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[PS]VSP Lookahead of the Bit Information: Considerations and Accuracy Analysis*

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Search and Discovery Article #42196 (2018)**
Posted April 16, 2018

*Adapted from extended abstract based on poster presentation given at AAPG Asia Pacific Region Geosciences Technology Workshop, Mumbai, India, December 6-7, 2017

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Abstract

Vertical Seismic Profiling (VSP) Lookahead has emerged as a vital technology in well planning and minimizing drilling risks. There are numerous published articles highlighting the impact of VSP Lookahead results on well planning and drilling risk mitigation. There are, however, limitations with this technology. VSP Lookahead results have uncertainties involved and such results should be used with caution before taking critical drilling and well planning decisions. This article discusses limitations of VSP Lookahead methodology. VSP Lookaheads were performed for ONGC in various fields with varying geological settings. VSP Lookahead results were analyzed and accuracy of the results have been discussed. Major factors effecting VSP Lookahead results as well are discussed.

Introduction

VSP survey is acquired using active source close to the surface and an array of receivers placed inside the borehole. Three component Receivers placed in the borehole records both the direct waves from surface-active source and the reflected waves from the subsurface below the receiver or ahead of the bit position. The reflected waves contain acoustic information that can be inverted for impedance and velocity profiles. This unique feature in estimating acoustic properties of the formation below the bit, is the only approach available to guide drilling or predict drilling targets ahead of the bit. Results of VSP Lookahead are used in taking critical drilling decisions and well planning, hence it becomes vital to understand their accuracy and at the same time implement the correct procedures that would give accurate results.

Considerations with VSP Lookahead

VSP Lookahead inverts the reflected arrivals to get impedance and velocity profiles ahead of the bit. The inversion process searches for a solution where an acoustic impedance profile is obtained that fits with the VSP processed corridor stack. Like any inversion process, the solution obtained is non-unique due to the missing low and high frequency information. It is important to retain the low-frequency component in the data which governs the time-depth curve below current TD (compaction trend) as well as the high-frequency component which increases velocity accuracy and reduce uncertainty in target depth prediction.

The natural frequency of a conventional moving coil geophone, such as the SM4 type, is limited to 10 or 14 Hz. The GAC sensor has a flat frequency response from 3 to 200 Hz (Kamata, 1999) and hence is expected to give better results. While VSP acquisition, attempts should be made to stop all disturbances other than seismic source. Noises present in VSP data, needs to be adequately suppressed before performing VSP Lookahead. Good quality data acquired with strong guns (ex: 3X150cc Gun cluster) gives better inversion results. Using correct a priori information (like logs from nearby wells, seismic derived velocities) as constraint, improves accuracy of inversion results. VSP Lookahead predicts acoustic impedance profile below TD. Density approximation below TD is required to derive velocity profile from impedance profile. Incorrect density approximations would give incorrect results.

Accuracy Analysis

VSP Lookahead results from various fields of ONGC with varying geological settings were analyzed. There were cases when VSP Lookahead was performed in intermediate runs. Sonic log as well as VSP data were then acquired in successive run. VSP Lookahead derived velocity profile (ahead of intermediate TD) of earlier runs have been compared with sonic and VSP Interval Velocity, acquired in next run. In cases where Lookahead processing was done considering multiple scenario, it was analyzed which scenarios are giving better results. Effect of density approximation below TD of the well was also analyzed.

Conclusions

For studied cases it was observed that for first 100 ms from TD, inverted velocity were very accurate with an average error of 3-5% and depth predictions had an error of less than 8 m. Accuracy of VSP Lookahead results reduces as we go further below the 100 ms from the TD. VSP inverted velocities had an average error of 4-8% and 5-9% in the interval 200 ms and 300ms respectively below TD. VSP Lookahead results below 300 ms were very high for some of the cases and in general are less reliable.

Considering limitations involved with the VSP Lookahead, entire VSP processing and inversion process needs to be handled with care. VSP Lookahead results is observed to be reliable till 300ms below TD with error of less than 10%. Gardener relation based density approximation and correct a priori information gives more accurate VSP Lookahead results. Three uncertainty analysis cases are displayed in Figure 1A, 1B, 1C. Figure 1D summarizes the observation from studied cases. (Figure 1 is Figure 5.1-5.4 in the poster.)

Acknowledgements

We thank ONGC Ltd. and Schlumberger management for the authorization to present this work and acknowledge the collaborative effort between ONGC Ltd. and Schlumberger.

References Cited

Kamata, M., 1999, An Accelerometer for Seismic Signal Detection: Proceedings of the 6th Underground & Construction Acoustic Emission Conference, p. 13-17.

