8th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2010"

P-157

Shear wave statics in 3D-3C : An alternate approach

C. B. Yadava, M Singh, Kuldeep Prakash, Kunal Niyogi*
GEOPIC, Oil & Natural Gas Corporation Ltd, Dehradun

Summary

3D-3C data was acquired in Sayan-Tadkeshwar area of Cambay basin to bring out sand geometry and pinch out prospects within Ankleshwar formation. Converted wave data of this volume was processed using two different approaches of shear wave statics refinement. Final processed PSTM stack with alternate approach of shear statics refinement, consisting of trim statics in receiver line domain after structural flattening, has brought out an improved image of subsurface.

Introduction

Sayan-Tadkeshwar area of South Cambay basin is south-east extension of Kosamba oil field (figure-01). The area is characterized by the presence of a series of NE-SW trending faults. NE-SW trending anticlinal structure on the up thrown side of the Kosamba reverse fault falls in the northern part of the area (figure-02). Out of 4 wells drilled in the area, well-A and well-B are oil bearing whereas well-C has encountered 8 mt of Hazad sand, suggesting the presence of good reservoir facies. In light of these discoveries leading to enhanced exploration interest in the area, 3D3C data was acquired with the objective to bring out sand geometry and pinch out prospect within Hazad and Ardol members of Ankleshwar formation.

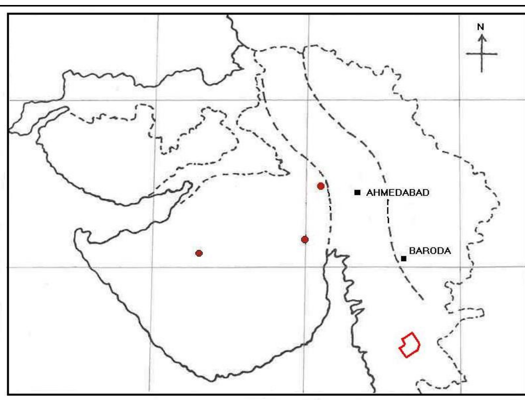

Figure-01: Map showing the area of study

PP data as well as converted wave data of this area was processed upto PSTM stage. Processing of converted wave 3D data is quite different from normal P-wave 3D. Appropriate gamma estimation, CCP binning, birefringence analysis and correction, shear wave statics estimation are some of the crucial issues in converted wave processing. Rotation of recorded components from X, Y direction to Radial and Transverse components is an additional step in the processing of converted wave 3D over 2D3C.

Study area is geologically very complex and presence of numerous faults and steep dipping beds makes the converted wave processing a challenge. Usual practice of shear wave statics refinement based on common receiver stack failed to provide fruitful results. This led to look for an alternate approach of shear statics refinement. This work deals with the main steps involved in the processing of this data set, along with the alternate approach adopted for shear statics refinement.

E-mail: yadava_cb@yahoo.co.in

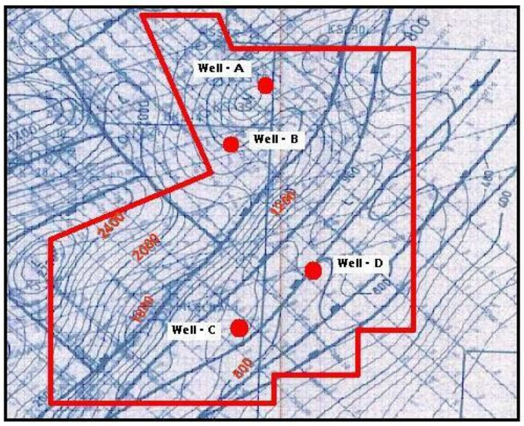

Figure-02 : Isochron map of Trap top

Input Data Analysis & Initial Binning

3D3C data was acquired with 10 receiver line and 15 shot line swath geometry, using asymmetrical split spread (96 + 48 channels). Minimum far offset present in the data is 2895m with foldage 60 and bin size 15m X 30m. Acquisition team deployed 3-component VectorSeis digital sensors and used 1 kg of explosive per shot point. Quality of data is fair to good. Figure-03 shows a part of shot gather after separation of three components.

