High Resolution Pore Pressure Prediction Using AVO Inversion

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Summary

Pore pressure information in the subsurface is important in planning and designing drilling. It becomes increasingly important in reservoir characterization in over pressured zones. Traditionally, the P-wave velocity obtained through stacking velocity analysis or reflection tomographic inversion is used to estimate pore pressure. This is problematic because these velocities have low frequency and thus low resolution. As a result, the predicted pore pressure often does not meet the requirements for drilling. This is especially true in those areas where lithological variations are significant. In this paper, we propose a method to obtain high resolution velocity for estimation of pore pressure. This method takes an approach combining stacking or tomographic velocity analysis with AVO velocity inversion. The resultant pore pressure has high resolution and enhanced accuracy. Additionally, the P- and S-wave velocities as well as Vp/Vs ratio and Poisson's ratio that resulted from this process can be used for reservoir characterization in over pressured zones.

Introduction

Well design and drilling safety in hydrocarbon exploration require accurate pore pressure files in the subsurface. The pore pressure is influential in reservoir characterization in over pressured zones because it has significant impact on seismic rock properties. Traditionally, pore pressure prediction is conducted based on the transformation of seismic velocities to vertical effective stress (VES) using overburden pressure (OBP) and hydrostatic pressure (HP). The most commonly used method is Eaton's

$$\mathrm{VES} = \mathrm{VES}_n(\mathrm{Vp}/\mathrm{Vp}_n)^b\ , \qquad (1)$$

where $\mathrm{VES}_n = (\mathrm{OBP} - \mathrm{HP})$, b is a local constant, Vp is the measured P-wave velocity, and Vp_n is the velocity of shale in normal compaction . Pore pressure (PP) can thus be calculated by

$$\mathrm{PP} = \mathrm{OBP} - (\mathrm{OBP} - \mathrm{HP})(\mathrm{Vp}/\mathrm{Vp}_n)^b, \qquad (2)$$

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where Vp is interval stacking velocity or reflection tomographic velocity. In velocity analysis, reflection tomographic velocity is considered more accurate than stacking velocity. Whichever of these two velocities is used, the resultant pore pressure has low resolution. This is because these velocities are the low frequency component of the velocity profiles in the subsurface. In this paper, we introduce a method that combines stacking velocity or reflection tomographic velocity with AVO velocity inversion. This method is able to produce high resolution and high accurate velocity for pore pressure prediction and reservoir characterization in overpressure zones.

Method

Figure 1 gives an example that shows a comparison of sonic logs and stacking velocities at two well locations in the South Gulf of Mexico. We see that the stacking velocity is actually the low frequency component of the sonic logs. Also, notice that the stacking velocity is unable to resolve individual formations. In addition, the stacking velocity reflects the average of the sonic velocity. At well 2, for example, the stacking velocity in the over pressured zone (above the Mioceno interface) is significantly higher than the sonic velocity. It implicates that the estimated pore pressure using stacking velocity will be significantly lower than the actual pore pressure.

Because stacking velocity or reflection tomographic velocity is the low frequency component of the velocity in the subsurface, we should be able to use them as background velocity for AVO velocity inversion in which velocity reflectivities are used. As a result, the velocity profile contains both the low frequency content that is from stacking or tomographic velocity and the high frequency content that is from velocity reflectivities. The velocity reflectivities, $\Delta Vp/Vp$ and $\Delta Vs/Vs$, can be extracted from CMP gathers by using the two-term AVO equation (Smith and Gidlow, 1987):

