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Synthetic Seismogram – A Tool to Calibrate PP & PS Seismic Data

P. Sugadha*, M. K. Jain, M. Singh, *ONGC*

Summary

Conventional P wave technology will not meet all the requirements of the industry. Hence, S wave information is required in addition to P wave to study the reservoir properties. Compressional waves are sensitive to rigidity, bulk modulus and density while shear waves are sensitive only to rigidity and density, this discrimination between P and S waves helps in identification of lithology, porosity, fractures and fluid content.

Recording S waves requires geophones that detect more than just vertical component. Digital sensor like SVSM (Standard Vector Seis Module) is a single sensor comprising of three geophones in orthogonal orientation that allows detecting S waves in all directions (Olav Barkved et al.). Since, the down going P wave and up going S wave velocities are different; the conversion point is not the mid way between source and the receiver. This, takes processing of converted waves (C waves) different from the P wave and its resultant effect on binning, foldage, offset and azimuthal distribution in the area.

In the study area, multi component data was acquired for the identification of the fractures. Both acquisition and processing was carried out to meet the exploration objective. Efforts are made to calibrate PS seismic with the available well information provided with DSI logs. In this paper, the main emphasis is on preparation of Synthetic seismograms for both Vertical and Radial component in order to calibrate our PP and PS seismic with the well data.

Introduction

Cambay Basin is an intra-cratonic rift basin with narrow elongated Graben running approx. NNW-SSE direction takes a swing in the southern part and aligns approx. in NNE-SSW direction. The basin came into existence during late Jurasic and Deccan Trap is considered as the technical basement of the Basin. Based on transverse fault system, Cambay Basin is divided into five tectonic blocks.

The present area Padra falls in the Broach Sub block i.e, in the rising flank of eastern basin margin of tectonic block as shown in fig 1. The main hydrocarbon producer in this block is from fractured and weathered traps, understanding the fault and fracture pattern adds value for hydrocarbon exploration.

The objective of the present study is to bring out fracture & fault pattern at Trap level and bring out the densely faulted/ fractured prospective area with zone of interest as 500-600 ms in the East to 800-900ms in the west.

The data was acquired with the digital sensors SVSM and recorded with I/O systems during the Field Season 2009-10. The acquisition parameters are tabulated below-

Bin Size	10m x 10m
Swath Geometry	Symmetrical Split spread
No of receivers per line	140
No of receiver lines	16
Receiver Interval	20m
Receiver Line Interval	140m
Shot Line Interval	140m
Shot Interval	20m
Spread Length	1390 m
Near offset	14 m
Far offset	1925 m
Foldage	80 (10 x 8)
Swath roll over	4 Receiver lines

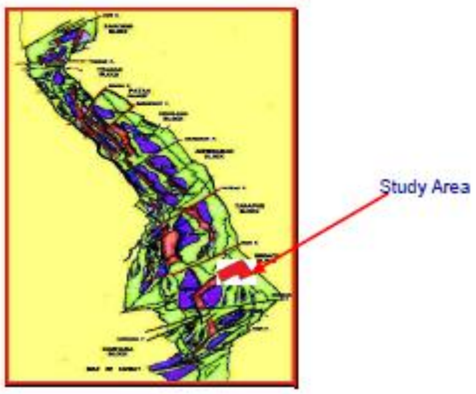

Fig 1: Location Map of the area

1st floor, RCC, Gaveshna building, ONGC , Makarpura road, Baroda-390009
Email: sugadha@gmail.com

Theory

In the PS data, the conversion point moves towards the receiver and from shallower to deeper part, it follows asymptotic path as shown in fig 2. Hence, binning for PS data, which is ACP binning is different from the conventional PP data.

Because of the low Shear velocity in the near surface, receiver statics for the PS data can be large. Computation of the shear (receiver) statics for the converted wave data is a challenge for the multi-component data processing.

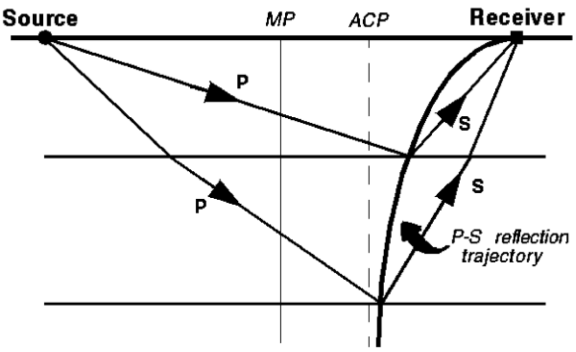

Fig 2: Asymptotic conversion point for the P-S reflectivity curve.

