The Optimal Use of Well Seismic Profiling (WSP) Acquisition Geometries

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Abstract

The focus of this study is the optimization of the use of various acquisition geometries based on the WSP technique geological sections from different wells in field XX of the Niger were used. Modeling was assisted by the GX-II software. Comparing different source/receiver spread with the perceived sub surface conditions showed which particular arrangement of sources and receives achieved the desired result. This study revealed how the use of WSP acquisition geometry can be effectively optimized in illuminating target objectives.

Introduction

Well seismic profiling (WSP) covers a series of techniques which can be used to investigate the sub surface on a scale between well log data and conventional surface seismic. The name VSP (vertical seismic profiling) is a poor description for many types of well seismic survey because of the large number of highly deviated and horizontally-drilled wells. Well seismic profiling is now a generally name which not only covers all type of borehole seismic measurement including the classical VSP and well shooting technique, but also covers techniques such as drill bit listening, cross-well surveys, and intra-well survey (Staal et al, 1996). In order to determine the extent of hydrocarbon accumulation found in well, seismic and well data need to be integrated and reconciled (Anstey and Gayer, 1996). Combining a WSP with seismic data has proved to be a reliable means of reducing exploration, development, and production uncertainties. This technology is used to convert seismic section from time to depth, to fill gaps where seismic data are not available, and to generate higher quality, quantitative and caliberated images (Heer, 1996). In the north sea for example, the integration of borehole data and surface seismic data produce a quantitative approach the selection of a de-multiple techniques (i.e., a method of removing seismic reverberations) and parameters, their by increasing confidence in the confirmation of the final surface data to the reflection sequence derived from borehole (Jauffred, 1990). WSP is applied on almost routine bases to judge the quality of the surface seismic and well-to-seismic machine. When WSPs are recorded in vertical or slightly deviated wells with a zero-off set source or in the case of more deviations as Walk-Above WSP (WAWSP) the result are mostly satisfactory (Stuble, 1996). MacDonald and Marsden in 1996 pointed out that the use of intermediate WSP in exploration is to be recommended. When acquired close to the target horizons, accurate depth prognoses can be obtained.

Modeling

Modeling is a term used in seismic exploration for producing artificial data to compare with actual data obtained by shooting (Coffeen, 1986) the modeling in this exercise was carried out using the GX-II software (a Shell proprietary software). The geological method were built and the materials properties assigned to the layers. The ray tracing (Ray trace through the model) was carried out using zero-offset WSP option. The synthetic traces were generated and were compared seismic and determined well synthetic data. The steps involved in the generation of the model are (Paul and Taylor, 1997):.

- On the menu bar the model icon is clicked , from which the parameter option was chosen. The map coordinate on the depth and offset axes were set to the desired values including number of traces. The values used for this were the actual depth from the selected wells (2100m-4200m).
- The curve determining the reservoir boundaries was drawn using curve editor in model icon.
- The layer boundaries were defined using horizon editor. This option enable the user to label the boundaries appropriately with like oil-water contact. etc
- The properties (velocity and density calculated from logs from the selected wells) for each of the define layer were keyed in.
- After all the model parameter have been set as in the step above, zero-offset option was chosen from the menu bar and appropriate source/receiver geometry, simulation type, and other ray parameters were selected. Rays where shot through the layers (virtual rays).

These steps allowed for the generation of the synthetic seismic traces along with the type of filters to be applied. The display icon was used to fix the type of traces to be displayed (i.e. traces including wiggles, variable area reverse polarity, and the option of a applying filters to the traces). The loops were displayed according to the Shell polarity format, i.e. decrease in acoustic impedance displayed as positive amplitude values painted black, while negative values are painted white (Ginn, 1983). Using the above steps, models created above were converted to SEGY format. The SEGY file was then transferred to SEISWORKS. After editing the file in SEISWORKS it was then printed out and then matched with the seismic data.

Testing the Effectiveness of Several Types of WSP Geometry

Once again the GX-II package was used to model the WSP acquisition geometry. It is instructive to keep in mind that in order to determine whether a particular arrangement of resources and receives will achieve the desired result, one must compare the different sources and receiver spread with the perceived subsurface conditions.

