

Analysis of multicomponent walkaway vertical seismic profile data

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Summary

A multicomponent walkaway VSP data was processed for PP and PS imaging as well to study the AVO response. To date, a PP wave corridor stack and VSP-CDP mapping have been completed and are correlated to synthetic seismograms. Overall, we saw a good correlation between VSP and synthetic data, and observed changes inside the reservoir, interpreted to be due to production. A common shot stack reflectivity gather was produced for AVO analysis. At the top and bottom of the target reservoir, the AVO responses of VSP PP wave data and synthetic gathers show similar trends. The results give us promise for inverting walkaway VSP data for reservoir properties.

Introduction

A vertical seismic profile (VSP) is a measurement in which the seismic waves are recorded by geophones secured in a borehole for a seismic source at the surface of the earth. Due to its geometry, a VSP survey is used principally to calibrate surface seismic data by giving an accurate depth-time measurement to geological features. VSP data has greater resolution than surface seismic data and provides more detailed image around the borehole. Besides broader frequency bandwidth, VSP survey has other advantages for AVO analysis (Coulombe et al., 1996): (1) VSP data has less noise interference due to the quiet borehole environment, (2) downgoing wavefield is also recorded and can be used to design the deconvolution operator. (3) a good estimate of the reflection coefficient from VSP is relatively easy to obtain. Considering all these advantages, the walkaway VSP is especially suited for AVO analysis. The application of converted seismic wave exploration enhances traditional compressional wave exploration in many aspects such providing a more robust way to derive rock properties. In this research, combining the advantages of VSP and converted - wave data, a multicomponent walkaway VSP data was used to undertake AVO analysis of the target reservoir. It makes the characterization of target reservoir more reliable and the results can be used to guide field development.

VSP data processing and interpretation

The University of Calgary participated the walkaway VSP data acquisition in 2011. Envirovibe and dynamite energy sources were applied at the same source location. After geometry setup and preprocessing, the zero-offset and far-offset VSP data were processed separately using different processing workflows. Figure 1 shows the flow charts of both zero-offset and far-offset VSP data processing as well as the AVO gather creation. The VISTA software from GEDCO was used for the data processing.

