Zero offset VSP data acquisition with innovative geometry

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Summary

Zero Offset VSP data was acquired in a deviated well using special geometry. The geometry was devised for obtaining an accurate Time-Depth curve which was the priority objective of the VSP survey. In this geometry, the shot points on the surface followed the borehole receivers in the well along the deviation direction. The geometry was devised based on deviation data of the well.

Introduction

Vertical Seismic Profiling (VSP) is a seismic profile just like surface reflection seismic method with 90^o rotation. The seismic detectors (borehole geophone tools) are lowered into the well through winch cable using pulley arrangement. The winch cable is connected with the depth meter system which continuously measures and displays the depth of the geophone tools. In addition, the tension in the cable is also measured. The borehole geophone tools are equipped with controlled motorized arm locking mechanism for having proper coupling of geophones with the walls of well. After locking the arm of the geophone tools rigidly with the borehole wall at a particular depth level of observation, the seismic waves are generated at the surface by explosives. These waves are received by borehole geophones and the recorded signal is transmitted through the winch cable to the seismograph.

If the surface shot location lies at the wellhead vertically above the borehole detector locations, the recorded rays travel along vertical ray paths, the method is known as zero-offset VSP (generally shot hole of Z-VSP is always kept within 100m from the bore hole). The output from a Zero Offset VSP is a Time-Depth curve and a corridor stack, a single trace free of multiples.

If the surface shot locations are offset laterally, the recorded rays have to travel along inclined ray paths, the method is known as offset VSP. The zero offset VSP in a deviated well is practically an offset VSP, as recorded rays have to travel along inclined ray paths. The output in an Offset VSP is CDP transform which gives a small section from well to the half distance between well and source location.

Walkaway VSP features a source that is moved progressively to the farther offsets and receivers are held in a fixed location. All these surveys (zero-offset, offset survey and walkaway survey) provide detailed image of the subsurface around the borehole. Walkaway VSP gives a 2D section from the well towards the shot locations.

VSP provides a direct correlation between subsurface stratigraphy and seismic reflections measured at the surface. This provides the seismic data processor with a means by which to calibrate seismic data in the time domain with depth. Additionally, due to its high resolution, VSP can image objects within the vicinity of a well bore that could not otherwise be defined by surface seismic techniques.

VSP data is useful in many ways. Some of them are listed here. It is used for precise correlation of surface seismic data with depth. Vertical Seismic Profiling has an advantage over other means of determining reflectivity coefficients (such as by synthetic seismograms derived from sonic logs) because the frequency content is similar to that of surface seismic data. VSP data usually are not as sensitive to borehole conditions such as washout when compared with other borehole methods. VSP data is used for separation of primary seismic reflectors from interbed multiples. Seismic interpreter uses Zero Offset VSP data for distinguishing accurately the multiple reflections from primary reflection events.

Zero offset VSP data acquisition with innovative geometry

Seismic reflectivity coefficients derived from well log data can be calibrated using VSP data. VSP surveys may be used to correct or validate nearby offset well log derived synthetic seismograms for use in surface seismic time-depth conversion. Supplementing VSP data and synthetic seismograms processed from wire line data acquired in offset wells is a more cost effective means of surface seismic depth control when compared to using only VSP.

Additionally, VSP data can also provide important parameters such as amplitude decay functions and deconvolution operators to the seismic data processor. This is particularly important for more advanced seismic analysis techniques such as Amplitude Variation with Offset (AVO) studies.

Theory/Methodology

Zero Offset VSP data was acquired in a well in Assam. It was a deviated well with maximum angle of 34.38° and maximum horizontal drift of about 1037 m. The well was completed using four casings: 20" casing from 0 to 397 m, 13 3/8" casing from 0 to 2482 m, 9 5/8" casing from 0 to 3646 m and 5 ½" casing from 0 to 4402 m.

The area is surrounded by tea gardens. The geology of area around the well is not complex and various horizons had very gentle slope. A section of line passing through the well along the well deviation direction is shown in figure 1.