Zero-Offset WSP Geometry

A vertical well was drawn on geophysical model, with the source close to the wellhead and the geophones laid in the well. Virtual rays were shot and synthetic traces generated. The seismic responses are shown in Figs 1 and 2.

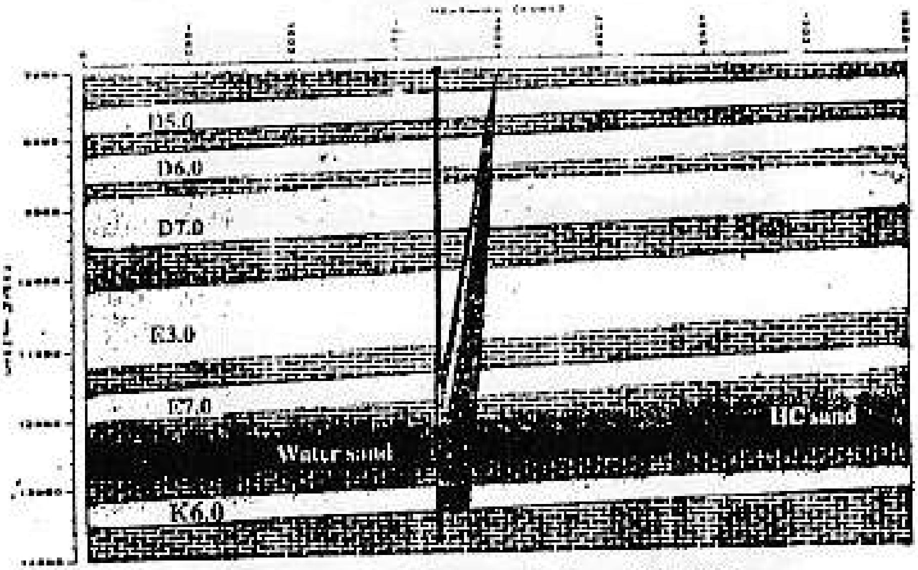

Fig. 1:Earth model and Ray-trace for Zero-offset WSP

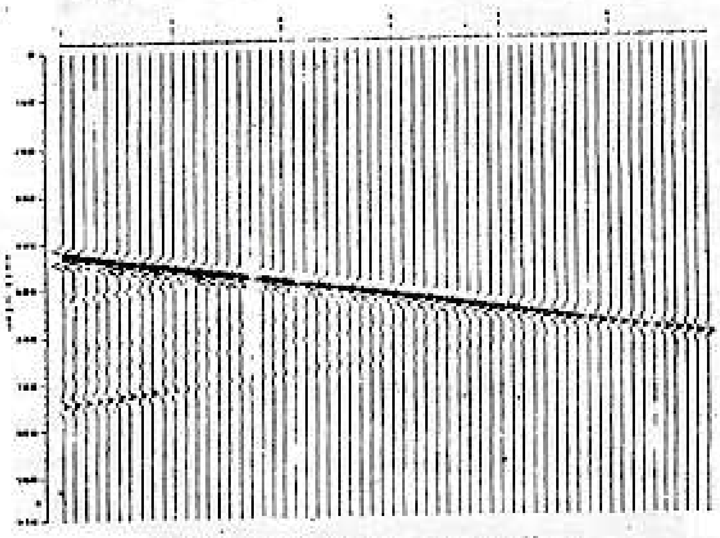

Fig .2: Stimulated WSP for Zero-offset.

Walk-Above WSP Geometry

A deviated well was drawn and the source position was located vertically above the receivers. Virtual rays were shot and synthetic traces generated. Figs 3 and 4.

