8th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2010"

P-123

Ray Trace modelling for Offset VSP acquisition

S.Bhaskaran, S.M.Pugazhanthi, M.Bhanu and G.Sarvesam,
Geophysical Services, ONGC, Chennai

Summary

VSP surveys have gone beyond a simple time-depth correlation. From VSP data important information about reservoir depth, limit and heterogeneity, fluid content, pore pressure, enhanced oil recovery progress, elastic anisotrophy, induced fracture geometry and natural fracture orientation and density are being derived.

Seismic modelling plays a critical role in understanding imaging issues and in evaluating the effectiveness of geometry in illuminating the targets before data acquisition.

This paper highlights the importance of forward modelling to determine the offset requirement for VSP data acquisition in an exploratory well in Adichapuram area in Nagapattinam sub basin of Cauvery basin.

Introduction

Vertical seismic profiling is a useful tool for obtaining rock properties (seismic velocity, impedance, anisotrophy etc), for understanding seismic wave propagation and in further processing and interpretation of surface seismic data. Offset VSP survey is one of the different types of VSP survey that is conducted to image some distance laterally away from the well bore in the direction of the energy source. The schematic diagram of offset VSP survey is is shown in Fig.1

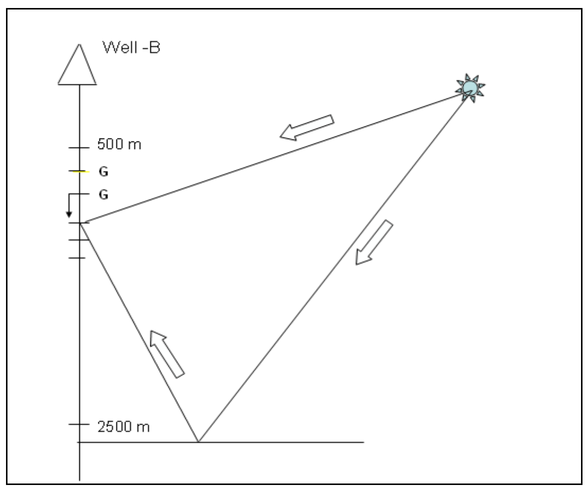


Fig.1

This study is an attempt to optimise source offset by forward modelling for conducting offset VSP survey in Well-B. Adichapuram prospect lies NNW of Kovilkalappal field in Nagapattinam sub basin. (Fig.2 shows the map of

Nagapattinam sub basin with Adichapuram prospect indicated by arrow).

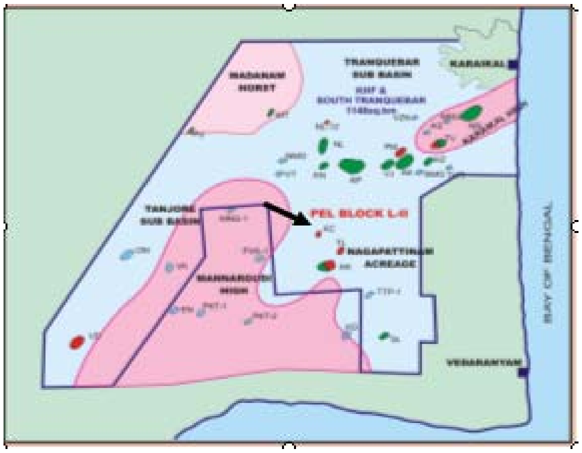


Fig.2 Prospect map of Nagapattinam sub basin

Well-A is a hydrocarbon producer from Andimadam formation of Albian age. Encouraged by hydrocarbon find in Well-A, Well-B was released to the west targeting the pay sand in Well-A. The structure map at Mid sand Top horizon showing the relative position of the two wells is shown in Fig.3.

