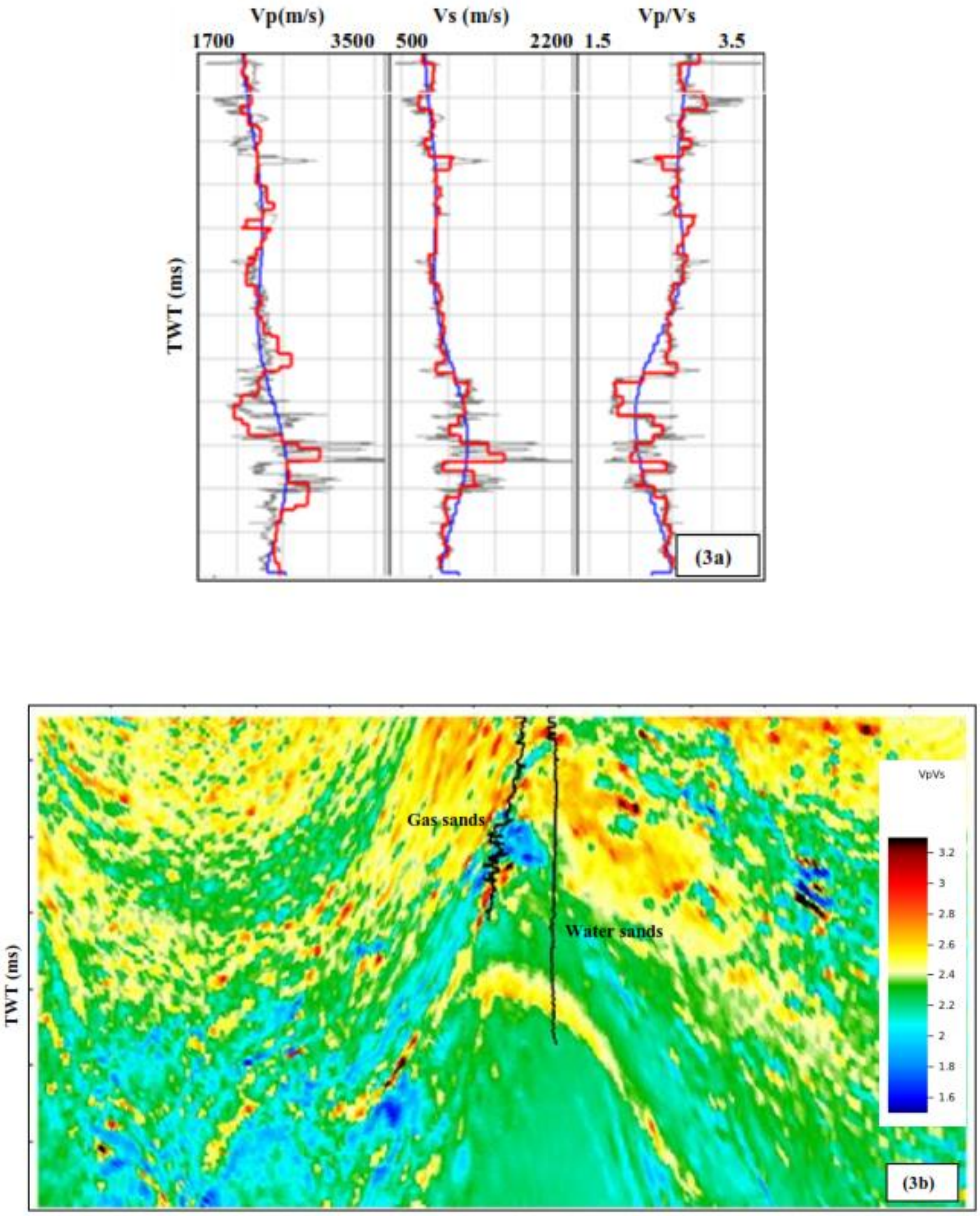
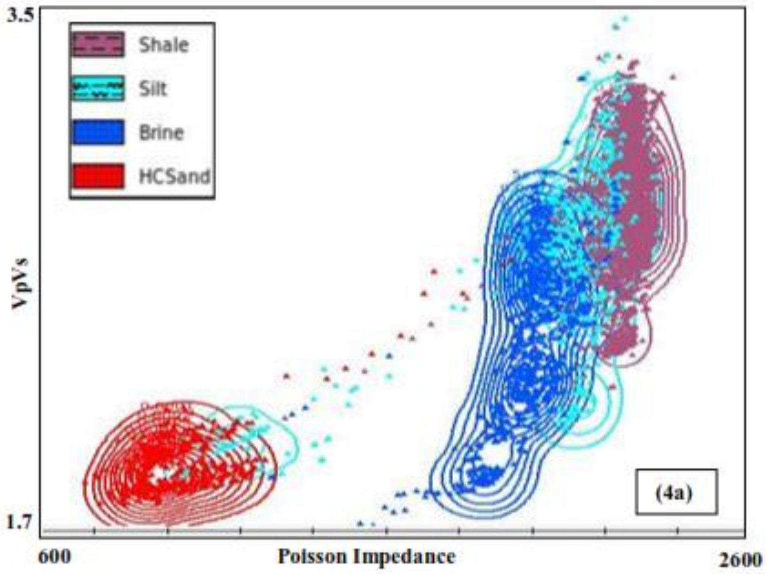