PP gathers were processed up to pre-stack time migration stage in a conventional way. Figure-04 shows the PSTM stack of PP data from the central part of the area. In north-western portion of the area Trap top is as deep as 2.5 sec on PP section, whereas it is very shallow in south-east (0.5 sec).

Because of asymmetric ray path, mid point binning is no longer valid for converted wave data and appropriate binning requires the detailed information of Vp and Vs in the area, which can be derived only at the later stage of processing. So the processing of converted wave always starts with ACP binning using apriori gamma value. Shot gathers were analyzed in different parts of the area, after separation of the three components. Two way time of prominent reflector was noted in X, Y components and the same event was identified on vertical component gather. Based on the two way times, apriori gamma value was derived, which was found to vary from 3.0 to 3.5, in the area. Therefore for initial ACP binning, gamma value was taken as 3.3.

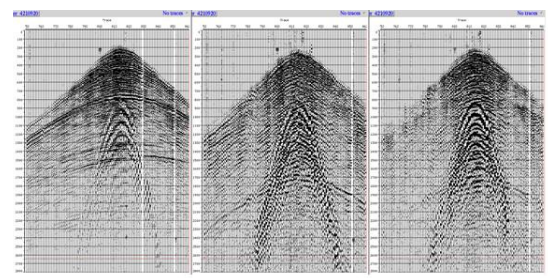

Figure-03 : Part of representative shot gather (vertical component, X component, Y component)

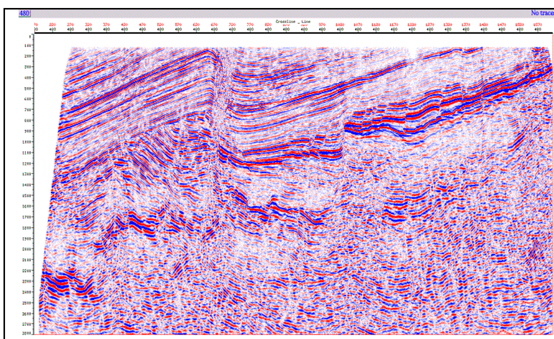

Figure-04 : PSTM stack of PP data from central part of the area

Component Rotation

In onland 3D3C data acquisition, receivers are oriented in such a way that one component records the horizontal vibration along inline direction (X-component) and the other one records the vibration along cross line direction (Y-component). Since the shot points fall in different orientations from the receiver, both X and Y components receive a part of shear wave energy. Therefore after header updation, before any amplitude distortion, X and Y components need to be rotated to Radial component (shot-receiver orientation) and Transverse component. Figure-05 shows X and Y components of a representative gather at the top; and R and T components at the bottom after component rotation.

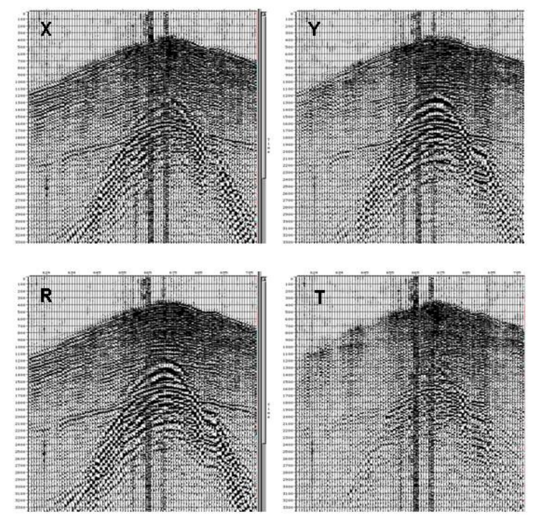

Figure-05: X and Y components of a shot gather (top); R and T component after rotation (bottom)

Birefringence Analysis

In presence of azimuthal anisotropy, shear wave gets split into fast moving (S1) and slow moving (S2) component, polarized in perpendicular directions. In such a situation Radial as well as Transverse component contain a part of S1 energy as well as S2 energy. This again needs a rotation to get pure S1 data set and S2 data set.

Shot gathers of Radial and Transverse component were analyzed in different parts of the area. It was observed that Transverse gathers have only random noise, part of ground roll, remnant P-wave energy; and were almost devoid of any useful reflection.