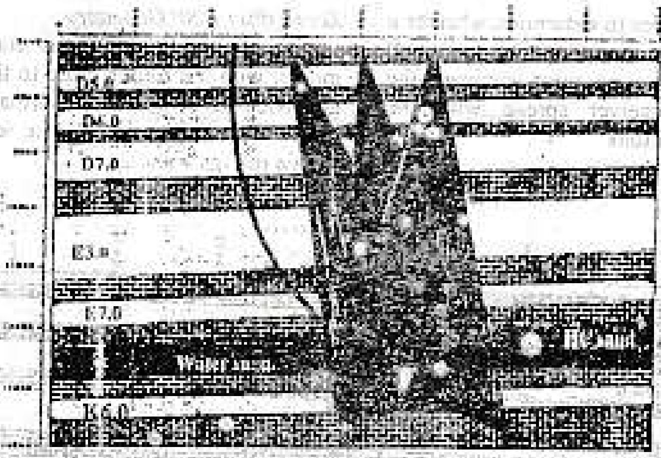

Fig. 3 Earth model and Ray-trace for Walk-above WSP

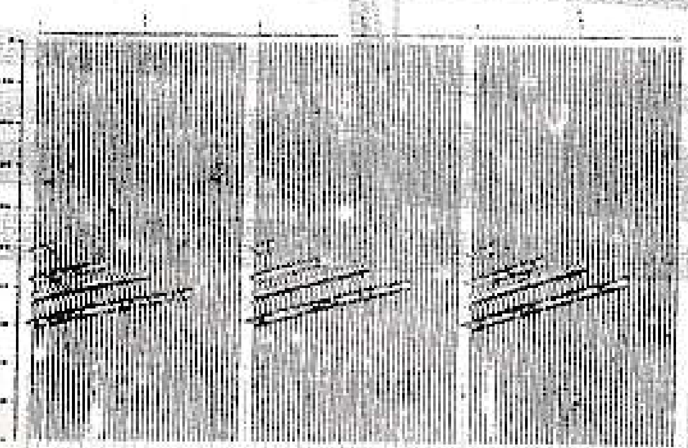

Fig. 4: Stimulated WSP response for Walk-above

Offset WSP Geometry:

The source was positioned at a fixed location away from the wellhead and the geophones were fixed in the well (for vertical and deviated wells). Rays were shot and synthetic and traces were generated; Figs 5, 6, 7 and 8.

