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Modelling Studies as a Tool for Offset VSP surveys – Case Studies

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Summary

Seismic surveys have been a major tool in the exploration and exploitation of hydrocarbons. Vertical Seismic Profiling (VSP) is a very important branch of this exploration activity. Zero-offset-source VSP surveys provide information about the subsurface only within the Fresnel zone centered at the well. Offset VSP (OVSP) survey- offsetting the source location moves the reflection zones away from the well thus provide lateral coverage basically the well environment.

Subsurface illumination studies are not most often applied to feasibility studies and survey design, but the concept offers a wider range of applications. Therefore modeling studies are crucial and have become a common way to deal with survey design. The objective of modeling studies is to analyze acquisition feasibility, optimize source and receiver geometries to obtain better sub surface illumination.

A 3-D depth model was constructed and subjected to ray tracing and synthetic sections were generated with different survey designs. Attributes along with synthetic sections were studied and to optimize a suitable geometry for data acquisition. The present case study deals with the determination of offset for VSP surveys with help of Modelling.

Introduction

VSP surveys are known to produce superior reflection images compared to images from surface seismic. VSP data acquisition has gone away from an accurately determine velocities to tie with surface seismic correlation. From VSP data important information about surface seismic image below the drill bit, higher Frequency data, and other petro geological parameters are being derived. Seismic modelling helps in understanding the imaging issues and in evaluating the effectiveness of the geometry before data acquisition

Offset VSP is one of the types of VSP survey, in which source is at a fixed offset from the well and geophones are at different levels in the well. Offset VSP infer the subsurface image away from well bore in the direction of the energy source.

A study was carried out in two wells for conducting offset VSP surveys one in Rajasthan and the other one is from Frontier basins to optimize source offset distance by forward modeling

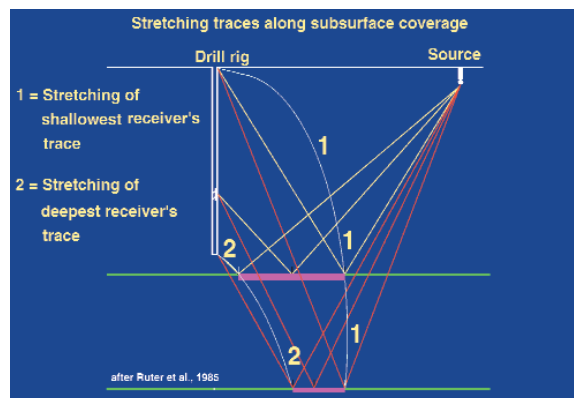


Fig. 1 schematic diagram of offset VSP survey

Keeping the geological aspects into consideration a detailed study was made on various offset designs and its attributes for P-waves (compressional waves). The basic assumption in the depth model was the layers were considered as homogeneous no lateral variation in the lateral Velocities, and density was derived using Gardener's formula.

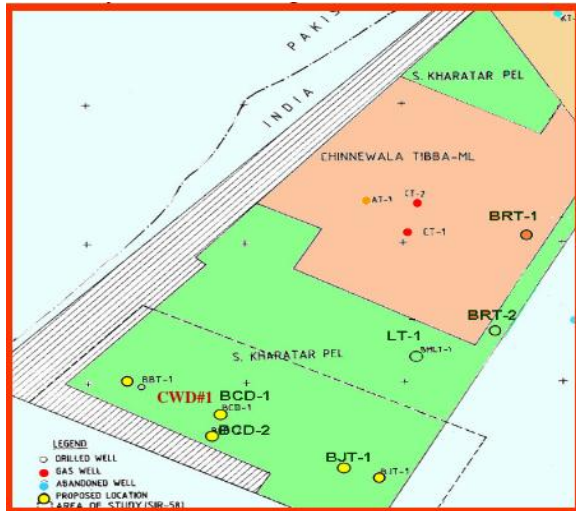


Fig 2: Prospect Map with project area

Modeling

Case study 1

The objective of the well CWD#1 in Rajasthan Basin is to explore the Lower Goru formation; the sands in the Pariwar formation; and the Baisakhi-Bhadesar formation. The well fall in South of Kharatar PEL