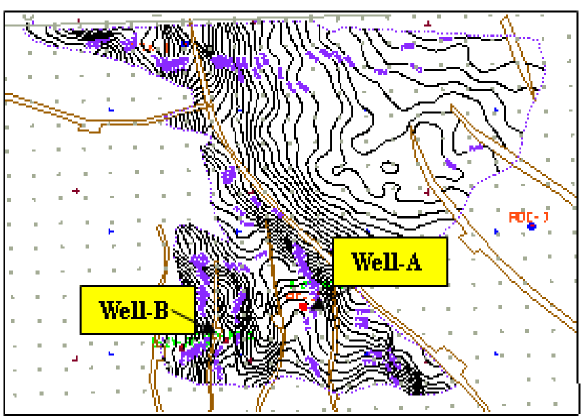


Fig. 3 Structuremap close to Mid Sand Top

Structurally, Well-B is shallower than Well-A and falls in a different fault block. Since the rate of production from Well-A decreased rapidly after a high initial production it was imperative to know if the fall in production is due to the limited extent of reservoir or due to well bore problem. It was thought that shooting an offset VSP profile in the direction of Well-A may give some insight to the reasons for decline in production. Fig.4 shows azimuth and distance between two wells. Before data acquisition, forward modelling was done for optimising source offset. The results for different offsets analysed are discussed in this paper.

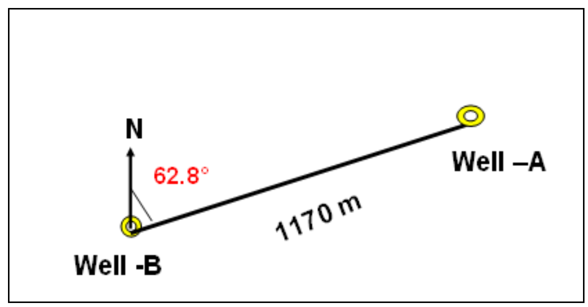


Fig. 4

Forward Modelling

Seismic modelling often plays a critical role in understanding imaging issues. Modelling tools are helpful in evaluating the effectiveness of geometry in illuminating the targets before acquisition. Though gap may exist between pre-survey modelling and actual data due to complexities involved in geology, the risk is considerably reduced in acquisition through pre-survey modelling.

For our study a 3D model was constructed with four interfaces viz. Cretaceous Top (A), G1 marker(B),

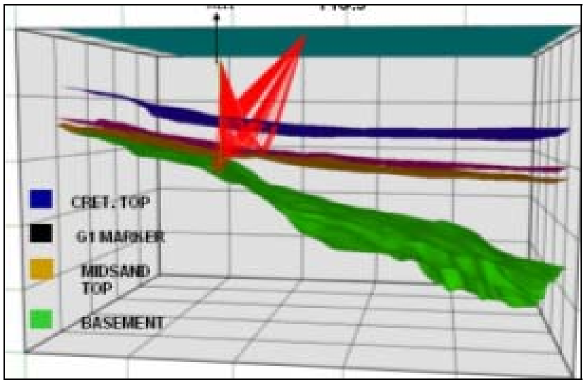


Fig. 5

Mid Sand Top(C) , Basement(D) and model parameters, density and interval velocity. The resulting subsurface model is shown in Fig.5. It is assumed that no lateral velocity variation exists along the offset profile. As per the model, dip changes associated with interfaces A,B,C are not much while the dip variations for interface D are significant.

The cross section of the model along the offset profile is shown in Fig.6.

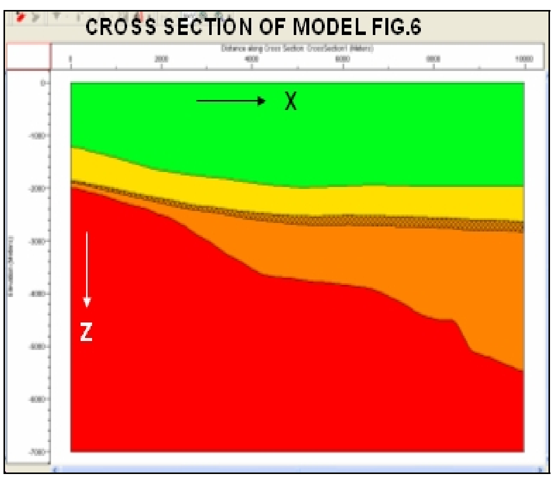


Fig.6

Geometry and Ray tracing

Ray tracing was done for four source offsets 1500m, 1800m, 2000m, 3000m with receiver array from 500m to 2500m (101 levels) with 20m geophone interval. Ray tracing was done for the same offsets with 10m geophone interval (201 levels).