Lim, T.K., R.K. Rana, R.K. Dutta, and K.M. Sundaram, 2010, Drilling on Target With VSP Lookahead Technique in Deepwater India Exploratory Environment: SPE-135846

Yang, H., J. Cai, S. Guo, Y. Gao, Li. Yanhua, and T.K. Lim, 2013, Predicting Drilling Target Ahead of Bit Using VSP Lookahead Technique that Help Mitigate Drilling Risk in Over Pressure Zone, a Case Example from South China Sea: SPE-165838.

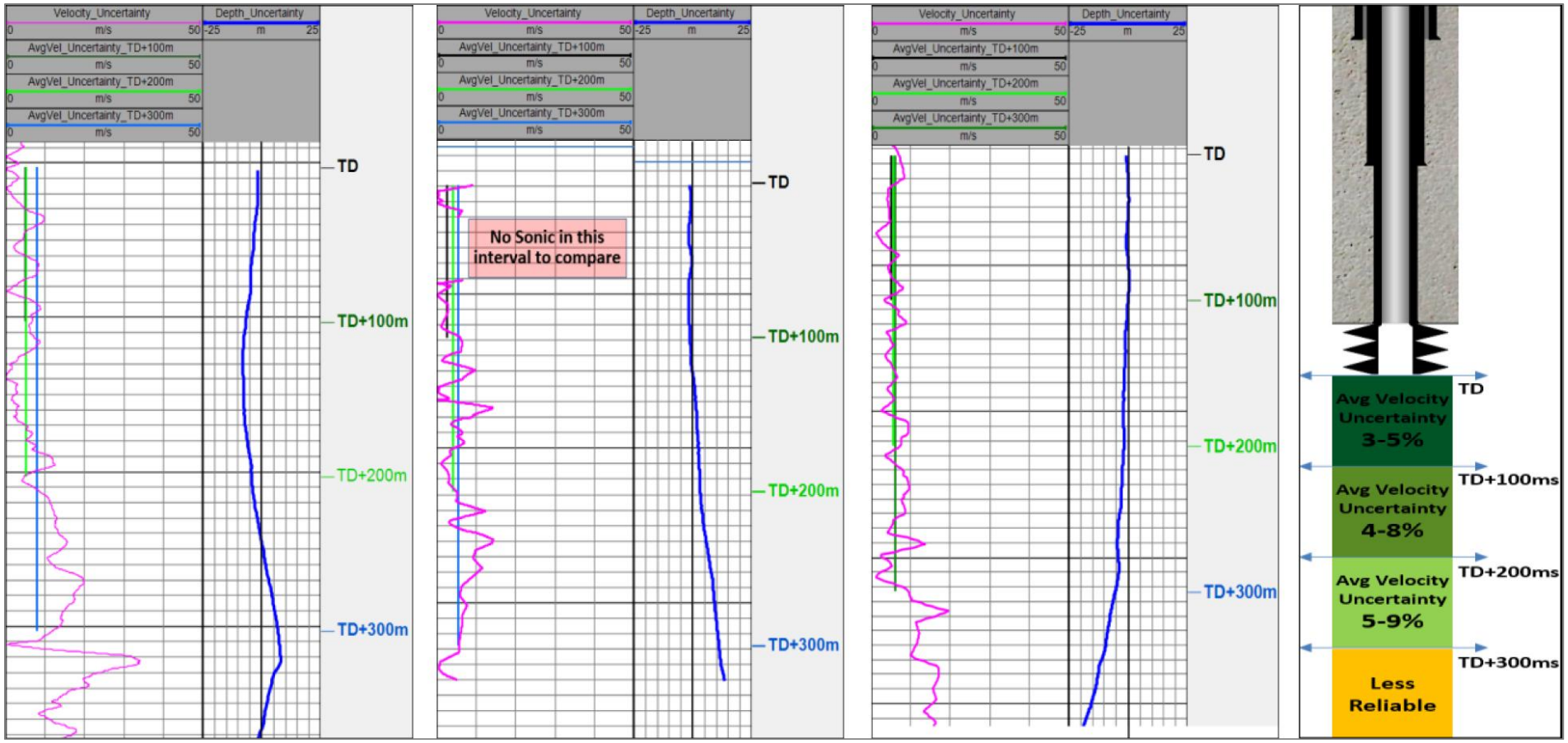

Figure 1. A-C: Velocity Uncertainty is the percentage difference between Lookahead-predicted velocity and Sonic/VSP velocity acquired in successive runs. Depth uncertainty is the difference between Lookahead-predicted depth and observed depths. D: Summary from cases of the study.