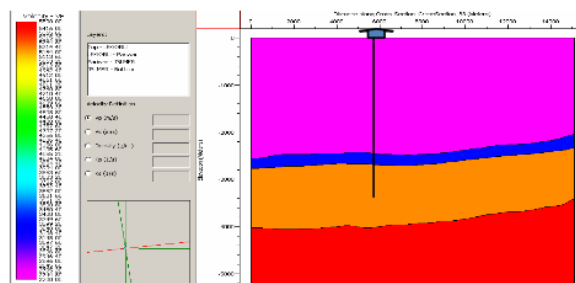


Fig 3: West - East section of the Model and well location

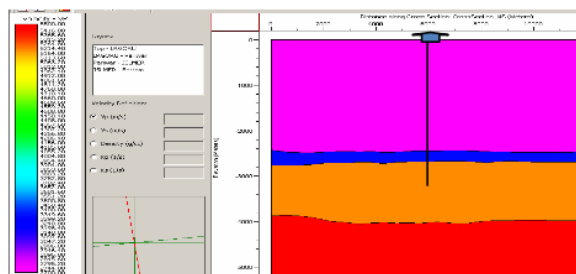


Fig 4: North -South section of the Model and well location

A 3-D depth model of area was built and the horizons viz LR Goru,, Pariwar, and Jaisalmer were taken into account for study. The W-E and N-S cross section were shown in Fig - 3 and Fig - 4.

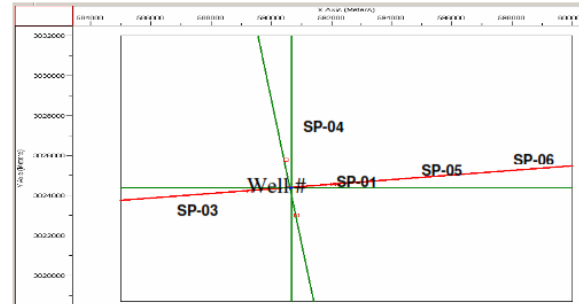


Fig 5: Layout of source locations

Keeping the geological objectives in mind, the offsets were consider for 1400m with following azimuths 83°, 173°, 263°, 353° as specified as Fig-5 as SP-01,SP- 02,SP-03,SP-04. Another two offsets 2200m (SP-05) and 2600m (SP-06) were also considered for the study in the eastern direction. On the 3-D depth model, modeling was carried out and reflections from the target surfaces were ray traced for all offsets.

The ray tracing studies were carried out keeping the target as Pariwar formation (Fig-6). In all offsets the coverage was observed approximately up to ~ 700m. The CRP fold for SP-01 near the well is having low fold where as the high fold of 3-4 fold was observed in away from the well. The CRP fold for SP-03 is having high fold near the well and low fold far from the well that was supported by ray tracing, synthetic seismograms and the other attributes such as Average Amplitude and TWT (Fig-8a,8b and Fig- 9). The event stand out was also good as shown in fig in monitor records except for SP-03.