Offsets	4	4
Recording Interval	500-2500	500-2500
Receiver Interval	20	10
Levels	101	201

CRP fold attribute which depicts the distribution of reflection points from well towards source was analysed for above eight combinations. The distribution of reflection points on any reflector is dependant on the reflector geometry and the lateral coverage increases with offset distance. For comparative study, plots for interface C which is close to the producing sand in well-A are shown in Fig.7 to 14.

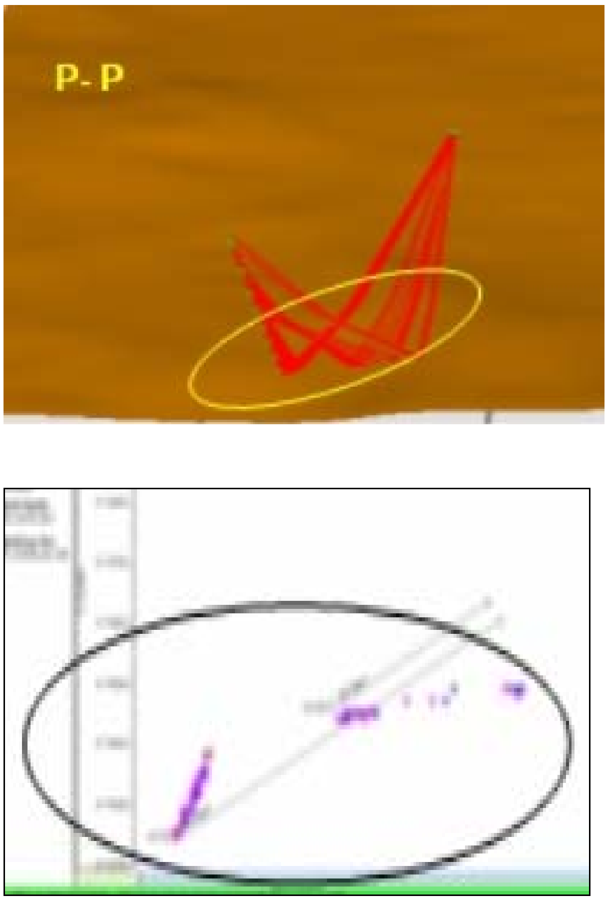


Fig.7 offset :1500 m Receiver spacing :20m

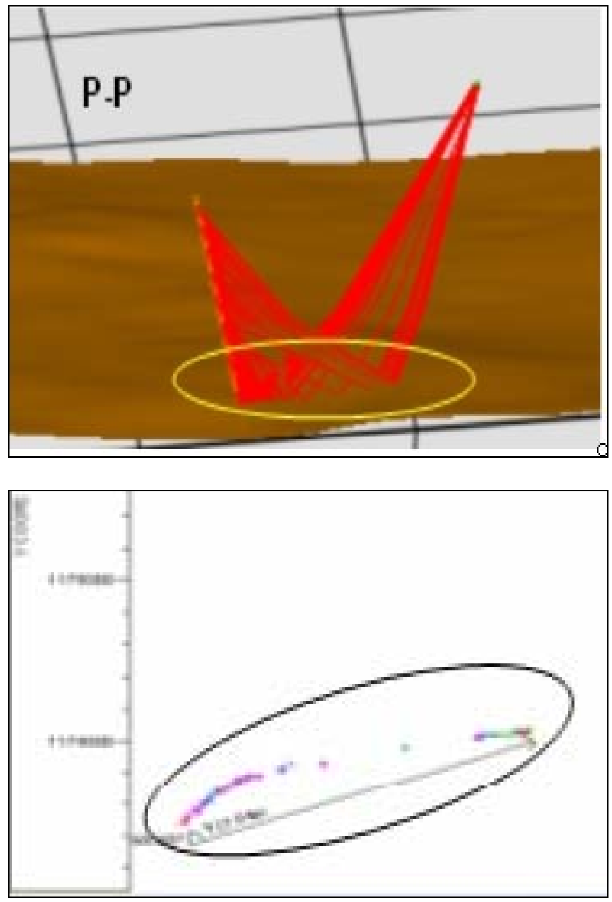


Fig.8 :Offset :1800m Receiver spacing 20 m

Fig.7 shows CRP fold map in x-y plane for 1500m offset and 20m receiver spacing. One would expect the reflection points to be aligned in source receiver plane. For an assumed flat bed the points do lie in source receiver plane. The reason why the points go away from the plane is attributable to dips associated with interface. The vacant area seen is probably because rays emerging after reflection are going away from the receivers.