In multi-component data processing, the initial Gamma (V_p/V_s) value is either calculated from the raw data of Z & X component or from Well data, if well data with dipole sonic is available. This is required for ACP binning in the processing.

In transmission through an azimuthally anisotropic material like fractures, shear waves get polarized and split into fast and slow polarizations, giving rise to two polarized converted waves (P-S1 and P-S2, fast and slow, resp.). P-S1 polarization which is parallel to the fractures arrives faster while P-S2 polarization which is perpendicular to the fractures arrives at a later time. The difference in travel times of P-S1 and P-S2 is related to fracture density.

Processing

For multi component data processing, first separate the three components and the vertical component was processed up to PSTM as a normal processing sequence. The raw record of PP data is shown in fig 3.

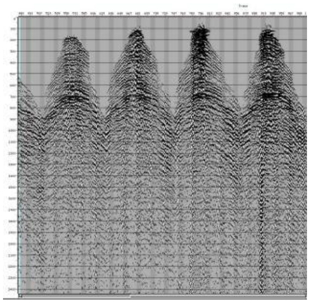

Fig 3: Raw record of Vertical component.

The horizontal components X and Y are taken up for Multi component processing. After the preliminary removal of spikes, the X and Y components are rotated to Radial and Transverse components. Further processing i.e, removal of coherent noise etc. are carried out in R & T. The raw records of X and Y and after rotating to R & T are shown in fig. 4 and 5.

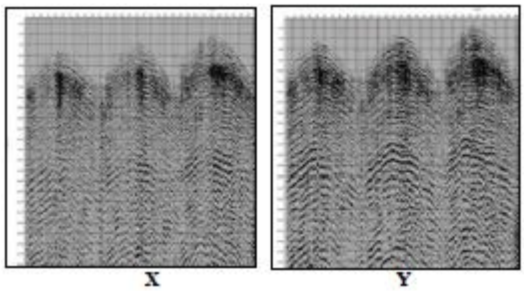

Fig.4 Raw data of X and Y

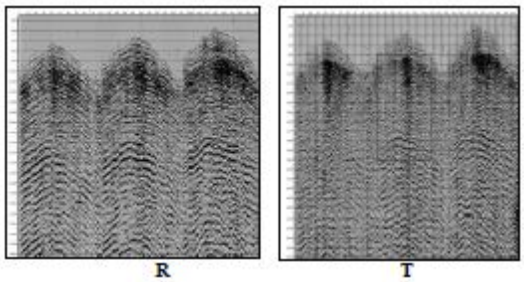

Fig 5: R and T after rotation

Computation of shear statics requires PP & PS data in common receiver domain. The difference in the travel times of any particular event in PP & PS section is calculated as shear statics. For the dipping events, Structural removal is done and then shear statics is computed. After shear statics calculation, PS velocity analysis is done to improve the data quality.

After rotation maximum energy is seen along the Radial component and Transverse component show very less energy. So Birefringence analysis was not attempted. Further, variable gamma or V_p/V_s can be determined by mapping T_{pp} and T_{ps}. To generate V_p/V_s values we take the ratio of PP and PS isochrons from the same interpreted horizons. Thus,

$$V_p/V_s = 2(T_{ps}/T_{pp}) - 1$$

Where, T_{pp} and T_{ps} are the travel times of single event corresponding to PP and PS sections respectively.

In the present study area, the available well information was taken to calibrate the PP and PS seismic section. There are 3 wells with DSI logs available. Hence, correlation for all these wells was attempted. Furthermore, the Gamma (V_p/V_s) values obtained from the well data at the important markers have been tied with the Variable Gamma derived from the seismic sections. The locations of the wells in the study area are shown in fig 6.

