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Application Of Shear Wave Velocities For Pore Pressure Prediction In High Temperature Overpressure Regimes

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ABSTRACT

Estimation of accurate pore pressure is important for safe well planning and its cost effective completion in regions where narrow pressure margins challenge the exploration and development opportunities. Overpressures associated with under-compaction generally possess a direct relationship between effective stress (ES) and velocity, whereas unloading related pressures do not provide such direct indications from porosity trend. A consistent overpressure evaluation challenge is observed in high-temperature environments due to multiple sources for pressure generation and porosity reduction. Moreover at high temperatures (above 100°C), complex kinetic reactions mask any usable relationship between ES and porosity due to cementation and chemical compaction effects. Understanding pressure mechanisms and their role in porosity-ES relationship is crucial in pore pressure prediction estimation.

A common challenge encountered at high temperatures is the high velocity behavior of the formation which manifests to a false normal pressure signature. This high velocity behavior at high temperature is attributed to mineralogical changes (smectite to illite) and aggressive cementation. The challenge in such chemically compacted system is to identify the fluid retention as an overpressure signature, which would normally be masked by the matrix effect. The critical parameter which controls the overpressure estimation in such environment is the identification of trapped fluid under such low porous conditions and an alternative solution is required to establish a successful relationship between ES and porosity. Since shear wave velocity is unaffected by change in saturation, the ratio of P- and S-wave velocities (Vp/Vs) can be used as an effective proxy to detect fluid/porosity retention in these chemically altered rocks. The compressional wave velocities have a bearing on matrix and fluid, whereas the shear wave velocities are affected only by matrix, thus the Vp/Vs ratios effectively enhance the fluid in the system.

Vp/Vs ratios are analyzed from the drilled locations to understand any possible relationship between ES and S-wave velocity, and indicate a distinct decreasing trend across the overpressure formations. This prominent cut back signature in Vp/Vs ratio observed against the high velocity formations is used as an overpressure signature. Furthermore, the Vp/Vs trends with depth illustrated distinctive patterns are correlatable to the overpressure magnitudes present at different pressure compartments. This effective correlation between Vp/Vs ratio and overpressure magnitudes is exploited to extract a velocity correction factor. A velocity correction envelope is resolved for overpressure zones by normalizing the Vp/Vs values across the normally pressured formations. This approach reinstated the usable ES-porosity relationship for effective pore pressure estimation by making the velocities sensitive for fluid effects in compacted and high temperature formations. Pore pressure estimation using corrected velocity from Vp/Vs analysis has shown high degree of accuracy on prediction trends.

Overpressures associated with chemical compaction regimes are extremely difficult to resolve using conventional pore pressure prediction methods. The Vp/Vs based pore pressure predictions are more effective and valid method, in which fluid effects out of chemically/diagenetically altered rock framework are extracted as velocity correction coefficient, thus making the velocities sensitive enough to estimate the actual pore pressures. However, this method can only be used after validation with other parameters that could affect the Vp/Vs trend. Application of this approach in future can be extended to other rock types, such as carbonates, in which diagenetic changes are complex and difficult to model.