Fig.8 shows CRP fold map for 1800m offset and 20m receiver spacing. The picture is far better with more number of reflection points in source receiver plane. The lateral coverage obtainable with 1800m offset is around 900m from the well. In the middle part holes are seen probably due to reflected energy going away from the source receiver plane.

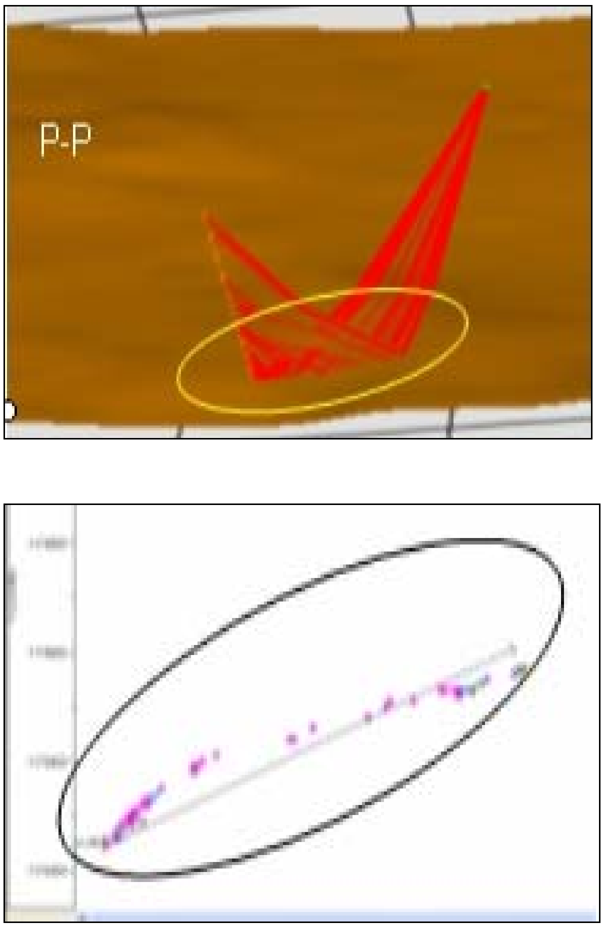


Fig.9 Offset 2000m Receiver spacing 20 m

Fig.9 shows CRP fold map for 2000m offset and 20m receiver spacing. This is comparable to 1800m offset except at the far end where the points go out of source receiver plane due to arrival of reflection energy from plane other than source receiver plane.

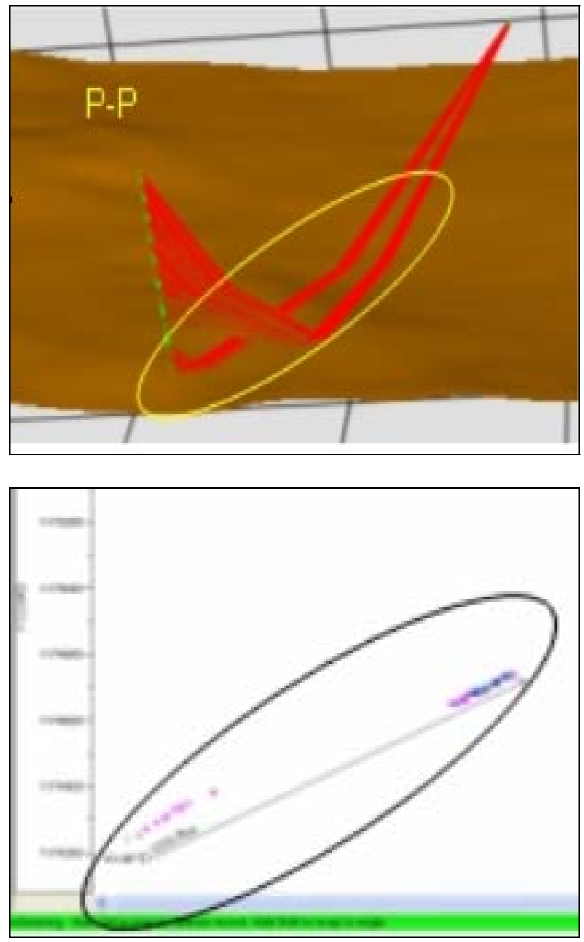


Fig.10 Offset 3000m Receiver Spacing -20m

In Fig.10 the picture deteriorates with increase of offset to 3000m.In the middle part illumination is not there meaning that receivers are not there in the direction of reflected energy.