In order to get an accurate Time-Depth curve which was the priority objective of the VSP survey, acquisition geometry was devised. In this geometry the shot points on the surface followed the borehole receivers in the well along the deviation direction. The geometry was devised based on deviation data of the well.

The locations of shot holes were calculated and a reconnaissance survey was conducted to decide the feasibility of the operation. After reconnaissance survey and stacking of shot points, VSP team arrived at the well for data acquisition. Crew used explosives as energy source. The optimum depth for placing the charge was decided by studying existing uphole data of previous land seismic investigation reports of the area.

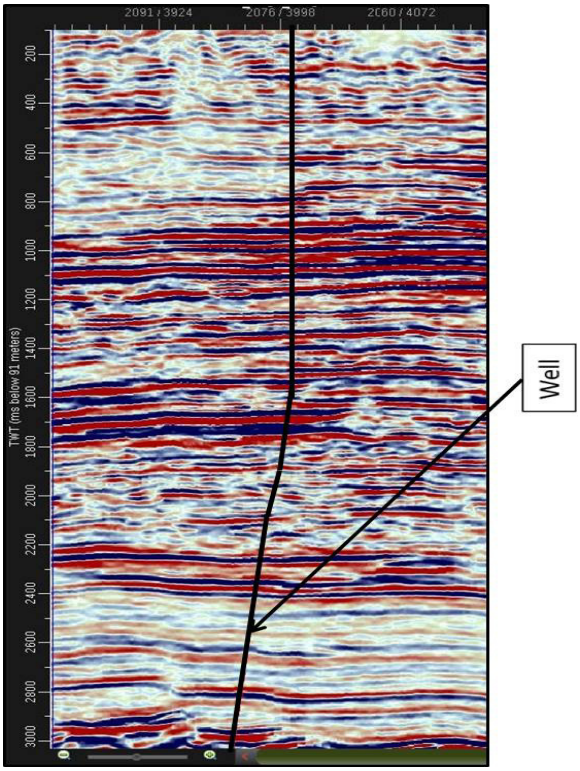

Figure 1: A section of line passing through the well along the well deviation direction,

A total of 48 shot-holes were blasted, of which 46 were falling within two meters of given optimum depth thus ensuring good quality data acquisition. The locations of shot-holes were rechecked after blasting to ensure there was no deviation from the location given by the survey crew, and the deviations in shot hole locations, if any, were noted.

The final recorded shot locations are shown in figure 2. Crew used Geowaves acquisition system of Sercel for VSP data recording by deploying four borehole tools (geowaves) at inter-tool distance of 20m.

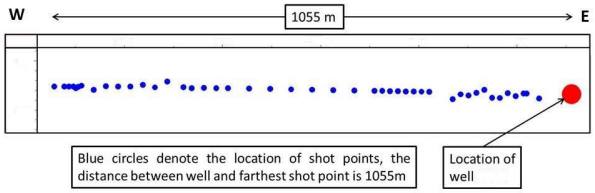

Figure 2: Location of Shot points and well

Though the well was drilled upto 4410m, the last borehole tool could not be lowered beyond 4320 m even after several attempts. Thus data was recorded from depth 4320 m to 500 m. The quality of raw data is excellent from depth 4320 m to 1500 m, but it is poor from depth 1500 m to 500 m possibly due to presence of three casings in the well upto 2482 m .

Thus for every shot location there were four borehole tools recording the data. The wave path for each shot-receiver group is shown in figure 3. As is evident from the schematic diagram the wave path for all shot-receiver groups is almost vertical, thus making it almost ideal Zero Offset VSP.

