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Estimation of the Vp/Vs Ratio Using Zero-Offset VSP Data

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ABSTRACT

The uses of three-component zero-offset vertical seismic profile (VSP) data have often been limited to the compressional P-wave data due to the noisy quality of recorded shear S-wave data. Extracting the shear-wave information from zero-offset VSP is very important in estimating the P-wave versus the S-wave velocity — the Vp/Vs ratio. The Vp/Vs ratio is an essential attribute in pore fluid identification and lithological discrimination, especially between sand and shale where both rocks have similar P-impedance values. The shear-wave data are important in (1) calibrating the shear logs for shear-wave synthetic seismogram, (2) producing high frequency S-wave corridor stacks, (3) computing Vp/Vs from the recorded VSP data, and (4) predicting the Vp/Vs ratio for subsurface geologic formations ahead of the drill bit. As a result, the Vp/Vs ratio was used in this study to delineate a sand reservoir with potential hydrocarbons.

We applied the following steps to compute the Vp/Vs ratio from zero offset VSP data that had been collected in the Eastern Province of Saudi Arabia: (1) Apply Hodogram analysis to enhance the shear-wave data based on maximizing the direct P-wave, (2) pick the first breaks of the compressional data in the vertical component and the shear down-going energy in the radial component, 3) calibrate the compressional and shear sonic logs, and 4) compute Vp/Vs ratio. To estimate the Vp/Vs ratio beyond the maximum VSP receiver level, we measured the travel time difference between two reflectors in the upgoing PP section and the travel time difference corresponding to the same reflectors in the upgoing PS section. Then the Vp/Vs ratio was calculated using the method of Ebrom et al. (2002). The predicted Vp/Vs ratio was 1.8 and the shear log was 1.7, both suggested the targeted zone has pure sand in nature.

We have developed a workflow to estimate Vp/Vs ratio from the zero offset VSP data. The accuracy of the estimation depends on the signal-to-noise ratio (SNR) of the converted shear-wave data. The prediction method for reflectors beneath VSP array works best if the picked reflectors are close to each other and close to the end of VSP receiver array.