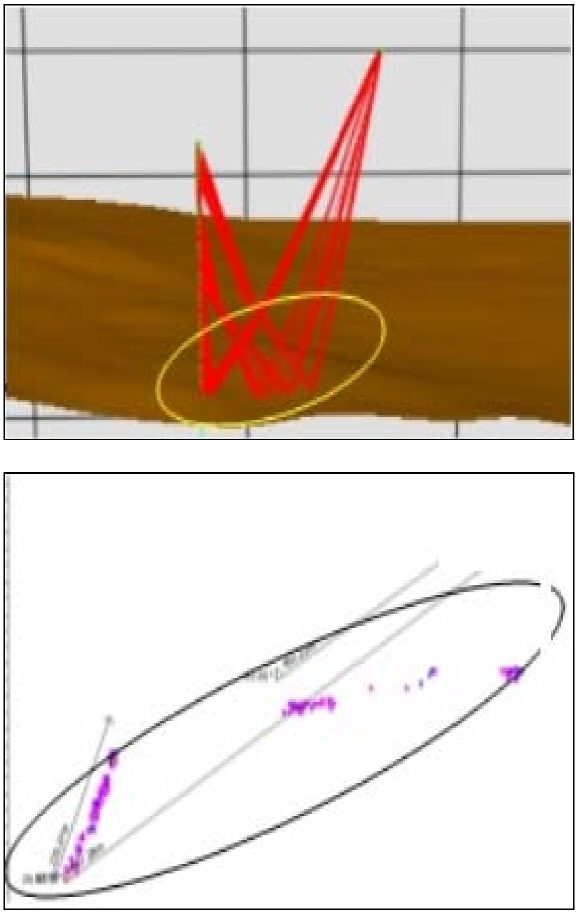


Fig .11 offset :1500m Receiver spacing 10m

Fig.11 shows CRP fold map for 1500m offset and 10m receiver spacing. Due to doubling of receivers ray count also increases. The overall pattern is same as the case with 20m geophone interval (Figure.7). Going for closer sampling is not going to help.

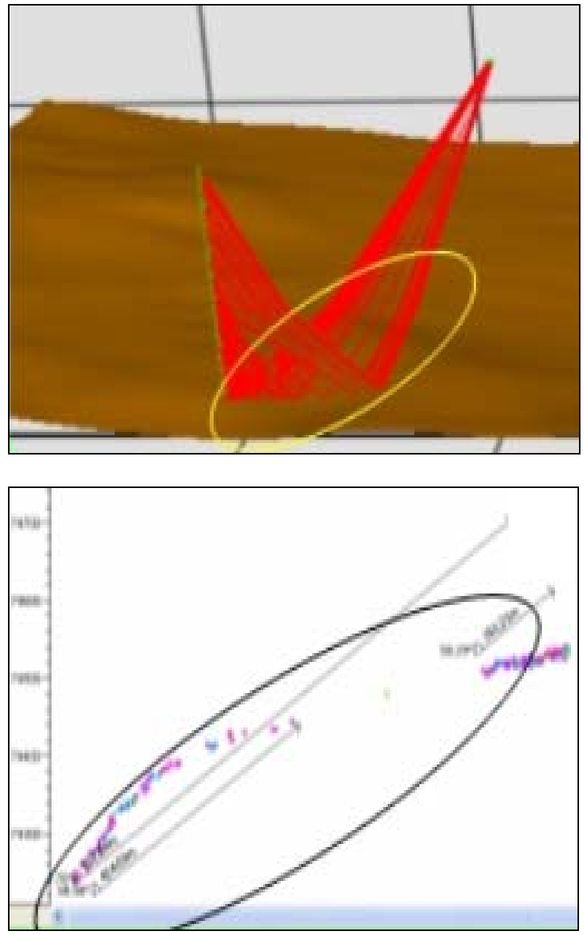


Fig.12.Offset 1800m Receiver spacing 10m

Fig.12 shows CRP fold map for 1800m offset and 10m receiver spacing. Though the distribution of points closer to well is more or less on the desired plane, beyond this there is a vacant area and far away from well the points are due to reflection from out of plane. 1800m source offset and 20m receiver spacing seems okay.