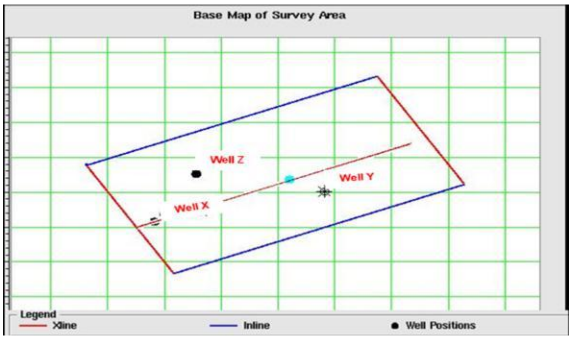

Fig 6: Location of wells in the study area

The final PSTM stack section for vertical and radial component along the Well X is shown in fig 7 and 8. Fig 7 shows the remarkable delineation of fault pattern at the Trap level indicating the objective of the present study.

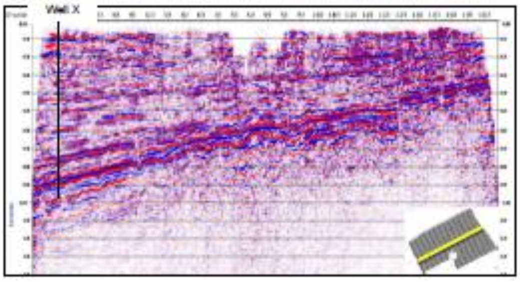

Fig 7: PSTM stack along the well X (Vertical comp.)

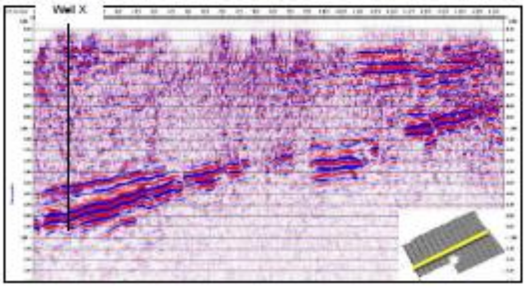

Fig 8: PSTM stack along the well X (Radial comp.)

Calibrating PP and PS sections with the well data

Synthetic seismogram is a forward modeling of extracting a wavelet and convolving with the reflectivity series. After getting reflected from an interface, an incident P wave is recorded as PS wave after Mode Conversion; hence generating PS synthetics is different from PP synthetics. Using PROMC the final PP and PS sections are correlated with the well data in the study area. For PS synthetic seismograms, the modeling algorithm uses the offset-dependent reflectivity and ray-traced travel times of both PP and PS events to create synthetics. The final PS stack to zero-offset travel time gives an average of the offset-dependent PS reflectivities (Robert R. Steward et.al, 2002 and Yufang Dang et al).

For correlation we need the acoustic velocity, density for PP correlation and DSI logs for PS correlation. Initially, in practice P wave synthetic seismogram is tied to the PP section and then PS synthetic seismograms are generated. Correlation is done by tying the markers from the well data to the interpreted horizons in the seismic volume.

Case 1: The results of PP and PS correlation for the Well X are shown in fig 9 and fig 10 respectively.

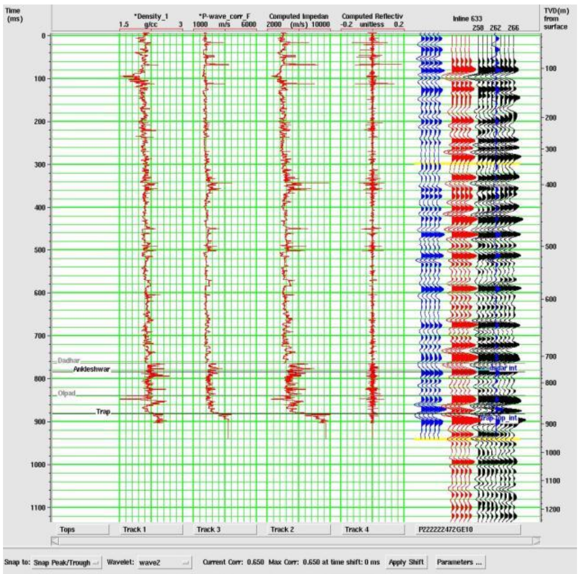

Fig 9: PP synthetic seismogram of Well X.