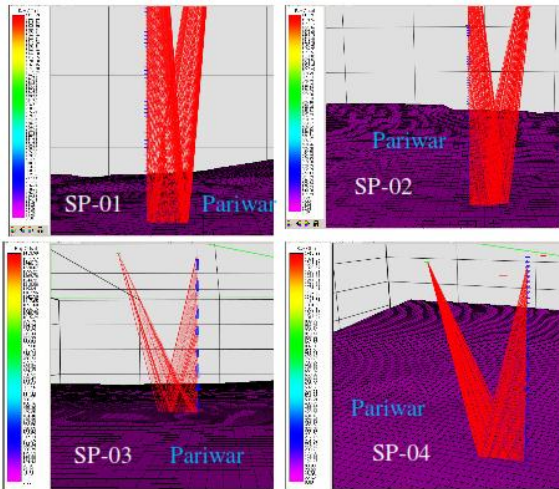


Fig 6: Ray tracing on Pariwar formation for offset 1400m

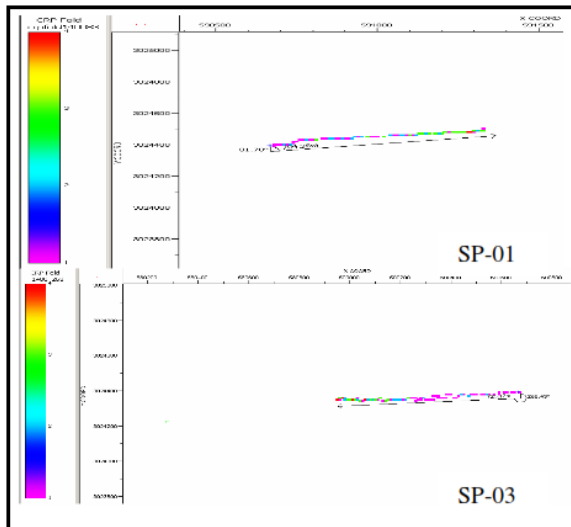


Fig 7: CRP fold for SP-01 and SP-03

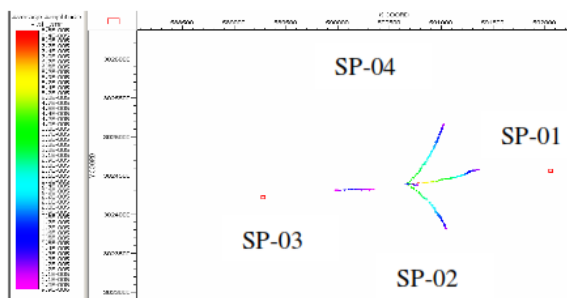


Fig 8a: Average Amplitude

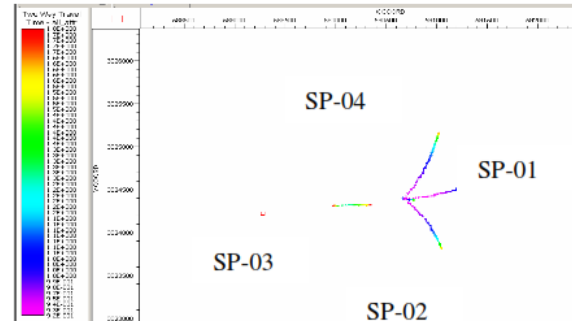


Fig 8b: Two way Travel Time

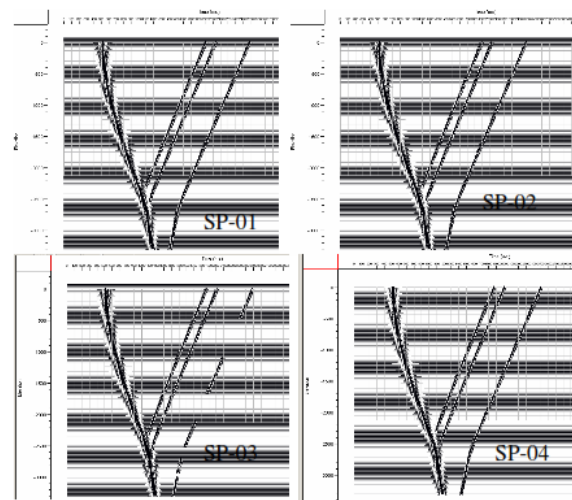


Fig 9: Synthetic Seismograms

Similarly for offsets 2200m (SP-05) and 2600m (SP-06) were also studied. After analyzing the various attributes like CRP fold, Amplitude, keeping the zone of interest in mind, 2200m was considered for carrying out OVSP in all four directions.