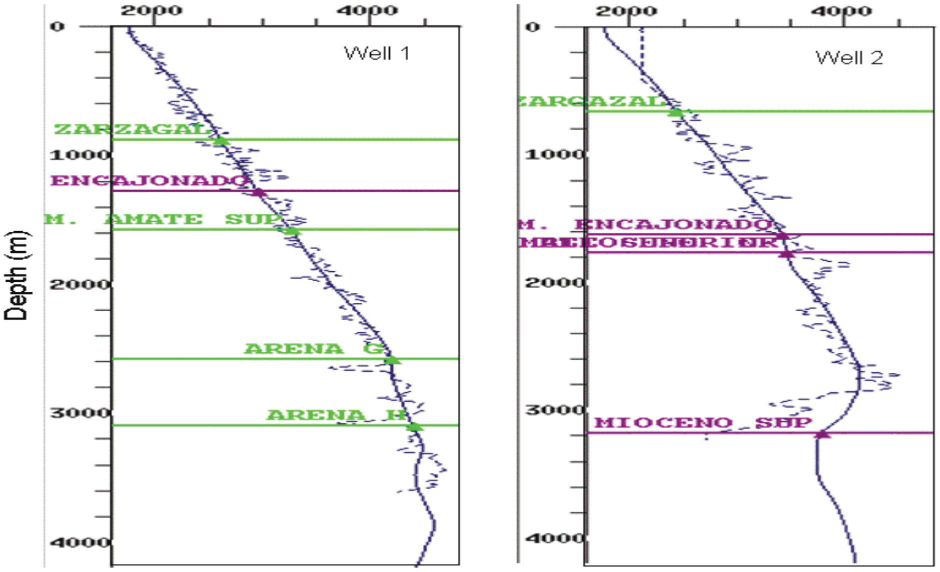

Figure 1. Comparison of sonic log with stacking velocity at the South Gulf of Mexico.

$$R(\theta) = \left\{\frac{\Delta Vp}{Vp}\right\}\left\{\frac{1}{2}\left(1+\tan^2\theta\right)+g\left(1-2\left(Vs/Vp\right)^2\sin^2\theta\right)\right\}\times\left\{\frac{\Delta Vs}{Vs}\right\}\left\{4\left(\frac{Vs}{Vp}\right)^2\sin^2\theta\right\}, \quad (3)$$

where g is from Gardner's relation $\rho = aVp^g$. Depending on the type of background velocity, we call the AVO velocity inversion using stacking velocity and tomographic velocity SVAVO and TOMOAVO, respectively. Figure 2 shows a workflow of AVO velocity inversion with pore pressure prediction.

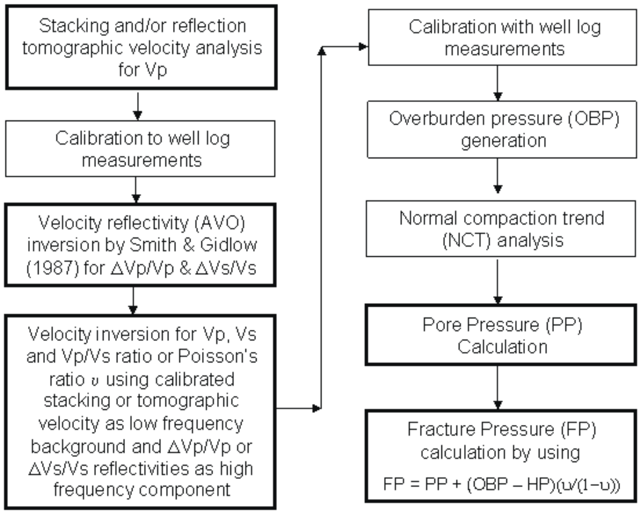

Figure 2. Workflow of high resolution pore pressure prediction.

Conclusions

We have proposed a new method to estimate high resolution pore pressure. This method is based on AVO velocity inversion with background velocity from PSTM stacking velocity or PSDM tomographic velocity. It has been demonstrated that the velocities from velocity analysis are the low frequency component of the velocity profile of the subsurface. Further, we have shown that in overpressure zones, the P- and S-wave velocities as well as Vp/Vs ratio and Poisson's ratio that are inverted from AVO velocity inversion can be used for lithology delineation and reservoir characterization.

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References

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