Mapping of Pore-Pressure from 2D Post-Stack Seismic data in Upper Assam, India

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Keywords

Seismic inversion, Velocity modeling, Pore-Pressure, Eaton's equation

Summary

Predrilling prediction of pore-pressure (PP) from seismic velocity has significant impacts on drilling of new wells. Model based post-stack seismic inversion has been carried out along an 8km seismic line passing across three wells. A velocity model has been developed for time to depth conversion of the inverted results by integrating all geological and velocity information for precise PP prediction. The inversion derived density and velocity models are used for mapping of overburden stress (S_V) and PP along the 2D seismic line using Eaton's sonic equation. Finally, the seismic derived S_V and PP have been correlated with log derived measurements and available Modular Dynamic Tester (MDT) data at specific depth points at well locations. The current study area is located in Upper Assam, the north-eastern part of India which constitutes one of the oldest producing petroleum provinces. Velocities vary between 2400-3800 m/s in the study area. The estimated SV and PP values range from 36-85.2MPa and 18-39.5 MPa respectively within a depth interval of 1650-3800m without any presence of abnormal pressure pockets. SV and PP are the key parameters for any geomechanical studies that are a necessity in north east Upper Assam which is known to be an active basin.

1. Introduction

Precise prediction of pore-pressure (PP) from seismic velocity prior to drilling can enormously increase on drilling efficiency. Using this methodology, pore pressure has been calculated along a 2D post-stack seismic section. The accuracy of pore-pressure prediction relies on successful generation of the velocity model, which has been developed by integrating all available geological and velocity information from well log and seismic data. The present study area is located in Upper Assam, the north-eastern part of India which constitutes one of the major petroleum provinces in India. In hydrocarbon exploration and production, pore pressure estimation is critically important for identifying probable hydrocarbon accumulation (from overpressurized zones), calculating horizontal stress magnitude and for overall wellbore stability analysis. (Soleymani and Riahi, 2012).

Conventional log data of three wells and 2D post-stack seismic line from Upper Assam basin have been used in this study. Mapping of pore pressure distribution has been carried out by implying results of post-stack seismic inversion and velocity modeling. Eaton's sonic equation has been used in this study for pore pressure prediction from well log and 2D seismic and finally both results are calibrated with the measured data.

2. Methodology

A successful reservoir characterization includes deriving rock properties from the seismic data and relates them to reservoir properties. The steps followed for pore pressure estimation are presented as a flowchart in figure 1a. An 8km 2D seismic section (Figure 1b) across wells M1, M2 and M3 has been used for well to seismic tie for model based seismic inversion (Gogoi and Chatterjee, 2019). Horizons have been picked along the seismic line by correlating the seismic events and tying their times with the well log data. The velocity and density model have been generated from acoustic impedance inversion of the post-stack seismic data using sonic and density logs which would be later used for geomechanical implementation.

2.1 Velocity modeling

A reliable velocity model that converts seismic data from time to depth domain provides an effective means to integrate the two domains. This is the key tool for modelling and developing a subsurface reservoir (Pandey et al., 2013). A precise depth

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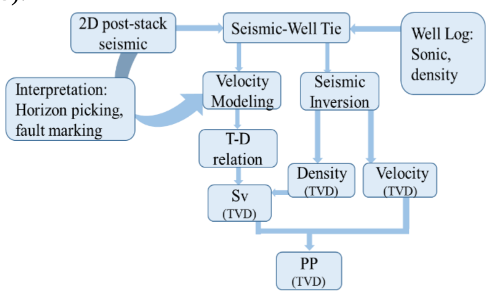
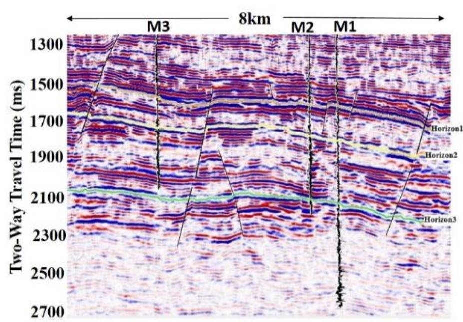
conversion has been created by tying the wells M1, M2 and accurately predicting depths at new locations. The instantaneous velocity can be described as a linear function of depth as: V(z) = V0 + kz, where V(z) is the instantaneous velocity at depth z, and V0 and k are the intercept and slope of the line. A velocity model is built here using picked horizons, p-wave velocities, and time-depth relationship. Velocities vary between 2400-3800 m/s (Figure 2a) (Gogoi and Chatterjee, 2018).