Source Offset from the Well:

- (a) Offset- I : 2200.00m/ 83° 00_ 00.0_
- (b) Offset- II : 2083.67m/353° 42_ 55.0_
- (c) Offset-III :2168.90m/263° 04_ 08.0_
- (d) Offset-IV :2000.00m/173° 00_ 00.0_

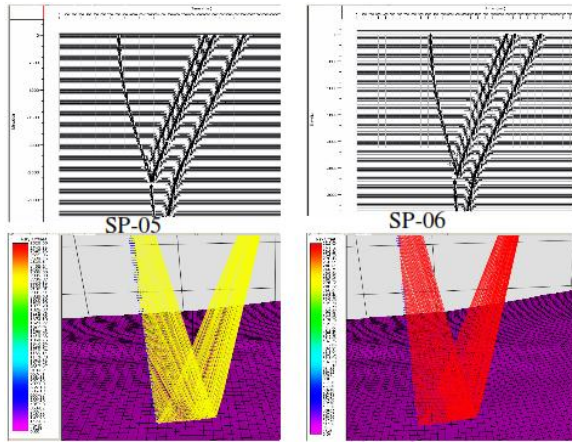


Fig 10: SP-05,SP-6 Ray tracing and synthetic seismograms

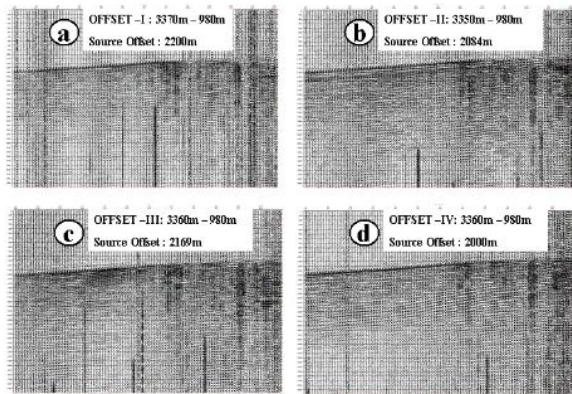


Fig 9: Field Monitor records

The field monitor records (Fig-11) and processed output mini sections (Fig-12), has good S/N-ratio, resolution and accuracy; the output shows the events in the zone of interest, thereby achieving the objective