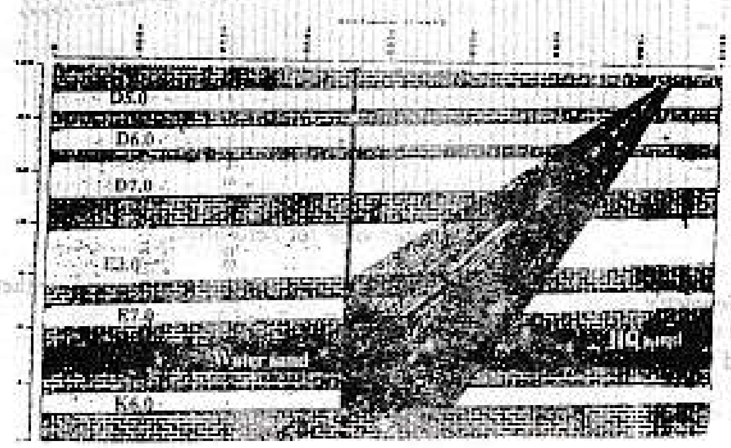

Fig. 5: Earth model and Ray-trace for Walk-above WSP

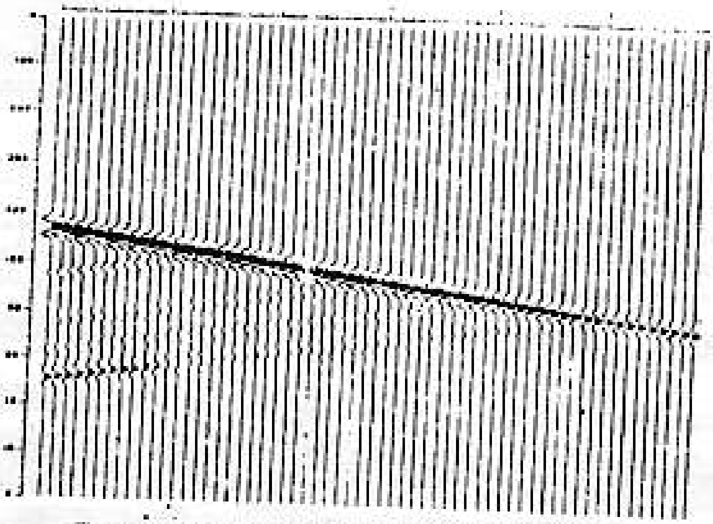

Fig .6: Stimulated WSP response for Walk-above

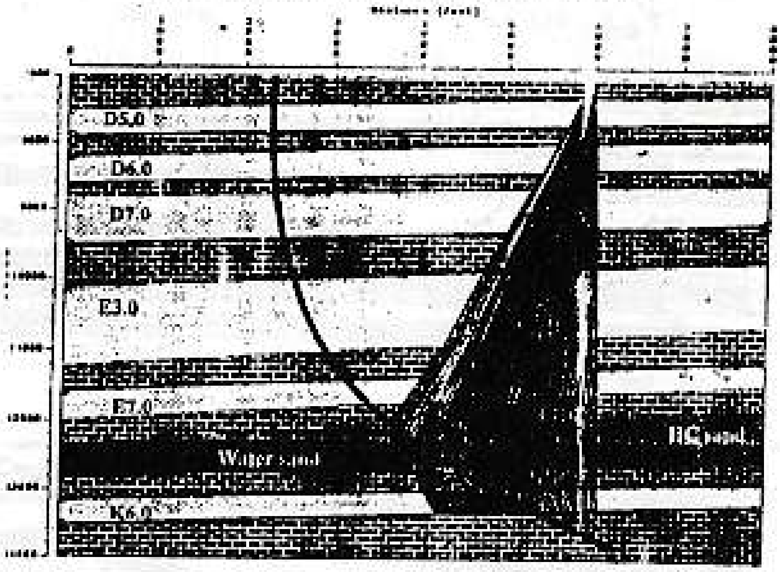

Fig. 7:Earth model and Ray-trace for Walk-above WSP

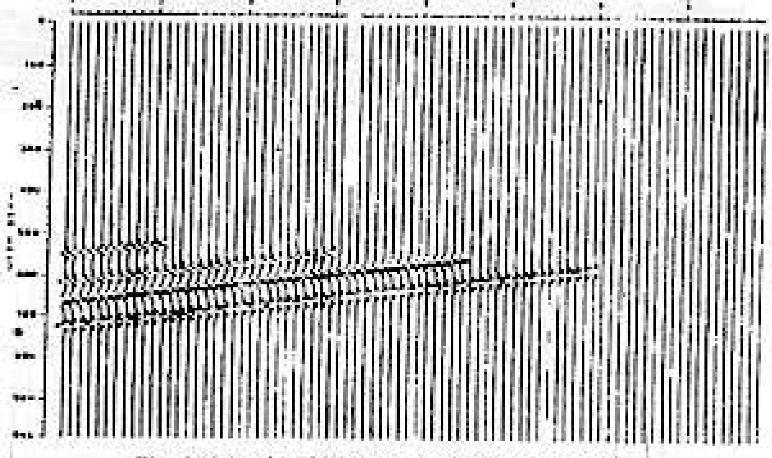

Fig .8: Stimulated WSP response for Walk-above

Walk-Away WSP Geometry

The geophone is secured at depth in the well and the source is fired at a series of positions along a line through the wellhead location. Virtual rays were shot and synthetic traces generated, Figs 9, 10, 11, 12, 13, 14.

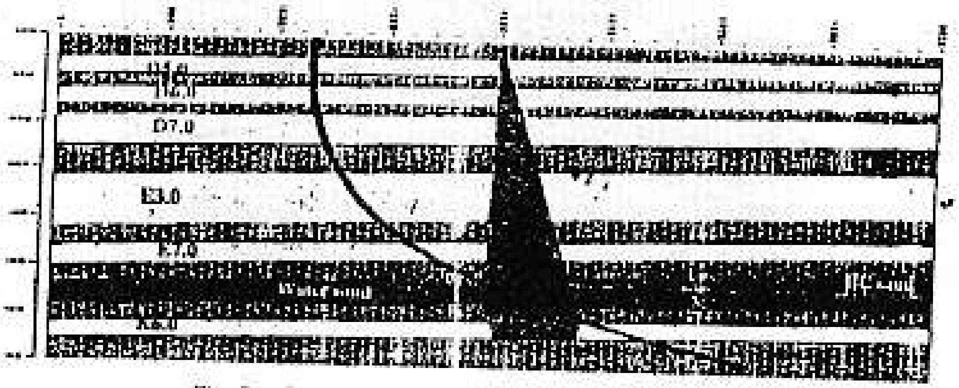

Fig. 9: Ray-trace for Walk-away WSP (offset 1700ft)