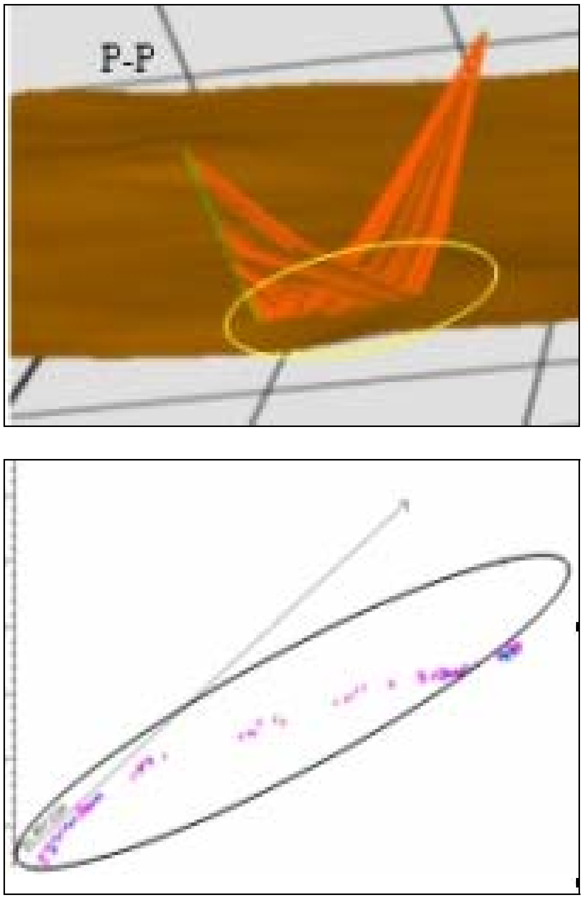


Fig.13 Offset :2000m Receiver spacing 10m

Fig.13 shows CRP fold map for 2000m offset and 10m receiver spacing. As we move away from the well, after some distance the shift of the reflection points from the desired plane is quite appreciable. Whereas for 20m geophone interval the points are close to the source receiver line.

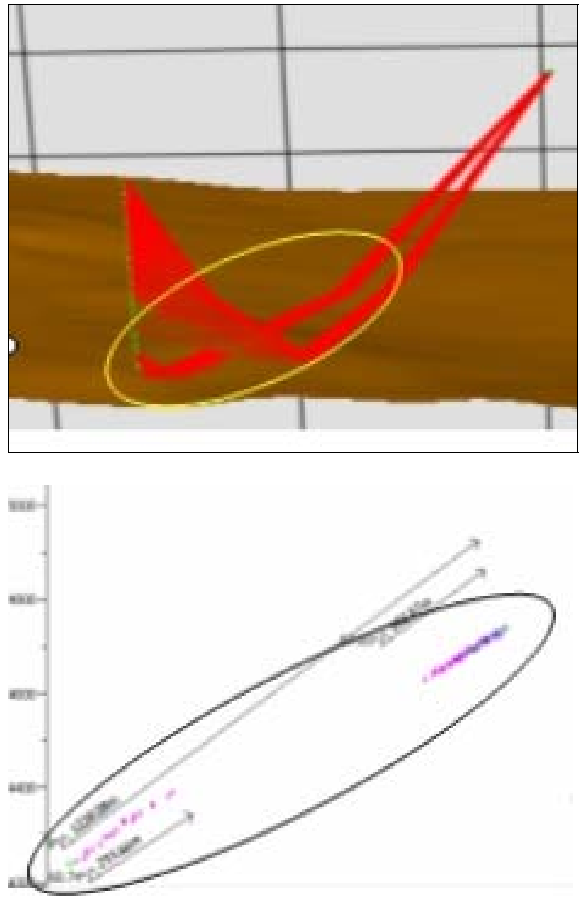


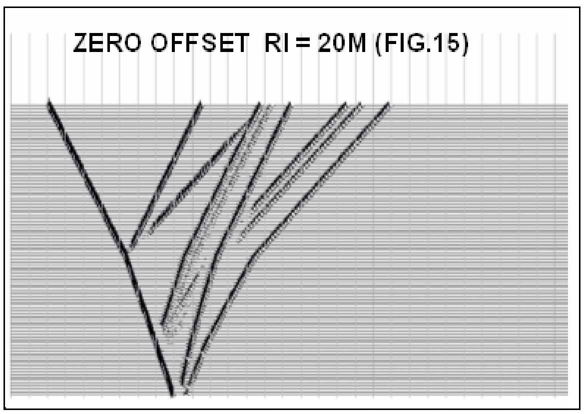
Fig.14 Offset : 3000m receiver Spacing -10m

Fig.14 shows CRP fold map for 3000m offset and 10m receiver spacing. The middle part is devoid of hits while near and far away from well the hits are seen.