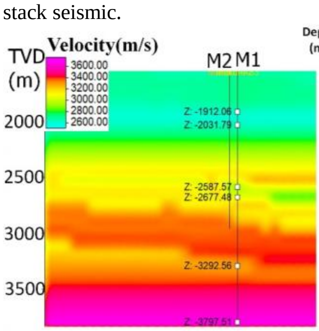


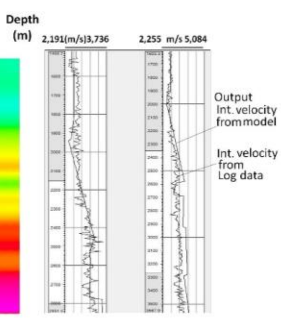
(a)



(b)

Figure 1: (a) Workflow of Pore-pressure prediction and (b) 2D post-stack seismic.





(a) (b)

Figure 2: Generated Velocity model in (a) depth domain along with (b) comparison of model predicted interval velocity with observed data from well log (Gogoi and Chatterjee, 2018).

The generated model is well matched with the log derived interval velocity from wells M1 and M2 (Figure 2b). As a validation of the method, the depth matching at each well location is performed with the known formation tops of the wells. The generated model is used on the inversion derived density and velocity section for depth conversion (Figure 3).

2.2 Geomechanical Implication

The vertical component of total stress or overburden pressure (S_v) at any depth, is the pressure resulting due to the rock matrix and its pore fluids overlaying a particular depth. The computed density model (Figure 3) in depth is used for estimation of S_v (Figure 5) which is calculated by integrating the bulk density (ρ) from the surface to the specific depth (Plumb et al., 1991)

$$S_V = g * \int_0^z \rho(z)dz$$

where ρ(z) is the density at depth z below the surface and g is the acceleration due to gravity.

Pore pressure (PP) has been calculated (Figure 6) using Eaton's sonic equation (Eaton 1972, 1975)

$$PP = S_V - (S_V - P_h) * (V_p/V_n)^n$$

where,

P_h = hydrostatic pressure gradient considered 10MPa/km

n = Eaton's exponent which has been considered 1 for the studied wells (Alam et al., 2019)

V_p = compressional sonic velocity derived from 2D seismic inversion results,

V_n = velocity computed from normal compaction trend (NCT).

A linear relationship $V_n = 1.1182V_p - 217.14$ between V_n and V_P has been derived from well log data (Figure 4). This relation is used to generate pore pressure section from inverted seismic data (Figure 6). Figure 7 shows that the seismic velocity derived S_V and PP are well correlated with their measured values from well log data for wells M1 and M3. Available Modular Dynamic Tester (MDT) data at specific depth points representing formation pressure has also been plotted and the Eaton's computed pore pressure matches well with the measured pressure data.

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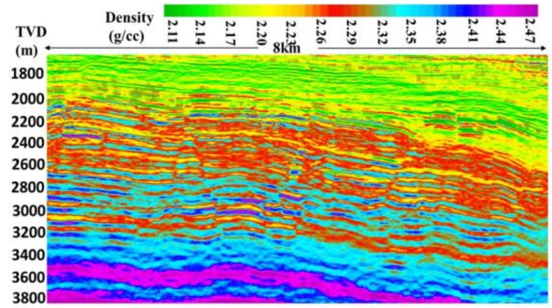

Figure 3: 2D density model along the seismic profile.