Fig. 10: Ray-trace for Walk-away WSP (offset 3700ft)

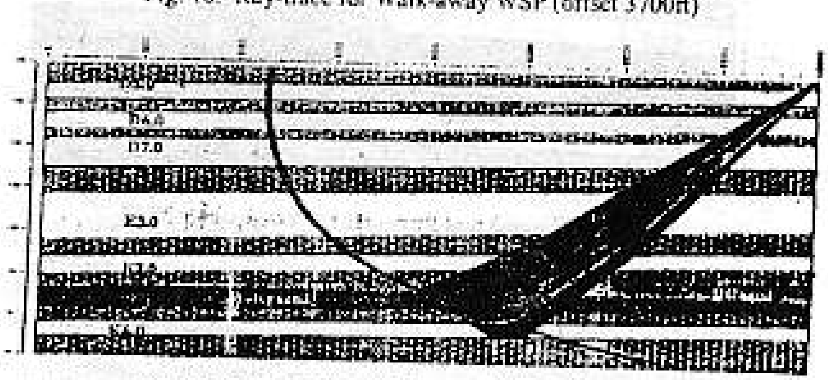

Fig. 11: Ray-trace for Walk-away WSP (offset 5700ft)

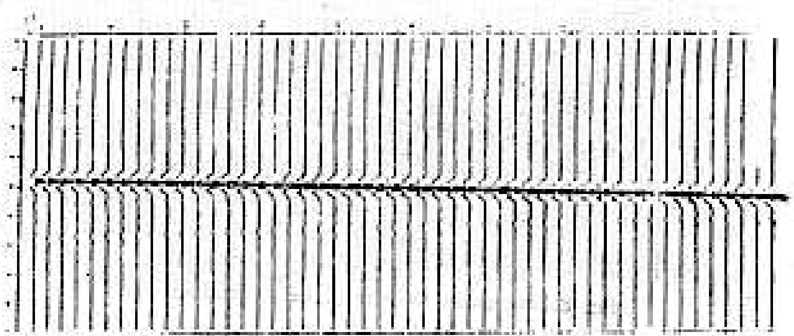

Fig. 12: Simulated WSP response for Walk-away (offset 1700ft)

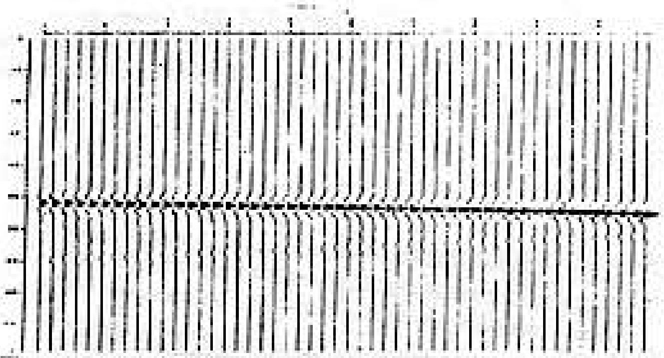

Fig. 13: Simulated WSP response for Walk-away (offset 3700ft)

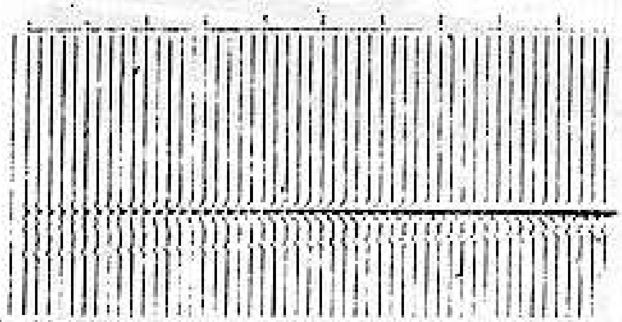

Fig. 14: Simulated WSP response for Walk-away (offset 5700ft)

Multi-Offset WSP Geometry

The sources were kept stationary at regular spaces from the wellhead and the downhole receivers were arranged up the well. Virtual rays were shot and synthetic traces generated, Figs 15 and 16.