In the fig. blue traces indicate the generated synthetic seismograms, black traces shows the final migrated stack data and red shows the composite traces generated from the seismic volume around the well location with a particular radius. In Well X the correlation coefficient for both PP and PS data is about 65%. At the trap level i.e, zone of interest, the synthetic data is tying well with the seismic data.

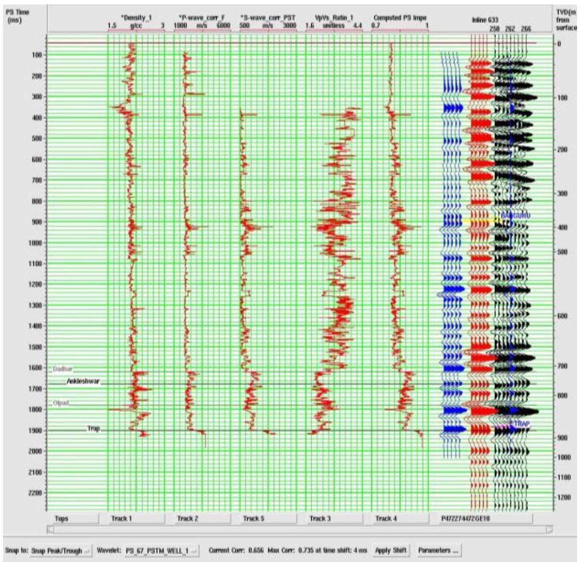

Fig 10: PS synthetic seismogram of Well X

Case 2: Similarly, the correlation results for PP and PS data in Well Y is shown in fig 11 & 12 resp. In this case, the correlation has come up to 70% for PP data and 49% for PS data.

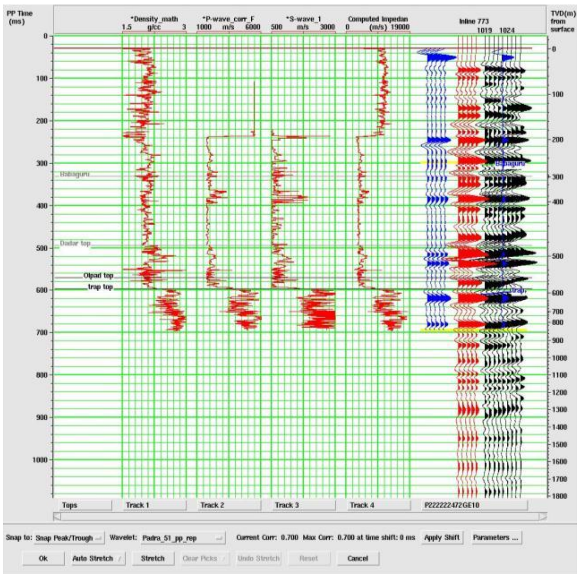

Fig 11: PP synthetic seismogram of Well Y.

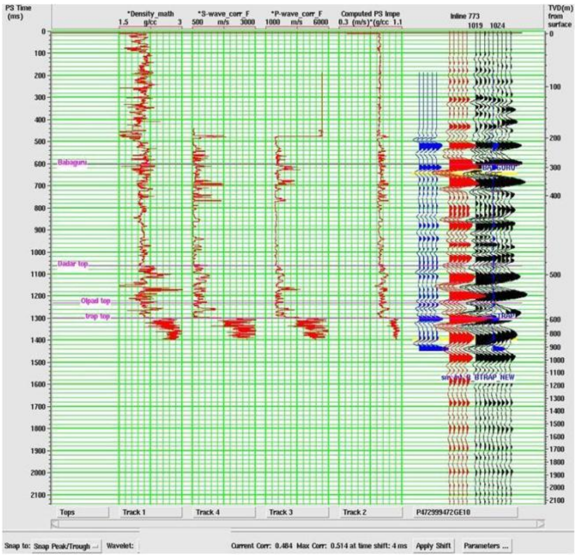

Fig 12: PS synthetic seismogram of Well Y.

Conclusions

The final results of PP and PS data shows good resolution upto the trap level (the zone of interest) with good delineation of the fault pattern. Calibration of PP and PS seismic with the available well information in the study area with DSI logs also shows good correlation coefficient. The Gamma values from the well data at major markers are matching with the variable Gamma values derived from PP and PS seismic. Thus correlation of PP and PS seismic section with the well data validates our outputs.

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