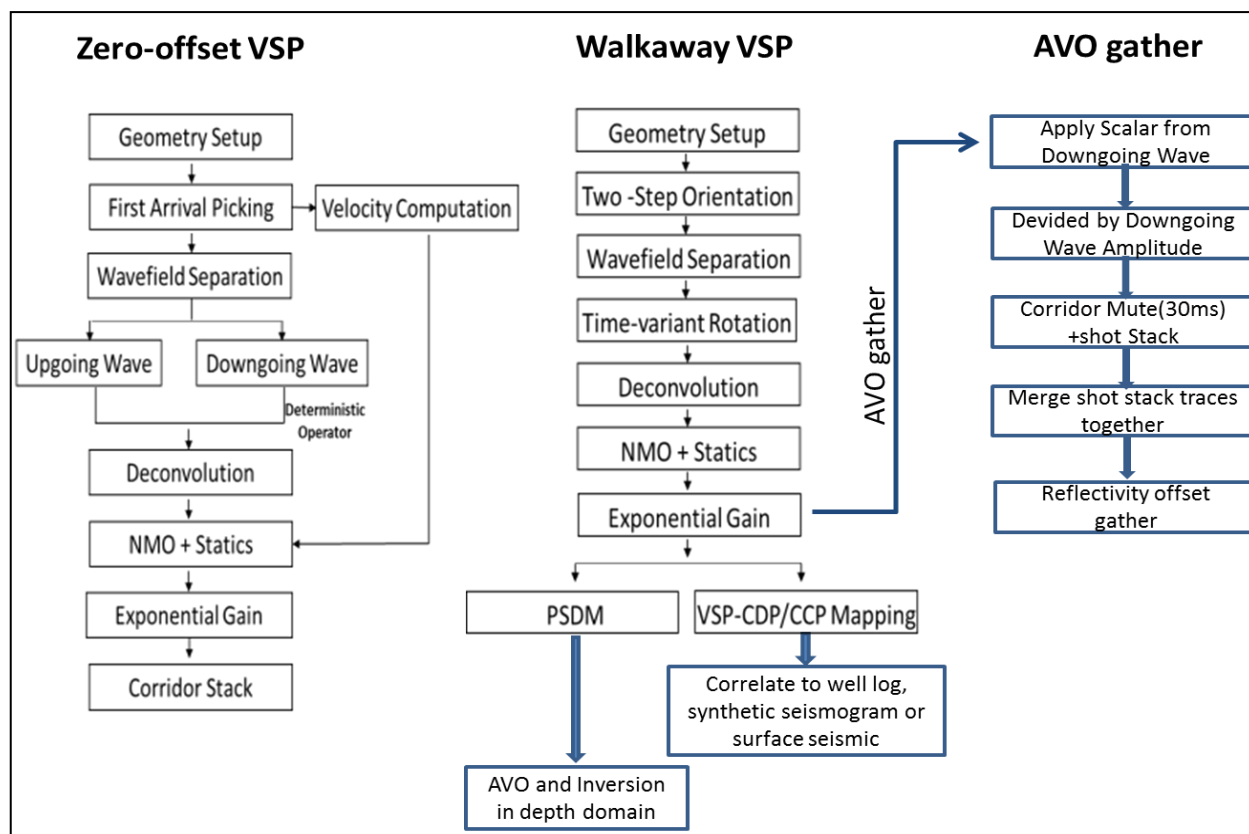


FIG.1. Zero-offset, walkaway VSP processing and AVO gather creation sequences

Following well log calibration, an offset synthetic offset gather was created using CREWES software SYNGRAM. The composite plots (Figure 2) show detailed correlation between sonic logs, VSP-CDP mapping of upgoing P wave of a far-offset VSP shot (dynamite, offset=153 m), processed upgoing P (PP) gather and stack traces of zero-offset VSP, and synthetic seismogram of PP wave. Overall, a reasonable correlation of the VSP to the synthetic seismogram was observed. However, some reflections within the reservoir on synthetic seismograms are not clear on VSP data. The reason is that thin high velocity layers yield strong reflections on synthetic seismic, but might be too thin to be resolved by seismic waves of VSP. Also, due to the small change of the P wave velocity and porosity, the impedances of the interfaces inside the reservoir are too small to be identified on VSP data.

An offset reflectivity gather was obtained for AVO analysis following the work flow shown in Figure1 . Figure 3 shows the correlation of the common shot stack to the synthetic seismogram and AVO responses of the top and bottom of the target reservoir. Inside the reservoir, the amplitude and phases of the VSP data show large differences from synthetic seismogram. There are three possible reasons for the difference: (1) the logged well is 200 m away from VSP borehole, the lithology of the fluvial channel deposit system may change greatly in this distance; (2) the study zone is currently under production, so the properties of reservoir could change during production; (3) the whole reservoir interval is about 50-75 m and 5 horizons were picked on the well log of this reservoir. Limitation of VSP resolution makes picking seismic horizons within the small time interval challenging.

Overall, the amplitudes picked from VSP and synthetic seismogram at top and bottom of the reservoir display a similar variation trend within offset range of 0 to 500 m. These results give promise of rock properties inversion using the walkaway VSP.