Radial component gathers were used for velocity analysis in a grid of 900m X 900m. ACP stacks were generated with this velocity for Radial as well as Transverse component data. Figure-06 shows the ACP stacks of Radial and Transverse components along the inline passing through central portion of the area. Once again it is observed that Transverse section is not having appreciable energy, which indicates that the study area is not having any noticeable azimuthal anisotropy.

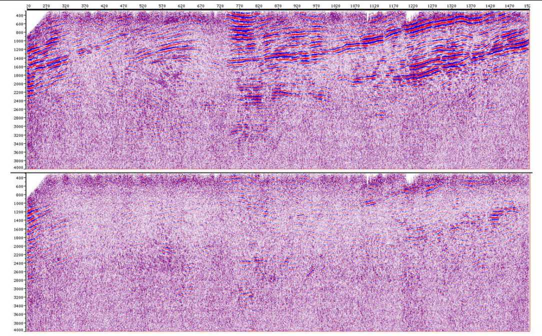

Figure-06 : ACP stack of Radial component (top) and Transverse component (bottom)

Statics Issues : Conventional Approach

For converted wave data, shot component of statics was taken directly from PP statics whereas receiver statics is derived from PP statics by scaling it with gamma function. Lack of detailed gamma information for top weathered zone, generally, leads to large statics error in the data. Generation of common receiver stack and interactive refinement of receiver statics is generally practiced to account receiver statics error. Residual statics estimation based on stack power optimization is the last step in this series of statics solution.

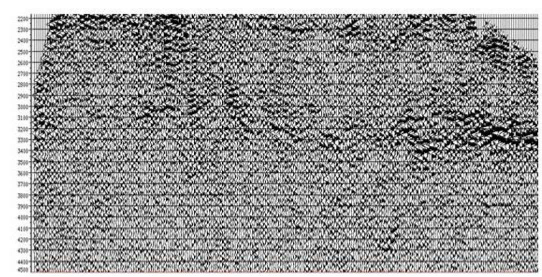

Figure-07 : Common receiver stack of a representative receiver line, generated after structural flattening

In absence of receiver statics error, common receiver stack will have the smooth appearance following the geological structure of the area, whereas presence of statics error will be manifested in the form of jittering. Figure-07 shows the common receiver stack of one receiver line, generated after structural flattening. Because of the steep dips involved and presence of numerous faults, quality of receiver stack is very poor. It is very difficult to track a prominent reflector on such stacks. As a result, any statics derived from such an inadequate quality receiver stack, whether manual (in case of 2D3C) or automated (in case of 3D3C), is bound to be unreliable.

Figure-08 shows the ACP stack before and after receiver statics refinement. It is found that shear wave statics refinement based on this established practice has failed totally, to give any improvement in the data.

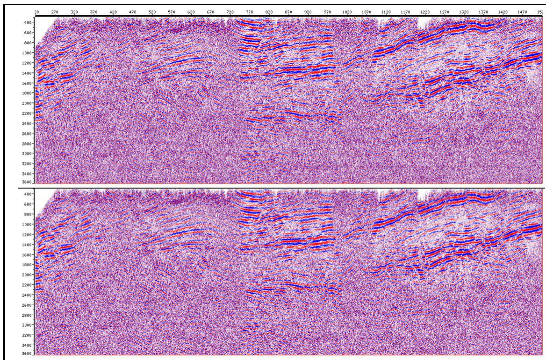

Figure-08 : ACP stack of an inline before and after receiver statics refinement (receiver stack derived statics)

Alternate approach for Shear statics refinement

Shot domain trim statics can be used as a substitute for interactive refinement of receiver statics in 2D3C, provided there is no major structural dip in the area (Yadava et al). Following this approach, shot domain trim statics was attempted on this data set. The result obtained by shot domain trim statics, were against the expectation and output quality became the worst. It was so because of two reasons. First, in case of 3D3C, any shot gather contains the receivers from different receiver lines, so the pilot generated for trim statics is not the correct for any one inline. Secondly, because of the steep dips in the area, shot domain trim statics destroys the structural features. Moreover in the area having azimuthal velocity variation, due care has to be taken to apply azimuth dependent move out correction, before trim statics.