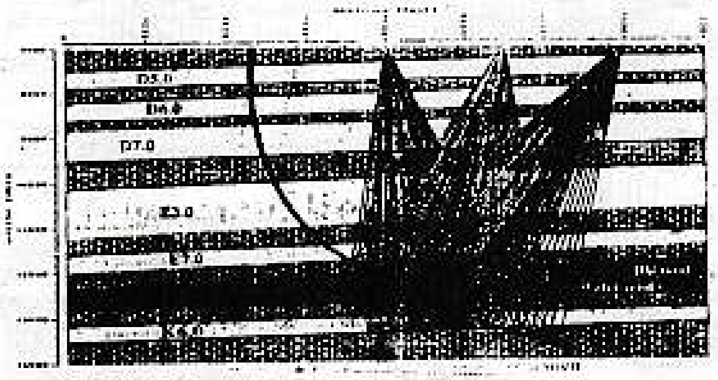

Fig. 15: Earth model and Ray-trace for Multi-offset WSP

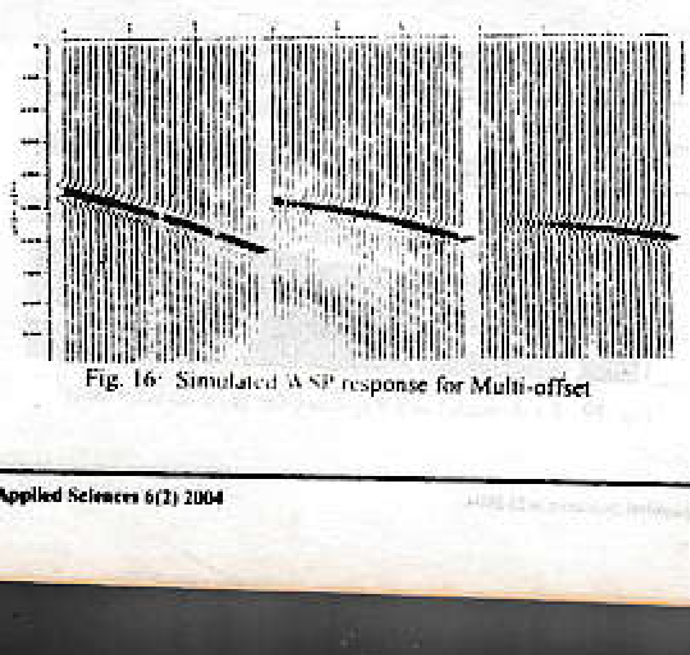

Fig. 16: Simulated WSP response for Multi-offset

Intra-Well WSP Geometry

Source and receivers were located in the same borehole. Virtually rays were shot and synthetic traces generated, Figs 17 and 18.