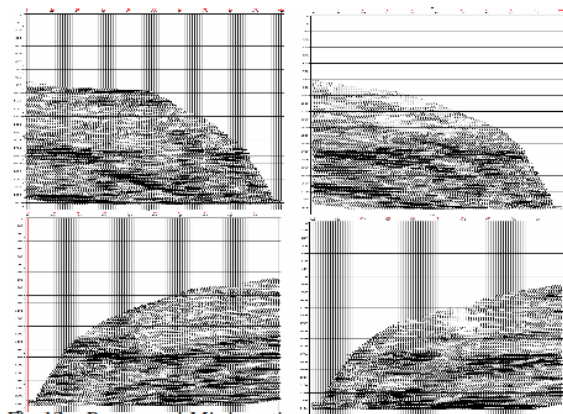


Fig 12: Processed Mini sections

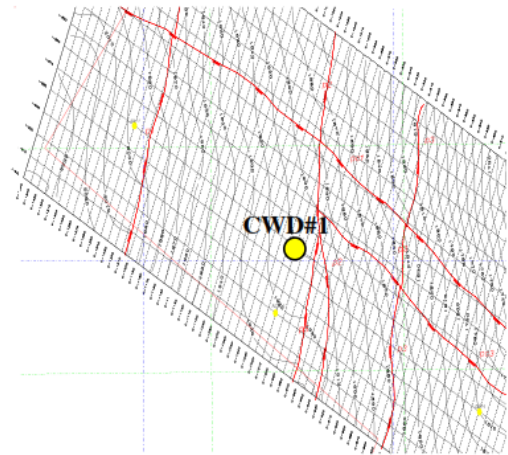


Fig 13: Contour map Of pariwar Fm before OVSP

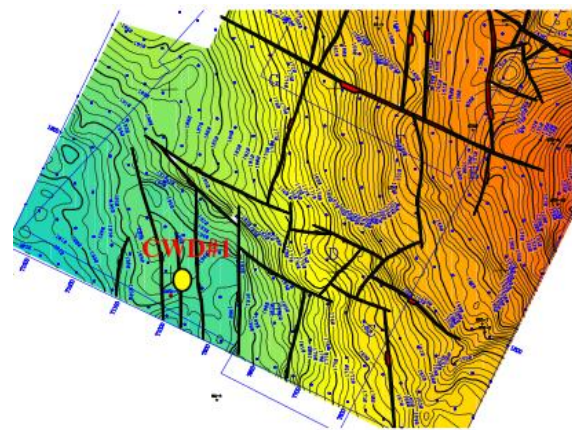


Fig 14: Contour map Of pariwar Fm After OVSP

After the completion of OVSP the faults were well defined (Fig-13, Fig-14) and gave good lead in exploration activity.

Case Study –II:

Well#1 (Fig- 13) is in Damoh-Jabera_Katni in Son Valley of Vidyan Basin, having a target depth of 4850 .This well is currently under drilling, encountering a gas reservoir at 1566 m. initiated to go for offset VSP for better understanding of the reservoir extension. The Two Way Time map (Fig-15) near Top of Rohtas Formation.

The Receivers 160 were placed at an interval of 20 mts vertically and sources inline and X-line directions. Offsets 500m, 1000m and 1500m, 2000m (Fig-16) were considered for modeling parallel and perpendicular to line 24-10. Similarly offset of 500m and 1500m were taken for modeling, along t line 28-05 on the both sides of the well.

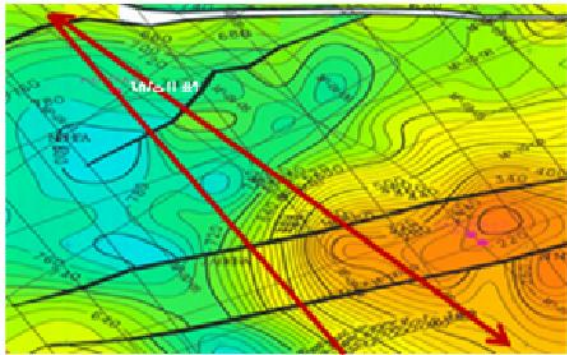


Fig 15: TWT map of Near Top of Rohtas Fm

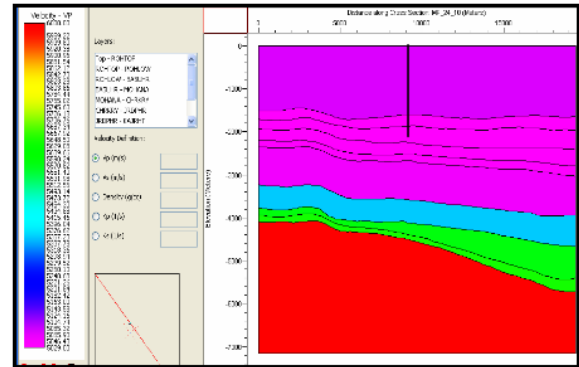


Fig 18: 3-D Depth Model with horizons

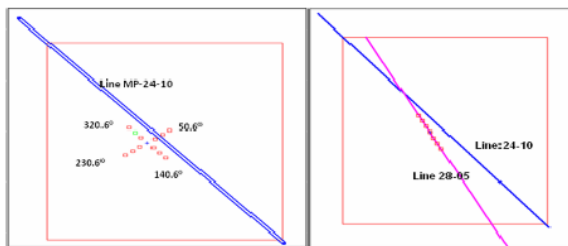


Fig 16: layout source positions

The depth model (Fig-18) is in tune with 2-D seismic section (Fig-17). Ray tracing was carried out and its attributes CRP fold (Fig-19) and average amplitude was studied in detail.. The diagnostic attributes displayed for the Target horizon Rohtas Top was considered. The CRP fold is observed higher for near offsets ie 500m and the coverage ~ 250m. Near the well location is fold is low, higher fold is observed away from the well. The coverage is approximately half of the offset distance. Better and uniform coverage is observed in 140.6° and 50.6°.