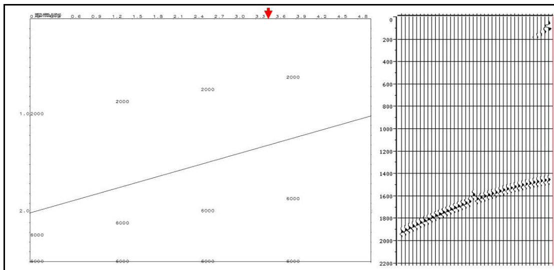

Figure-09 : Geological model with dipping reflector and synthetic gather generated using this model

To test a better approach of statics refinement, synthetic SP gather was generated for a simple 2D geological model having a single interface with a constant dip. A statics error was introduced in one of the traces of this shot gather as shown in figure-09. Figure-10 is the shot gather after move out correction and the pilot derived from it for trim statics. It can be seen that due to the dip involved in the data, pilot trace has a blurred event. Figure-11 is the same shot gather after move out correction followed by structural flattening; and the pilot generated from it has a sharp event. Trim statics estimated and applied on this gather generated figure-12a and de-flattening followed by removal of move out correction provided figure-12c, which is the ultimate shot gather without statics error.

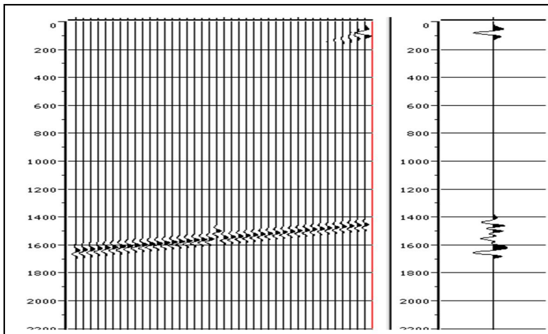

Figure-10 : Synthetic shot gather after move out correction and pilot derived for trim statics

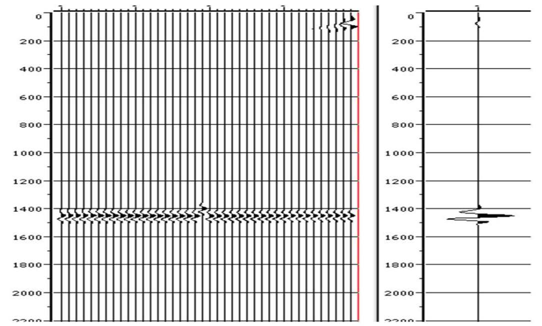

Figure-11 : Synthetic shot gather after move out correction followed by structural flattening and pilot derived for trim statics

To apply this approach on real data, input data was sorted in receiver line domain. It was already found that the study area is not having any noticeable azimuthal anisotropy and velocity variation with azimuth is negligible. Gathers were subjected to move out correction and structural flattening. Since move out correction was done with closely picked velocity and structural dip component was removed by flattening, trim statics estimated from this volume provided the error present in the receiver statics only.

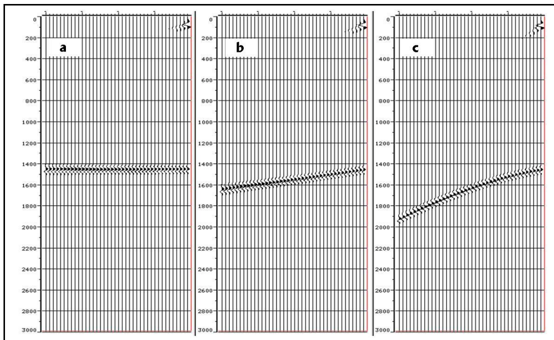

Figure-12 : Gather after trim statics (left) followed by de-flattening (centre) and removal of move out correction (right)

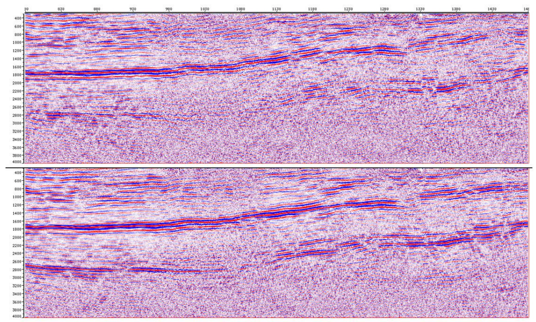

Figure-13 : ACP stack after statics refinement by conventional approach (top) and alternate approach (bottom) on the inline with smooth dip