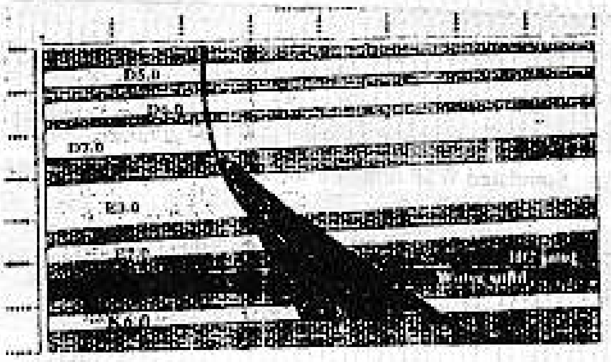

Fig. 17: Earth model and Ray-trace for Intra-well WSP

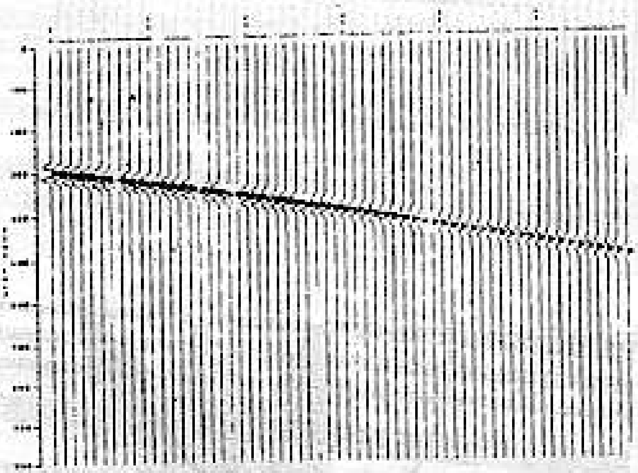

Fig. 18: Simulated WSP response for Intra-well

Cross-Well Or Well-to-Well WSP

This is a well-to-well recording. The source was located in one well and the geophones in an adjacent well. Virtual rays were shot and traces were generated. The resulting seismic traces are shown in Figs 19 and 20.

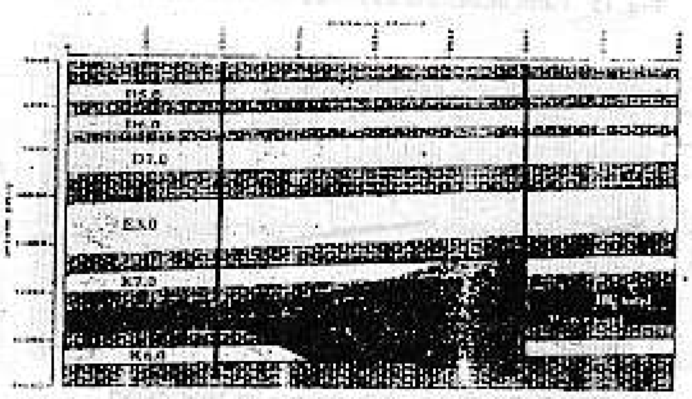

Fig. 19: Earth model and Ray-trace for Well-to-Well WSP

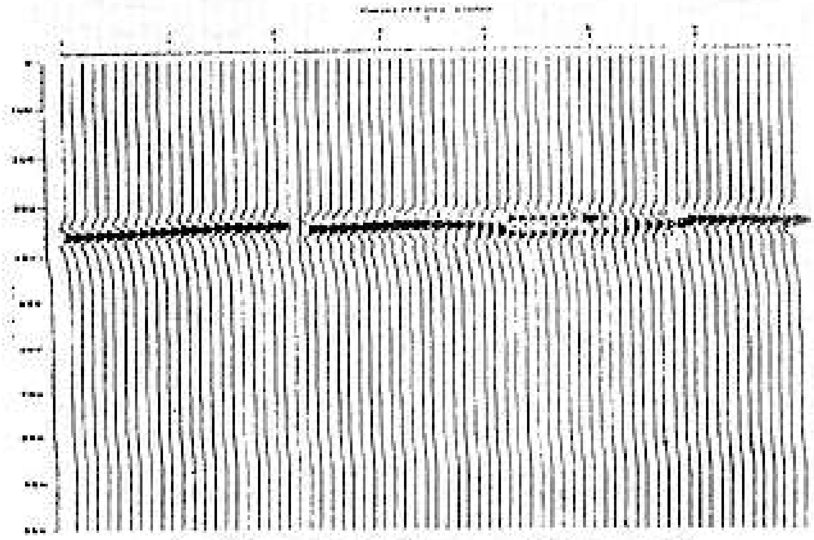

Fig. 20: Simulated WSP response for Well-to-Well

Inverted WSP Geometry

The source was located in the well and the receivers at the surface so that for one shot a large number of geophones can be recorded. Rays [illegible] shot and traces were generated. Figs. 21 and 22