Fig. 3 (a) Comparison of inversion results with up scaled logs at well location (b) Inverted VpVs section passing through wells.



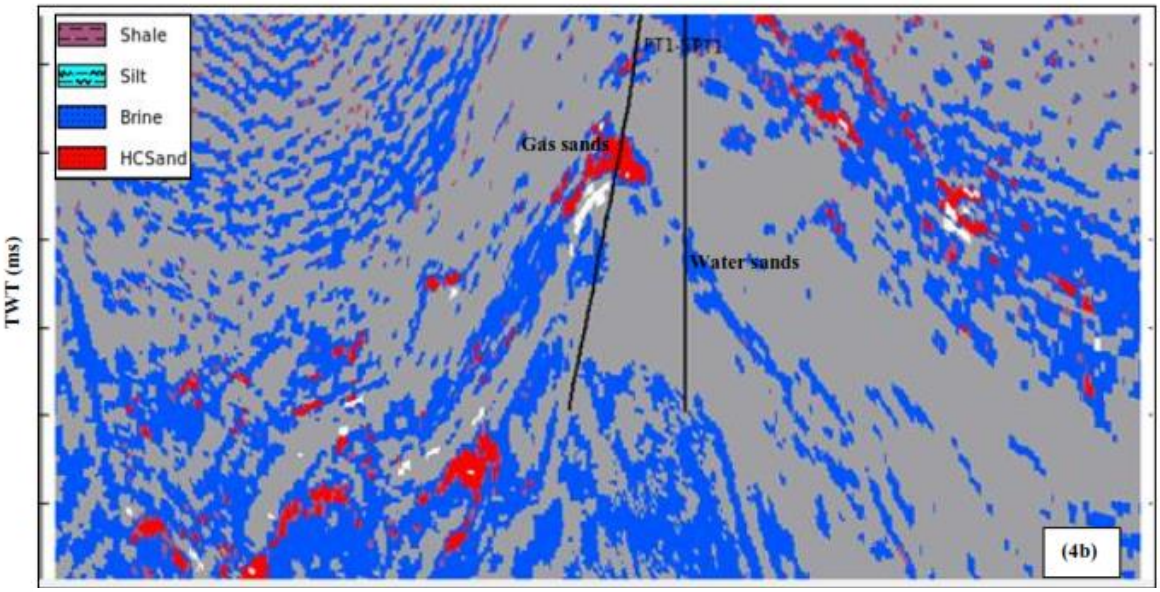


Fig. 4 (a) Probability density function of Poisson Impedance x VpVs from well logs (b) Section of most probable litho facies passing through wells