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3D – 3C Seismic Surveys as Tool for Fracture Identification – Survey Design Case Study

**T Krishna Prasad*, Sanjib Sett, G B Ramamurty, U P Singh,
U K Chatterjee, Dr S Viswanathan**
ONGC Ltd., India

Summary

Land multicomponent seismic has gained a significant growth in the last few years, due to its cost and quality concerns and understanding of its data, have limited its use as a routine exploration tool. Three-dimensional (3-D) seismic surveys have been maintaining its significance in the exploration and exploitation of hydrocarbons. The quality of the overall design is evaluated based on surface attributes such as uniformity of fold and regularity of offset sampling in common mid point (CMP) domain. This is equivalent to an implied assumption of a layered, constant velocity subsurface model. Illumination is only considered as a forward problem. Illumination maps may be constructed at the target reflectors in common reflection point (CRP) for each of a few competing geometry templates and the best one selected by a qualitative comparison of those maps.

Fractures dominate storage and movement of gas, developing a tool to identify and map the best fractured zones was a high priority. The converted wave (C-wave) dataset proved to be that needed tool, because the data provided azimuthal definitions of S-wave velocity differences that could be used to map variations in fracture orientation and intensity (Ref:1). Although this is an important step in the right direction, there is no guarantee that the chosen geometry will in fact produce optimum illumination and useful for fracture identification. In such cases three component (3C) surveys and their studies will be helpful in identifying fractures. A 3D-3C study was carried out at Padra area of South Cambay Basin. A 3-D depth model was constructed and subjected to ray tracing and synthetic sections were generated with different survey designs. Various attributes along with synthetic sections were studied and optimized a suitable geometry for data acquisition by a detailed study of P converted PS-waves. The present case study deals with the various aspects of illumination studies and PS-wave impact on survey design and its parameters.

Introduction

The potential benefits of multicomponent data include improved conventional P-wave data, more reliable rock property information, lithology discrimination, fluid identification, fracture identification, as well as improved imaging. Due to the acquisition advances, such as digital multicomponent sensors like Micro Electro Mechanical System (MESM) and in compatible processing techniques lead to explore the possibility of Fracture identification in

Padra area. The Padra field (Fig-1) is located in the eastern rising flank of the prolific Cambay Basin. The main source rock is Cambay Shale, the producing Hazad sands are not developed in the area. Fractured, weathered Deccan Traps and Olpad is main hydrocarbon producer. Ankleshwar sands are also produced in some parts of the area. Different fault blocks have different oil habitat and understanding of fault orientation and fracture pattern is essential for hydrocarbon exploitation. The Hydro carbon distribution is not fully understood due to lack of detailed seismic data.

Geophysical Services, Western Onshore Basin, Baroda * prakrutee@gmail.com

With the available 2-D data, mapping of fractures and fault patterns is difficult. The need is to bring out detailed fracture and fault patterns especially in the trap level in the prospect area.
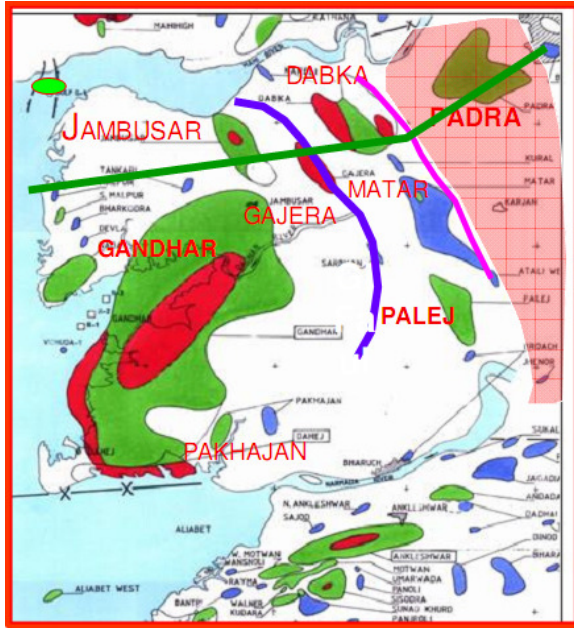

Fie 1: Prospect Map with project area

Methodology

Keeping the geological aspects into consideration a detailed study was made on various survey designs and its attributes for P-waves (compressional waves). These conventional 3D designs were mainly concentrated on analysis of bin attributes in particular: fold, offset distribution, and azimuth distribution in CMP domain. Achieving the optimum fold does guarantee a good signal to noise ratio and overall illumination, but not necessarily proper resolution. This P-wave data had a great role in exploration and exploitation of hydrocarbon in oil industry. But this is not sufficient to handle all types of geological problems. Converted shear wave component data compensates the deficiency and helps in resolving various

imaging problems such as fracture identification, reservoir characterization etc. Designing 3D-3C surveys is more complicated when compared to conventional 3D seismic surveys, due to its asymmetry. Compressional wave (Pwave) with uniform fold will result a non uniform fold in the converted wave (PS-wave) domain. The Vp/Vs ratio and the roll over (reoccupation of receiver lines) play an important roll in obtaining smooth PS fold. Considering all the above facts into consideration various options were studied