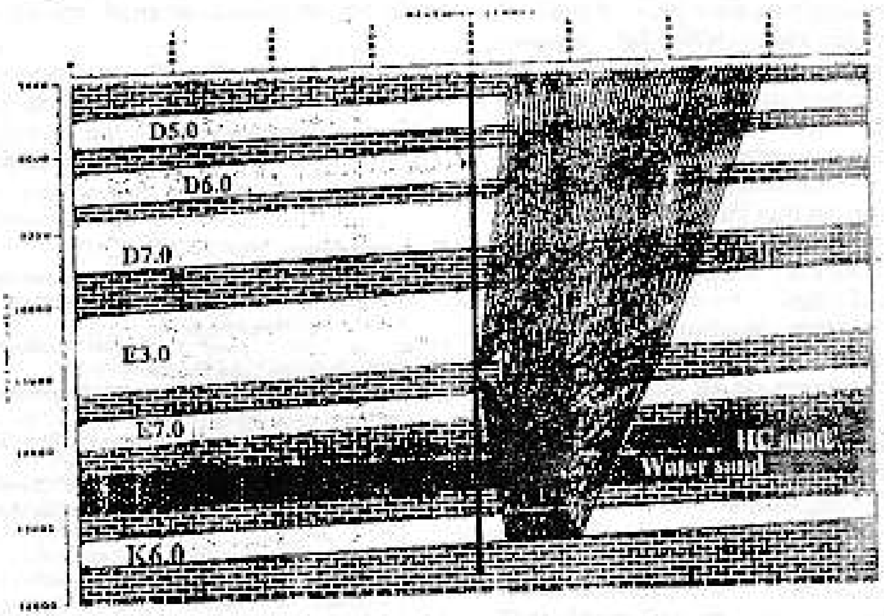

Fig. 21: Earth model and Ray-trace for Inverted WSP

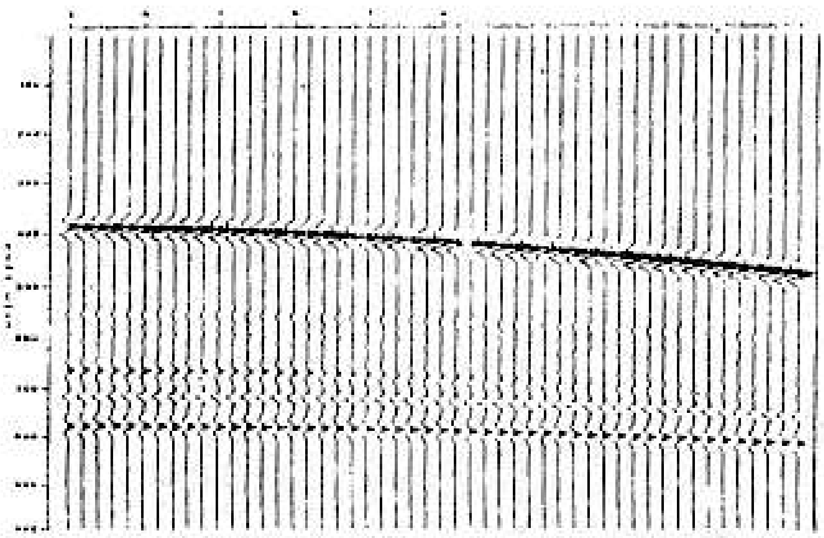

Fig. 22: Simulated WSP response for Inverted

Discussion of Result

Horizon E7.0, K3.0, and K6.0 of well 2 were used for the testing of the eight different types of WSP acquisition geometries. The seismic response observed for the zero-offset WSP geometry showed strong reflection event from the E7.0, K3.0 and K6.0 reflectors. The zero-offset WSP find important application for well-to-seismic ties, primary multiple recognition, velocity determination, and prediction ahead-of-bit. The walk-above WSP showed a better subsurface imaging and higher resolution than a zero-offset WSP. The offset WSP has more illumination on the chosen horizon than that of the vertical well. This is because of the angle of deviation of the well.

In the walk-away WSP geometry rays were shot at intervals of 510m, 110m, and 1710m from the side of the well head; the seismic response here showed a good resolution and revealed the reflection event due to each source. In the multi-offset WSP configuration the sources were spaced and kept stationary at a distance of 510m, 900m, 1410m from the wellhead and the seismic response showed a highly resolved image. The intra-well WSP geometry configuration provided a good geological representation and could be away in terms of the source and receivers that were both located in the same well. The cross well or well-to-well WSP techniques assisted in the mapping of reservoir continuity; the seismic response of this configuration showed a high resolution. The inverted WSP geometry is the reverse of the normal WSP geometry. The seismic response that was obtained that was obtained gave a better image of the horizon of interest.

Conclusion

There is no doubt now that each of the different geometry configuration resulted in image resolution far more superior to the surface seismic resolution. In this case uncertainties encounter in interpreting seismic data are greatly minimized.

Acknowledgements

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