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Travel-Time Methods of Vp/Vs Determination for Pore Pressure Prediction Using Lookahead VSPs

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Abstract

The increase in subsalt exploration drilling activity, and the drilling problems associated with exiting salt, have led the oil industry to scrutinize subsalt drilling practices and the methods commonly in use for pre-drill pore pressure forecasting. Integrated drillability assessment utilizing a combination of offset well information, seismic derived velocities, and basin fluid flow modelling has improved the accuracy of pre-drill pressure forecasts, but significant uncertainty still exists in quantifying the stress regimes immediately below salt.

Recently, 2D walkaway VSPs designed specifically to address the subsalt pressure uncertainty via Vp/Vs estimates and empirical models for Vp/Vs to pressure conversion, have been successfully used to impact drilling operational decisions and improve subsalt drilling success. The process of using lookahead VSP's can be subdivided into three distinct phases: 1) modeling to establish feasibility of a walkaway VSP for revealing reasonable Vp/Vs and for establishing an optimum 2D acquisition, and calibration of the Vp/Vs to pressure conversion model 2) acquisition of the VSP and real time processing using AVA and kinematic methods to establish the subsalt Vp/Vs, identify inclusions, and refine the base of salt depth prediction, and 3) pressure prediction from the Vp/Vs and review and update of the salt exit Mudweight/salt exit drilling procedures. This paper will focus on the kinematic methods employed for estimating Vp/Vs in the second phase of this lookahead VSP workflow.

Pore Pressure Calculation from Vp/Vs

In the last few years a number of workers have described or implied that shear velocity as well as Vp/Vs should be as sensitive or more sensitive to pore pressure of mud rocks as the typical compressional velocities, Vp or travel time, we have used for years for pressure prediction and pressure detection while drilling (Huffman and Castagna, 2001; Huffman, 2002; Eberhart-Phillips et al., 1989). In some cases recommendations for drilling overpressure in deep water in the shallow, riserless section, most often referred to as the shallow water flow zone, have been based on the prediction of unusually high Vp/Vs in sediment derived from surface seismic data. The high Vp/Vs is interpreted to be due to very unconsolidated conditions likely reflecting relatively high overpressure. Our work focused on evaluating the response of shear velocity and Vp/Vs to overpressure, that is low effective stress, and if possible create a workable technique to calculate the magnitude of overpressure (Heppard et al., 2002; Ebrom et al., 2003).

Our process began by reviewing shear (Vs) and Vp/Vs as measured by dipole sonic tools from a number of wells from six petroleum basins in the Americas, Africa, and Asia. Our process was similar to the way we in the industry have evaluated compressional sonic travel time or velocity via comparing measured responses to an expectation of velocity under normal pressure conditions (Figure 1). Our expectation of normal Vs and Vp/Vs used a combination of a porosity prediction with increasing burial, and overburden and effective stress and equations that relate velocity to porosity, effective stress and lithology in the manner described by Scott and Thomsen (1993) for Vp, and using the Eberhart et al. (1989) equations based largely on measurements of a range of clastics