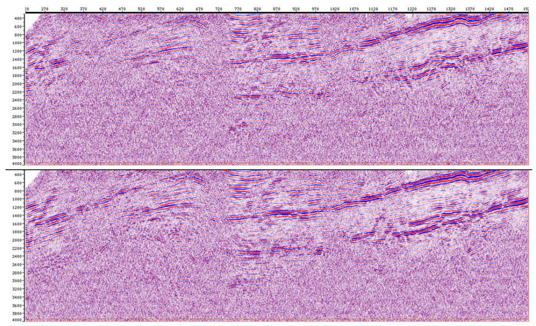

Figure-14 : ACP stack after statics refinement by conventional approach (top) and alternate approach (bottom) on the inline with steep dip and major faults

For comparison purpose, ACP stacks were generated using statics derived by receiver stack approach as well as the statics derived by the alternate approach of trim statics along receiver line after structural flattening. Figure-13 shows the comparison of stacks along an inline which has smooth dip, whereas figure-14 shows the comparison on an inline which has steep dips as well as a series of major faults. It is found that in both the situations, alternate approach of statics refinement has produced a better result in comparison to the conventional approach of statics refinement based on common receiver stack. Complete processing sequence incorporating the alternate approach of statics solution is given in table-1.

TABLE-1

Geometry definition & ACP binning
↓
Rotation to R and T components
↓
Spherical spreading correction
↓
PP shot statics
↓
PP receiver statics scaled by gamma
↓
Surface consistent deconvolution
↓
PS velocity analysis
↓
Sorting to Receiver line domain
↓
Moveout correction & Structural flattening
↓
Receiver line domain trim statics
↓
De-flattening & moveout correction removal
↓
Automatic surface consistent residual statics
↓
Converted wave Pre-stack time migration
↓
Detailed Gamma and PS velocity analysis
↓
Final Converted wave Pre-stack time migration
↓
Stacking of muted PSTM gathers
↓
Post stack processing

Pre-Stack Time Migration

First round pre-stack time migration was run with detailed PS velocity and apriori gamma value for target lines. Target line PSTM output was used for close grid PS velocity analysis and detailed gamma estimation. After finalization of velocity and gamma functions, full volume pre-stack time migration was run. Two sets of output were generated, one in which statics was refined using receiver stack approach, and second one in which statics was refined using alternate approach of trim statics in receiver line domain after structural flattening. Figure-15 shows the PSTM stack of one inline with conventional approach, whereas figure-16 is the PSTM stack in which statics was refined by alternate approach.

Conclusion

Converted wave 3D data of Sayan-Tadkeshwar area of Cambay basin was processed adopting two different approaches for shear wave receiver statics refinement. PSTM stacks were generated using same PS velocity and gamma function. Processing sequence consisting of receiver line domain trim statics after structural flattening has resulted in improved imaging and better continuity of events.

References

Harrison M. P., 1992, Ph. D. dissertation on Processing of P-SV Surface Seismic Data: Anisotropy Analysis, Dip Moveout, and Migration

Zabik G., Podolak M. W., 2006, Land 3C-2D Seismic Data Processing- Analysis of Crucial Issues, presented at SPG-2006

Stewart, R. R., 2006, Advances in Converted Wave Seismic Exploration, presented at SPG-2006.

Yadava, C B, Muralimohan, T R, Niyogi, K., 2008, Application of shot domain trim statics as a substitute of interactive refinement of receiver statics in converted wave processing, presented at SPG-2008.

Acknowledgements

The authors place on record their sincere thanks to Director (Exploration), ONGC, for his kind permission to publish this work. The authors are deeply thankful to Shri S. K. Das, ED – HOI, GEOPIC, ONGC, for providing opportunity to take up the work and constant encouragement. Thanks are due to Shri T R Muralimohan, DGM(GP), GEOPIC, ONGC for valuable technical discussions from time to time.

NB: The views, expressed here, are solely of the authors and do not necessarily reflect the views of ONGC.