A study was carried out with Orthogonal, Slant, Brick and Cross slant geometries with split spread configuration having a bin size of 10m X 10m contains 16 receiver lines with 140 stations per line. The shot line spacing was 140-meter with a good aspect ratio. The roll over was changed from single line, two-line four line and half swath roll over of 16 receiver template. These parameters allow the acquisition of uniform 80-fold in PPdomain
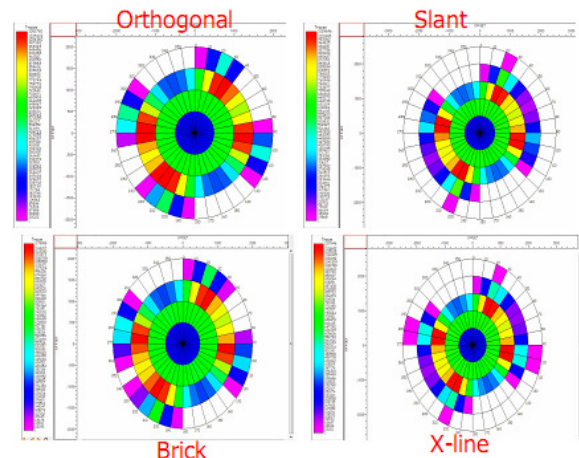

Fig:2   Rose diagram

The basic parametets offset distribution, Azimutal distribution, offset variability etc., were studied in detail. The rose diagram (Fig- 2) for all the geometries was giving a good azimutal ditribution. The orthogonal and brick geometries are having better wide azimual ditribution. Similary the study for offset variability (Fig-3) was also carried out, and the orthogonal geometry was given better

variability. Vp / Vs ratio another important factor which play a very crucial role in obtaining smooth PS fold. The well data in the assigned area suggested the Vp / Vs ratio is varying between 1.8 to 2.0. The CCP fold distribution (Fig-4) was observed for all the four geometries and it was observed that the variation (65-98) was better in orthogonal geometry when compared to other geometries, against Nominal P- fold of 80.
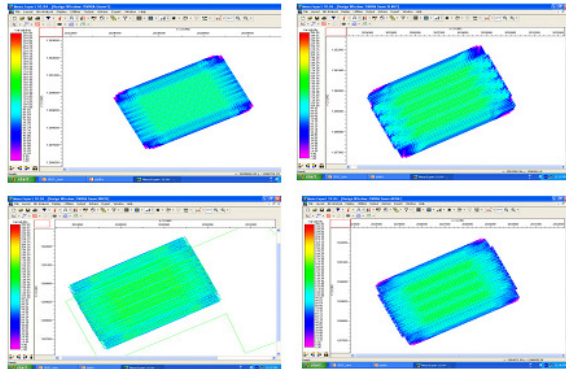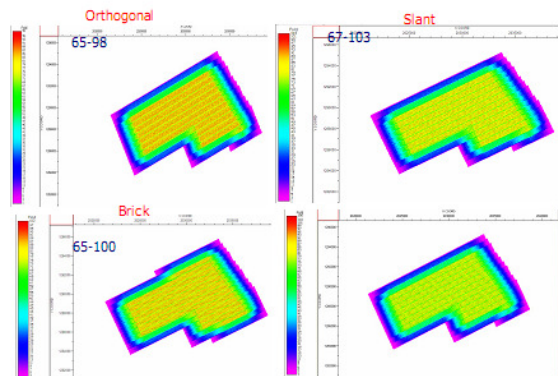

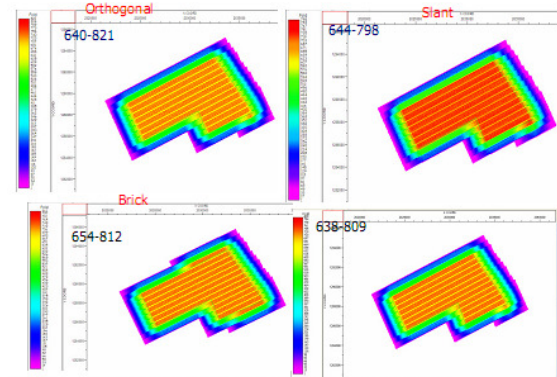Fig:3   Offset variability diagram

Fig:4   CCP fold diagram

Fig:5   CCP fold diagram with 30 x 30 bin size

The Conversion Bin Size (B) is always greater than the 3D CMP Bin Size.