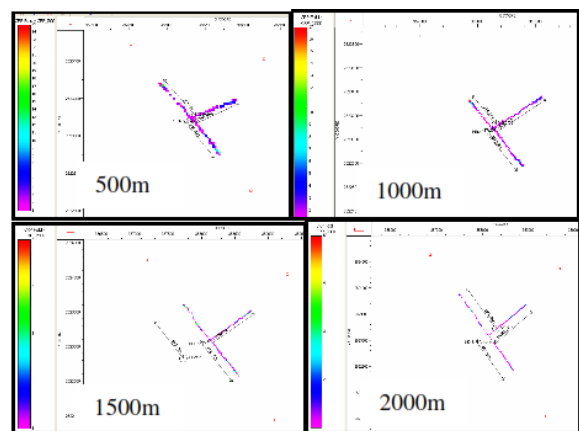


Fig 19: CRP fold attribute for different offsets

Synthetic seismograms for offsets 500m and 1500 m (Fig-20, Fig-21) are showing a good continuity and stand out especially with all azimuths except for the offsets in 320.6°

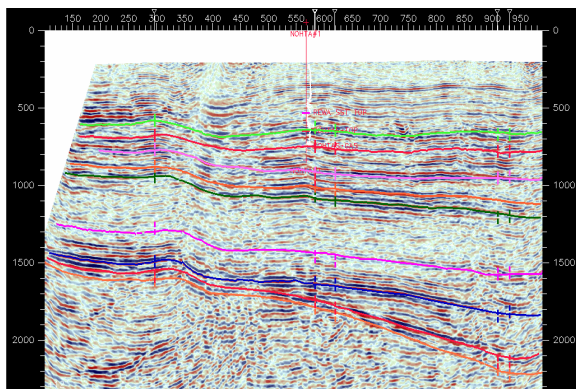


Fig 17: 2D section with the horizons and well location

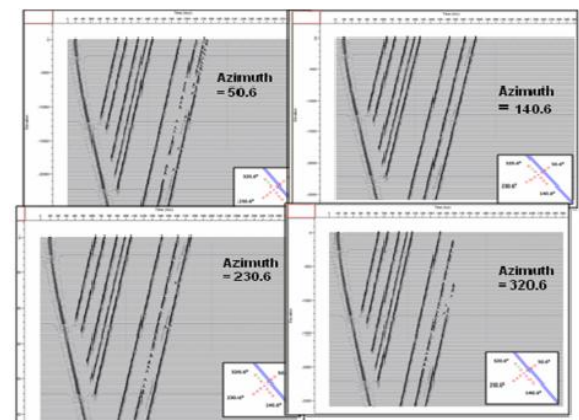


Fig 20: Synthetic seismograms of 500m offsets

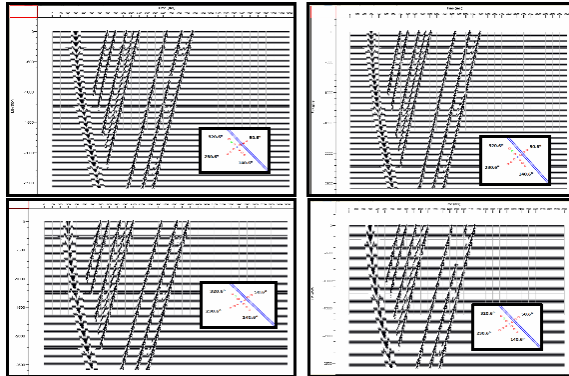


Fig 21: Synthetic seismograms of 1500m offsets

Based on the results of attribute studies and synthetic sections an offset of 500m and 1500 m offset seems to optimal as the interest is shallow as well as deep and the direction preferably parallel to the line in 140° and 320° . At least one offset 500 m/1500m in 50° was also advisable.

Conclusions

- Modelling studies is an important tool in finalizing the offset and direction for the placement of source.
- Better sub-surface image well defined faults gives confidence in understanding the subsurface
- Value addition for achieving the exploration objectives.

References

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Acknowledgments

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