In final analysis, 1800m offset with 20m receiver spacing was selected.

Synthetic data generation and processing

The acoustic impedance model was convolved with zero phase Ricker wavelet and synthetic shot gathers for zero offset case and offset case were generated. Instead of single frequency, wavelet frequencies determined after doing frequency analysis on VSP data of AC-2 well which is nearly 1200m east of experimental well were used for convolution. The synthetic data showing direct primary, reflected primary and P-SV waves are shown in Fig.15 & 16.



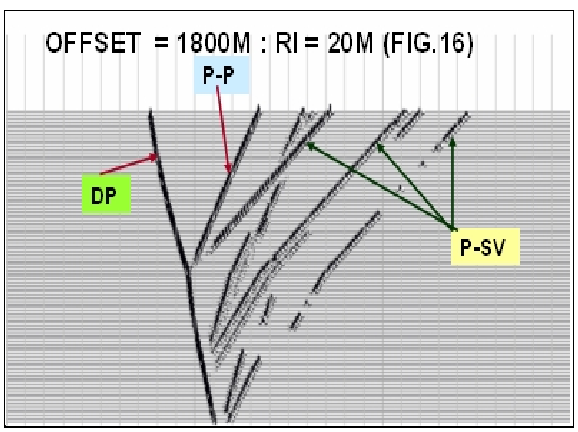


Fig.15 & 16

The synthetic data was processed and corridor stack and offset section were generated for correlation with surface seismic. Figure.17 shows tie between corridor stack, synthetic offset VSP section and 2D seismic section along reconstructed line passing through both wells

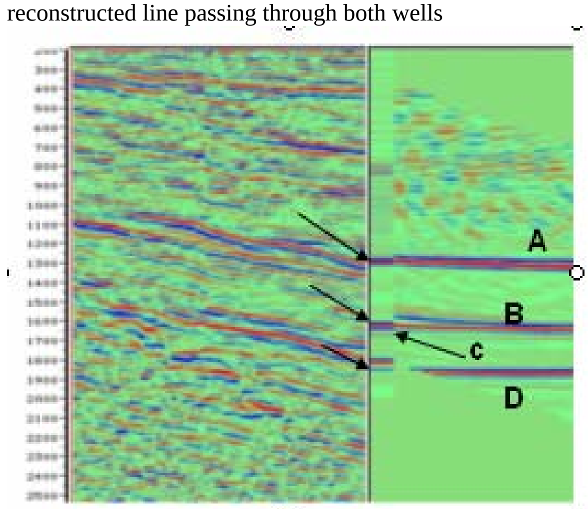


Fig.17 (Left to Right) Surface Seismic Corridor stack and offset stack

Conclusions

Based on the above study, it can be concluded that the required offset for the VSP surveys is 1800m for the receiver interval 20m of 500 to 2500m well column.

Forward modelling studies for offset VSP survey has helped in identifying the required offset and direction for placement of source to image the sub-surface. Such studies before offset VSP survey bring in value addition for meeting the required exploration objectives.

Acknowledgements

The authors thank Oil and Natural Gas Corporation Ltd. for permission to present this paper. Authors also thank members of Cauvery basin interpretation group, Dr.R.C.Iyer, DGM In-Charge (Operations) and Shri.K.Ramakrishna CG(S) for their valuable suggestions.

References

Offset VSP: A tool for development drilling by Mark Pucketi , The Leading Edge, August 1991

Borehole Seismic data sharpen the reservoir image by Phil Christie et.al, Oil Field Review, Winter 1995.

Seismic Interpretation of meander channel point bar deposits using realistic seismic modelling techniques by J.N.Noah et.al, The Lleading Edge, August 1992.