B = RI/ (1+Vs/Vp) where RI –Receiver Interval

If CCP Bin is not changed to reflect this conversion point location, CCP fold Distribution map has a stripped appearance possibly with holes. The stripping effect can be reduced by keeping Shot Line Interval with ODD multiple of Receiver Interval and by increasing the CCP Bin Size. In this regard a study was carried out to see a fold in the super bin of 30m X 30m and studied the uniformity of CCP fold. The study (Fig- 5) suggested orthogonal geometry having an edge over the other geometries.

Modeling

There are several methods available in order to investigate both the illumination regularity and resolution quality. 3-D ray tracing followed by target – oriented binning method is the most common of the illumination methods in the industry because it is relatively simple to handle, robust and cost effective.
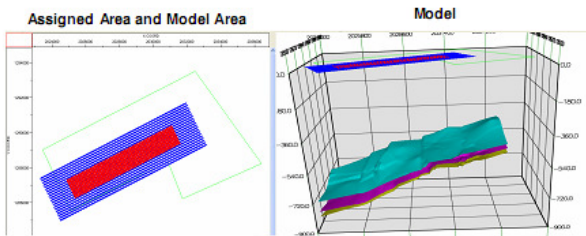
Fie 6: Assigned area and 3-D Depth Model

A 3-D depth model (Fig-6) of Padra area was built with the help of well data and three horizons viz Ankhaleswar, Olpad and Trap. The basic assumption in the depth model was the layers were considered as homogeneous. Velocities were taken from the available sonic logs and density was derived using Gardener's formula. On the 3-D depth model, reflections from the target surfaces were ray traced for all short listed four probable geometries for further Modelling study.

Ray tracing allows not only computation of two way travel times, but also many other attributes like CRP fold, AVO average and maximum incidence angle, CMP to CRP displacement and attributes were mapped on the target surfaces for all the geometries. With the available software on MESA, synthetic gathers and sections were generated for these geometries.

Discussion

The diagnostic attributes displayed for the Target horizon Trap was considered. Synthetic seismic sections were also analyzed for all the geometries.

- **CRP fold**:

  CRP fold (hit count) is the number of hits on each bin cell of the target surface. It gives illumination aspect of the focusing areas as well as identifying potentially low S/N ratio areas (low fold Zones). The CRP fold (Fig-7) is displayed for Trap level for PP and PS. The fold pattern is almost same in PP and PS respective

domains. The "NO" Illuminations zones may be due to fault patterns. The CRP fold in PS domain having a higher value compared to PP fold.
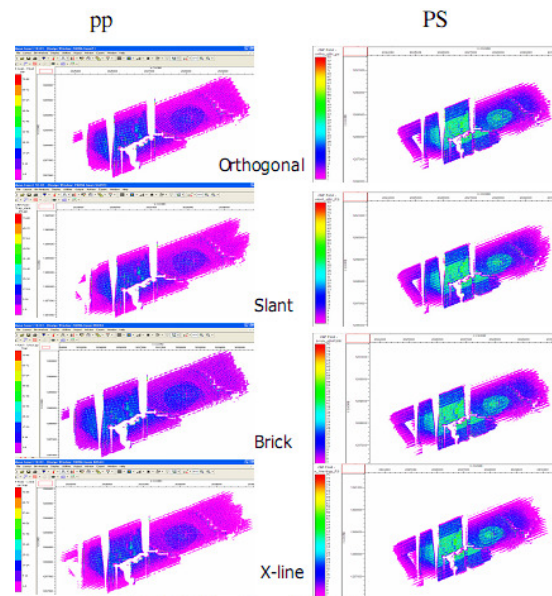

Figure 7: CRP Fold at Trap Levl

- **CMP-CRP displacement:**

  It computes the average horizontal displacement between CRP and CMP for all the rays and the values are then plotted at the CMP location. It gives a direct estimate of migration aperture. After a detailed analysis this attribute (Fig-8) it was found that the displacement values were varied from 0 to 72 mts in all the options for PP-waves, where as at fault edges it was showing an higher average value of 150 mts.

- **Two Way Travel Time:**

  the two ways time (TWT) (Fig-9) for PP is 0.60 sec Eastern part to 0.85 secs in the western part. For PS waves TWT is varying 0.8 secs in the shallow zone in the east and 1.20 to 1.50 secs in the west where the objective is deeper.