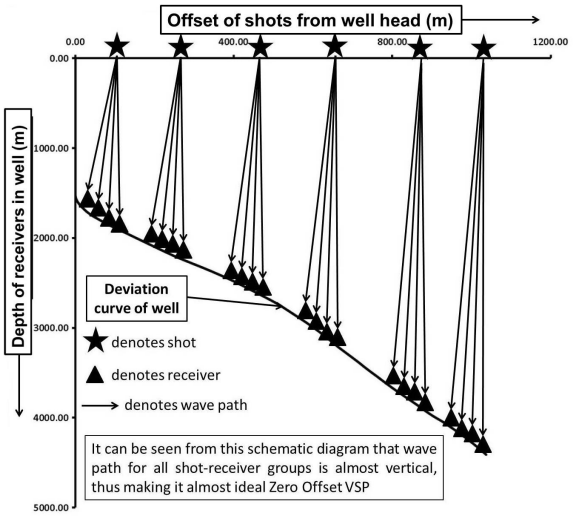

Figure 3: Schematic diagram showing wave-path for shot receiver groups

After completion of the operation, the data was processed at the processing center. The data contained all shot records, information of all shot locations, corresponding borehole receiver depths and static corrections of all shots. During processing, shot location of every point was taken into consideration for evaluating its seismic contribution.

The raw VSP data is shown in figure 4. The VSP corridor stack embedded in one of the RC-lines of surface seismic mega-merge volume is shown in figure 5. There is excellent match of events from corridor stack to that of RC-line from surface seismic mega merge, which validates the accuracy of Time-Depth table and Time-Depth curve obtained. The accuracy of Time-Depth curve was also corroborated by interpretation group.

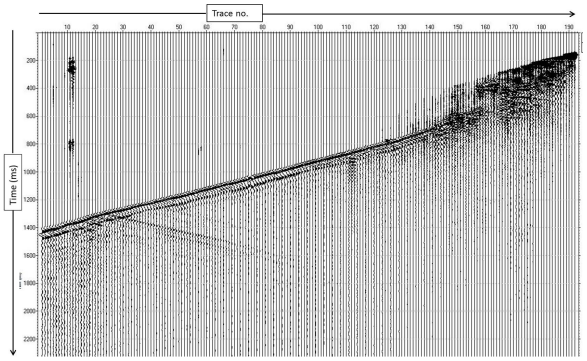

Figure 4: Raw data of Zero Offset VSP

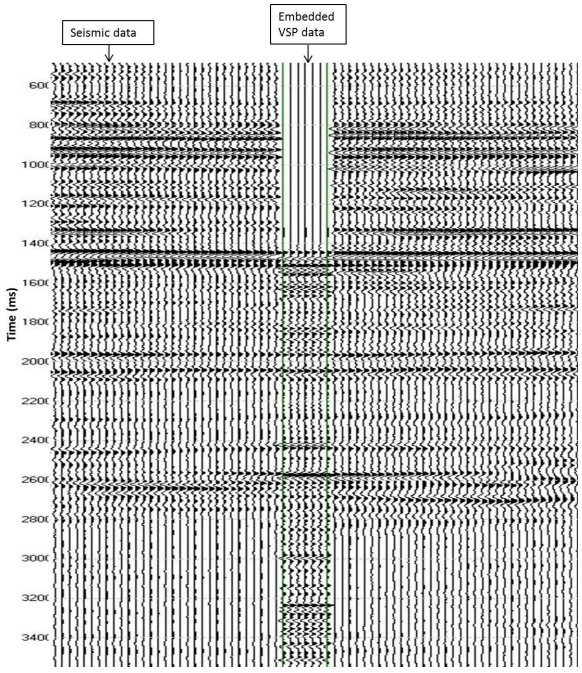

Figure 5: Corridor stack embedded in corresponding RC-line of mega-merge volume (time in Y-axis is in ms), the absence of VSP data at shallow level is due to poor VSP data at shallow level which could not be processed

Conclusions

We conclude that the geometry of shots following the borehole receivers in deviated well could be useful to obtain accurate Time-Depth curve in areas not having complex geology along well deviation direction. However for deviated well in geologically complex areas, other methodology needs to be devised to acquire VSP data for generating accurate Time-Depth curve.

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