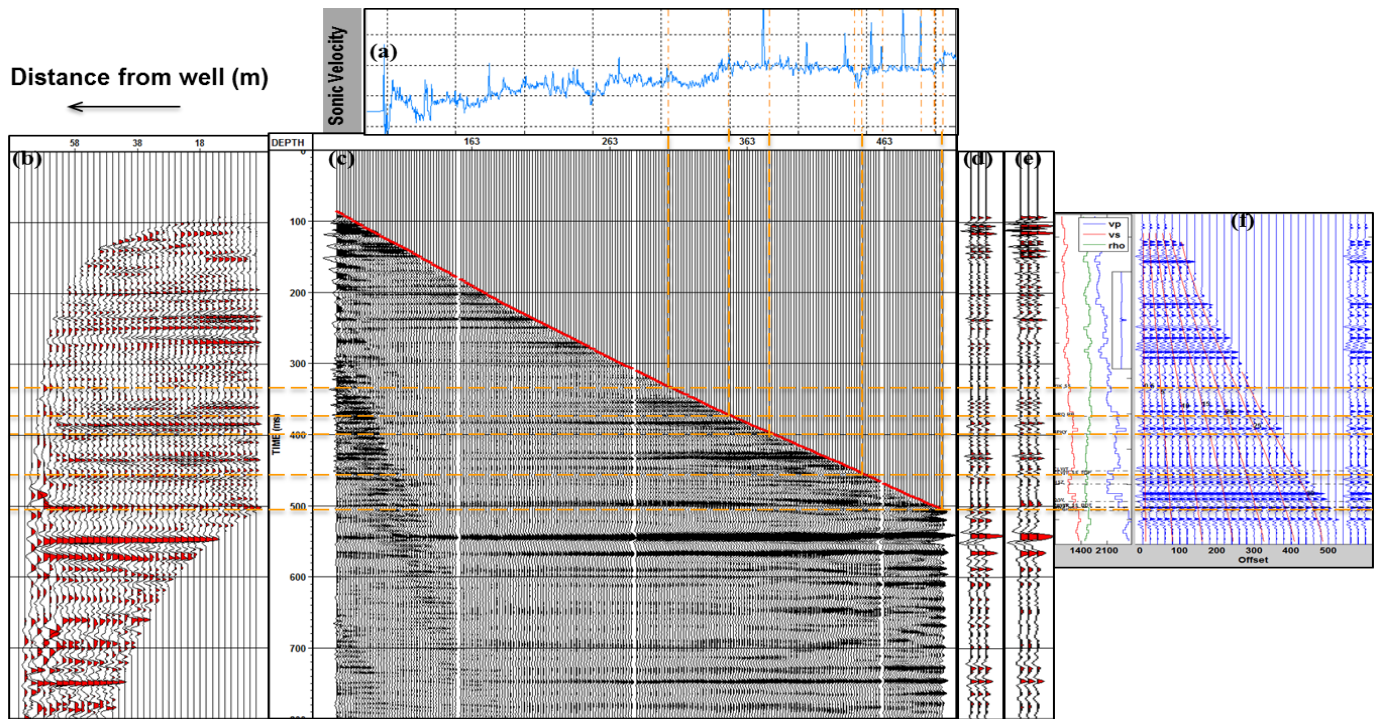


FIG. 2. Composite plot of sonic log, VSP data and synthetic seismogram. (a) sonic log, (b) VSP-CDP mapping of upgoing P of a far-offset VSP (offset=153 m), (c) processed upgoing P wave gather of zero-offset VSP, (d) corridor stack, (e) non-corridor stack, (f) synthetic offset gather and its stack trace (repeated 3 times).