- **Synthetic sections:**

  Synthetic sections (Fig-10)were generated with limited processing procedures using MESA software for PP and PS waves. The study of these sections suggests that all these sections are comparable, and better delineation of fault was observed in Orthogonal and Brick geometries.
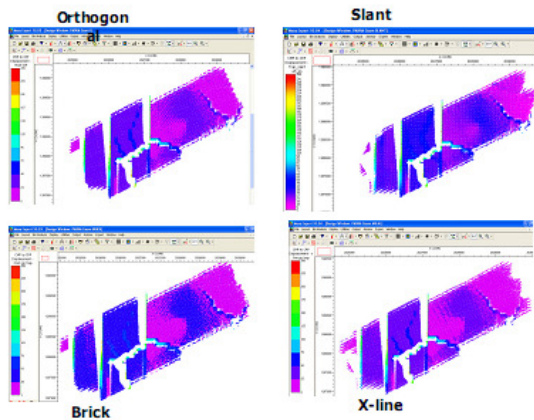

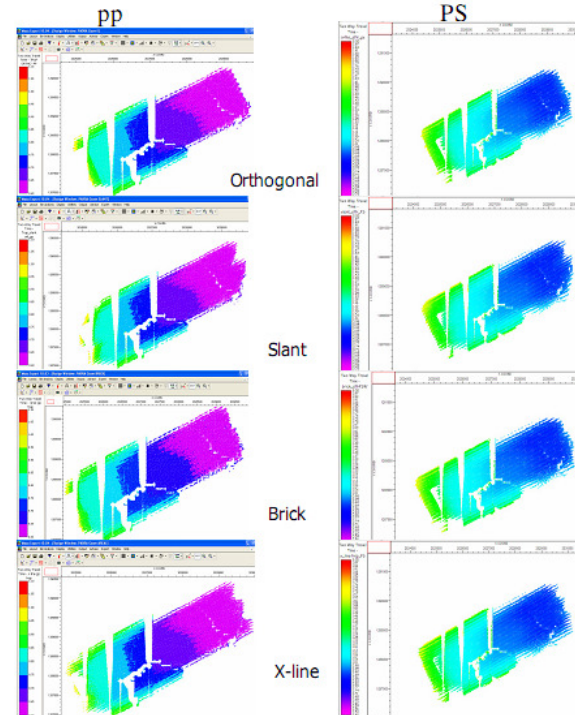Fig 8: CMP-CRP displacement at Trap level

Fig 9: Two way Travel Time from Trap Level

The attributes of the modeling studies for all geometries are having more or less similar pattern but the orthogonal geometry is having a slight edge over the other geometries. Based on the results of design attribute studies and clue from synthetic sections and modeling attributes orthogonal geometry is preferred for operational purpose.

Conclusions

Survey design is an important aspect in 3D-3C seismic data acquisition, uniform P-fold does not mean a uniform PSfold. Optimization of geometry with a stable PS-fold without stripping (zero fold patches) with wide azimuth is an important task in Converted wave survey design. Full azimuth P-wave data give an improved structural picture with good fault resolution, where as converted wave (Cwave) data gives valuable information that will define

imbedded sand - shale sequences that were the areas of optimal fracture intensity. Fractures dominate storage and movement of gas, developing a tool to identify and map the best fractured zone was a high priority. The C-wave data proved to be the " Needed Tool ", because it provides azimuthal definition of S-wave velocity differences that could be used to map variations in fracture orientation and intensity. Hence, in order to have a good converted wave data a detailed study of Survey design is very essential with respect to fractures identification.

References

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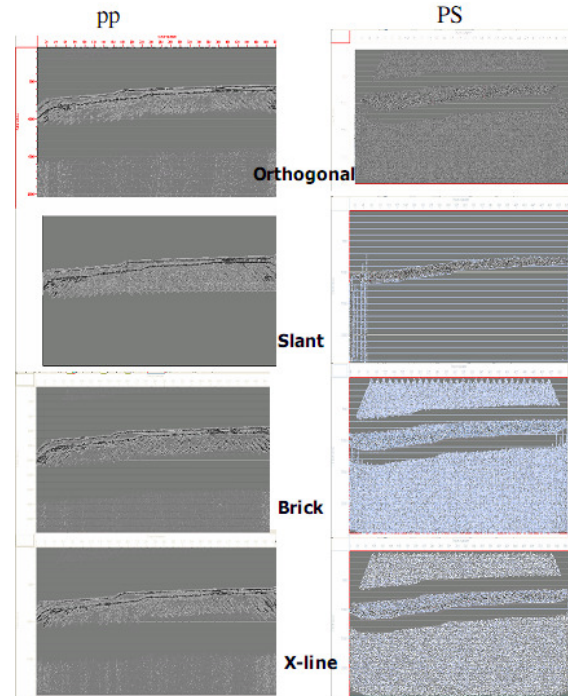(*Coordinated by Robert Kendall VeritasDGC Inc, Calgary, Canada*)

Acknowledgments

Fig10:Synthetic Seismic sections with different Geometries.