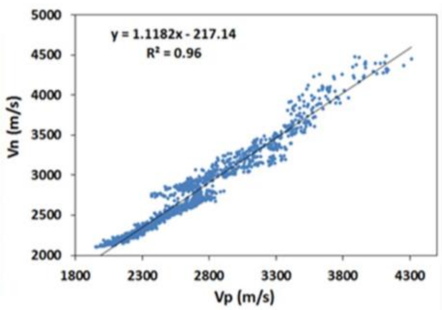

Figure 4: Correlation between Vn and Vp with R2=96%.

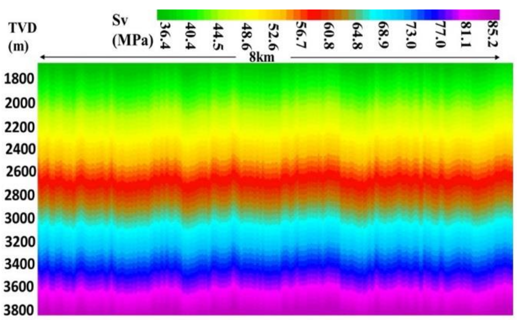

Figure 5: Overburden Stress (S_V) along the seismic line.

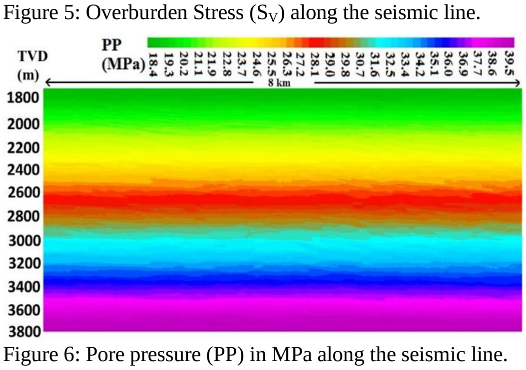

Figure 6: Pore pressure (PP) in MPa along the seismic line.

3. Results and Discussion

In this study, the workflow as shown in figure 1a, utilizes density log, sonic log, post-stack inversion and seismic velocity modeling to generate pore pressure distribution/model. The overburden pressure stress, has been mapped along a 2D seismic line using inversion derived density and seismic velocity. Its value ranges from 36-85.2MPa. The estimated pore pressure following Eaton's sonic equation exhibits a gradual increase within depth interval 1650-3800m from 18-39.5 MPa without any significant abnormal pressure pockets. Alam et al., 2019 has shown in their work that little to no overpressure exits in the wells M1 and M3 which reinforces the outcome of this study. The seismic derived Sv and PP gradient has been found to match well with the log derived pore pressure and overburden stress. Available Modular Dynamic Tester data has also been shown to match with results.

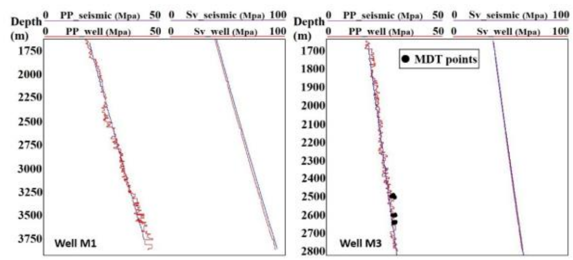

Figure 7: Correlation of seismic and log derived pore-pressure & vertical stress along with measured MDT data at well locations.

4. Conclusions

Upper Assam in north east India is host to one of the world's oldest producing hydrocarbon basin. Pore pressure serves as the backbone of any production process. Proper PP information is a necessity not only to detect producible zones but also for safe wellbore practises (minimum, maximum mud weight estimation).This study attempts to present a visual representation of pore pressure in predrill conditions. Overburden stress has also been mapped along the seismic line that has been considered for the study. These two parameters are also the key inputs for any geomechanical studies that are a necessity in north east Upper Assam which is known to be an active basin.

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Acknowledgement

Authors are thankful to Oil India Limited, Duliajan for providing well log data and drill cutting samples. We thank Dept. of Applied Geophysics, IIT(ISM) Dhanbad for helping us in performing the research work.