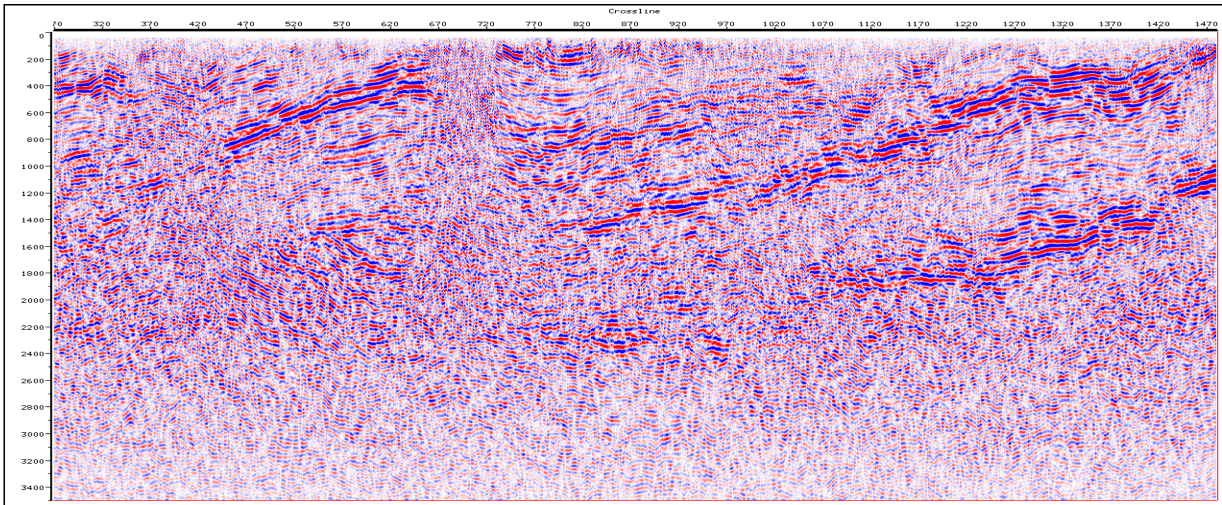

Figure-15 : PSTM stack of Radial component along an inline using input data in which shear statics refined by conventional approach

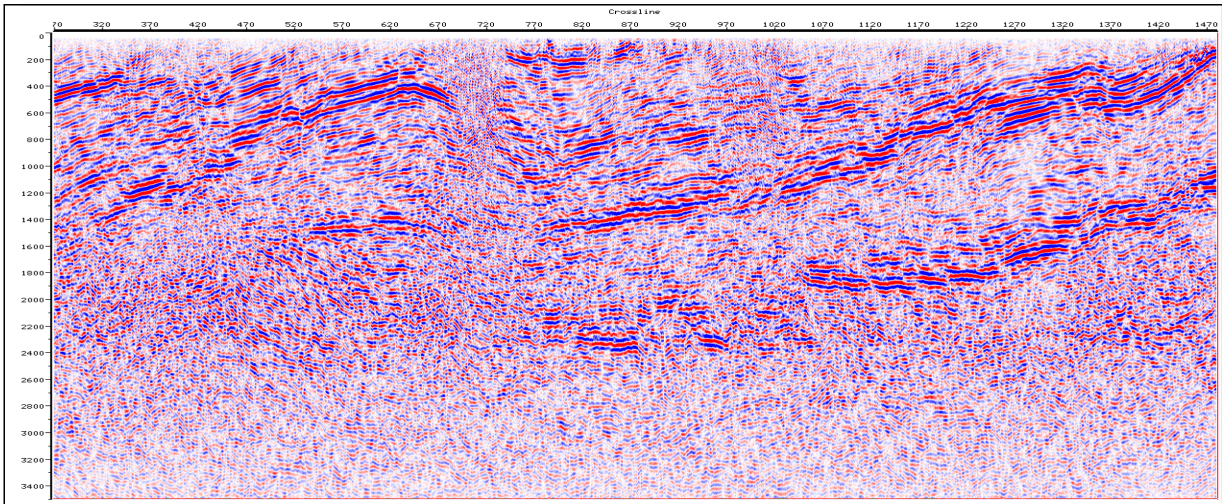

Figure-16 : PSTM stack of Radial component along an inline using input data in which shear statics refined by alternate approach