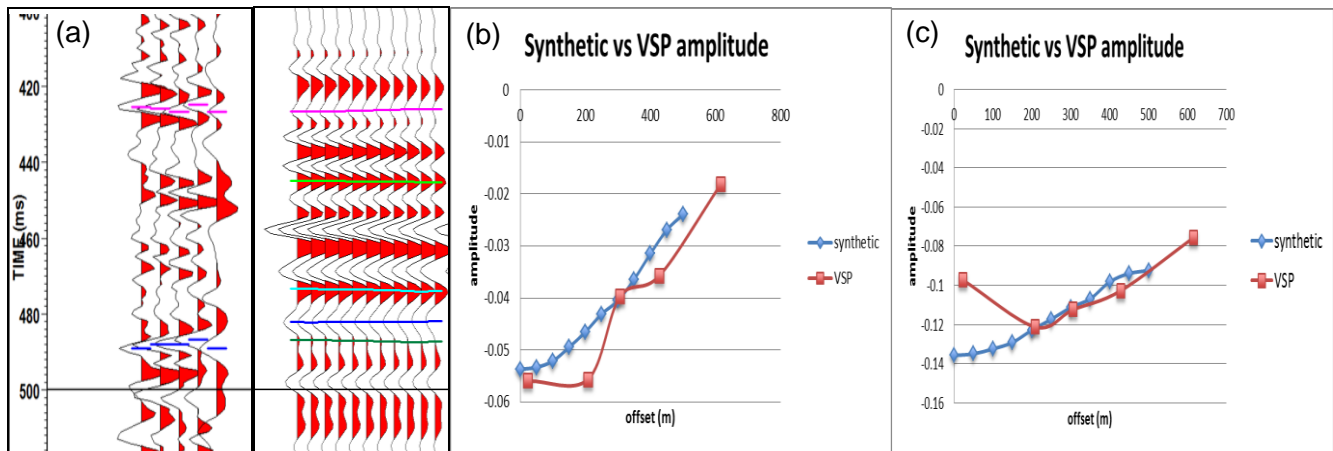


FIG.3. (a) Correlation between common shot stacks (receiver-offset gather) and synthetic offset gather; Comparison of amplitudes picked from VSP and synthetic seismogram; (b) amplitude response of top reservoir; (c) amplitude response of base reservoir. In both the response shows similar trends along offset.

Conclusions

A multicomponent walkaway VSP data was processed and correlated to synthetic seismograms. Overall, the PP mode of VSP data shows good consistency with synthetic seismograms. Inside the reservoir, difference was observed due to production. The distance between analyzed well location and the VSP borehole may also degrade the accuracy of the interpretation. The PP wave AVO responses of VSP gather and synthetic seismogram show similar trends at the top and bottom of the reservoir. The results give us promise for rock properties inversion by the walkaway VSP data.

Future work in this research includes obtaining a more accurate PS wave velocity to process and correlate the PS data to PP data then undertaking PP-PS joint inversion to predict the rock properties.

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References

- Bubshait, S., 2010, VSP processing for coal reflections, M.Sc. Thesis, Department of Geoscience, University of Calgary.
- Coulombe, C.A., Stewart, R.R., and Jones, M.J., 1996, AVO processing and interpretation of VSP data, Canadian Journal of Exploration Geophysics, Volume 32, 41-62.
- Hall, K. W., Lawton, D. C., Holloway, D., and Gallant, E.V., 2012, Walkaway 3C-VSP, CREWES Research Report, Volume 24.
- Hardage, B. A., 1983, Vertical seismic profiling-principles (1st ed.): Amsterdam, Geophysical Press, 470p.
- Hein, F., Weiss, J., and Berhane, H., 2007, Cold Lake Oil Sands Area: Formation Picks and Correlation of Associated Stratigraphy, The Alberta Energy and Utilities Board/ Alberta Geological Survey (EUB/AGS) Geo-Note, 2006-03
- Hinds, R.C., Kuzmiski, R.D., Botha, W.J., and Anderson, N.L., 1989, Vertical and lateral seismic profile, in Anderson N.L., Hills, L.V. and Cederwall, D.A., Eds., Geophysical Atlas of Western Canadian Hydrocarbon Pools, CSEG/CSPG, 319-344
- Hinds, R.C., Anderson, N.L., and Kuzmiski, R.D., 2007, VSP interpretative processing: Theory and practice, SEG Continuing Education Course Notes.
- Hinds, R.C., and Kuzmiski, R.D., 2001, VSP for the interpreter/processor for 2001 and beyond: part1, CSEG Recorder, Volume 26, No.9, 84-95.
- Lawton, D.C, Gary, M. F., and Stewart, R. R., 2012, Reflections on PS: An interactive discussion of problems and promise in converted-wave exploration, CREWES Research Report, Volume 24.
- Lines, L.R., and Newrick, R.T., 2004, Fundamentals of geophysical interpretation, Geophysical Monograph Series, Number 13, Society Of Exploration Geophysicists.
- Margrave, G.F., 2008, Methods of seismic data processing, Geophysics 557 Course Lecture Notes, Department of Geology and Geophysics, University of Calgary.
- Wiggins, J.W., Ng, P., and Mazur, A., 1986, The relation between the VSP-CDP transformation and VSP migration: 55th Ann. Internat. Mtg., SEG Expanded Abstract.
- Xu, C., and Stewart, R. R., Ross Lake 3C-3D seismic survey and VSP, Saskatchewan: A preliminary interpretation, 2003, CREWES Research Report, Volume 15.