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C-Wave processing of 3D seismic data of Cambay Basin-A case study

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Summary

Multi component survey have become one of the leading areas where state of the art technology is being applied to areas where the exploitation potential has not been fulfilled due to difficulties in obtaining an interpretable seismic images. Converted shear wave data allows images to be obtained that are unobstructed by the gas and / or fluids. This reduces the risk for interpretation and subsequent appraisal and development drilling in complex areas which are clearly petroleum rich. In addition, rock properties can be uniquely determined from the compression and shear data, allowing for improved reservoir characterization and lithologic prediction.

Data acquisition and processing of C-wave data involves both similarities and differences when compared to conventional technique. Processing for the compressional data is the same as for a conventional seismic survey, however asymmetric ray paths for the converted waves and the resultant effect on fold-offset-azimuth distribution, binning and velocity determination requires radically different processing methodologies.

3D seismic data was acquired in study area with single digital sensors (SVSM). The acquisition geometry was designed to fulfill the exploration objective by vertical component only and it was not planned for 3D-3C survey. However an attempt was made to process X & Y components also, recorded during the course of acquisition by digital sensors along with Z (vertical) component. The objective and idea to process C-wave was to have additional information than P-wave viz. to get information about mode conversion of down going P wave and to study the azimuthal anisotropic behavior in the area. The proper delineation of fault pattern may be of exploration interest in the area. Initial Vp/Vs ratio was estimated from the data due to absence of any well information with dipole sonic. After orientation QC of the field data, the acquisition coordinate system i.e X & Y was changed to processing coordinate system i.e R & T. ACP stack of R and MC stack of T component was generated after denoising of data, initial velocity estimation of shear waves and computation of shear statics. Processing of all the components were attempted up to PSTM for fully integrated interpretation of the data.

Introduction

3D data was acquired by ONGC in the study area in Cambay Basin with single digital sensors (SVSM) and I/O system during the field season 2007-08 as shown in fig1 The SVSM sensors are capable of recording three components with full seismic signal bandwidth The objective of the survey was to identify structural and stratigraphic prospects in Eocene and Paleocene section in the zone of interest of 800-3000 ms(TWT).

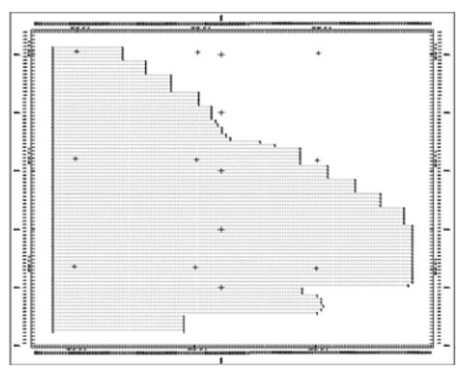

Fig.1 Base Map of the area

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Cambay Basin is an intra-cratonic rift basin with narrow elongated graben running aprox NNE-SSE direction, takes a swing in southern part and aligns approx. in NNE-SSW direction. The Basin came into existence during late Jurassic. During the late Cretaceous major volcanic activity took place, and the Deccan trap formed is considered as the technical basement of the Basin. The survey area is situated in Cambay-Tarapur tectonic block of Cambay Basin and is located in the North-Eastern rising flank of Tarapur depression. Cambay shale formation overlying the olpad formation is gradually thinning towards eastern margin. Steep dipping, longitudinal faults and cross faults give rise to separate fault closure for structural entrapment. Eocene pays of EPIV equivalent to Kalol IX and Kalol X reservoir are main exploratory targets in addition to reservoirs within Cambay shale and Olpad formation.

Data was acquired with the swath geometry shown in fig.2

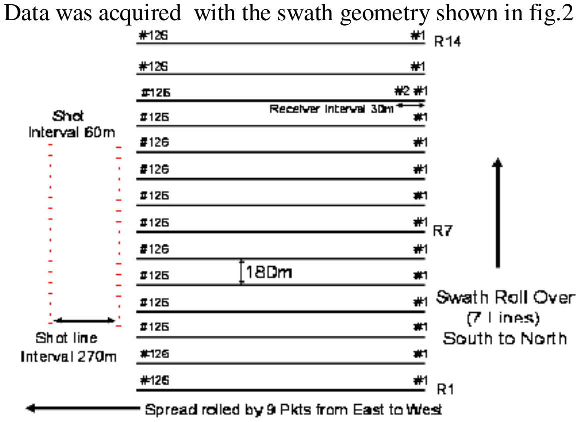


Fig.2 Swath Geometry

The acquisition parameters are given below.

Foldage	49(7x7)
Group interval	30m
X line Source interval	60m
Bin Size	15x30
No. of Receiver line	14
No. of channels	1764(126x14)
Far trace offset	3807m in line/4226m x line
Type of shooting	End On
Sampling interval	2 ms
Instrument	I/O System Four
Sensors	SVSM 3C single digital sensors
Record Length	8.0 sec
Shot line interval	270m
Receiver line interval	180m

Theory

Processing methodology is quite different in the case of converted waves than that of conventional P waves. A shear wave processing sequence is basically similar to a conventional P wave processing sequence, provided that birefringence is ignored. Because of the asymmetric characteristic of the P-S ray paths shown in fig3, its

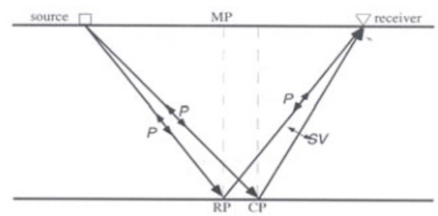


Fig3. PS Ray Path

processing is difficult and different than the P-wave processing. For an isotropic medium with a flat reflector, the P-P ray path is symmetric whereas the P-S raypath is asymmetric due to the fact that the S wave velocity is lower than the P wave. Moreover, their polarization directions are also different. In the processing of PS data, the main concern is to define an approximate value of the velocity ratio (Vp/Vs) to start the processing. Vp/Vs ratio can be obtained by associating on PP record (Vertical) or PS record (Horizontal) reflections from same geological interface.

When no azimuthal anisotropy exists, the processing is said to be in VTI environment, the processing is concerned only for radial component, the transverse component can be discarded. In the presence of the azimuthal anisotropy the line orientation does not coincide with a natural orientation of the shallow geo materials and PS1 and PS2 modes have to be separated before further processing.

Azimuthal anisotropy is observed in a variety of rocks, particularly in carbonates affected by fractures and in rocks subjected to tectonic stresses. In such cases the shear mode original polarization, generated from a shear source or by a PS conversion, is split into two orthogonal components conventionally called natural orientation or natural coordinates (fig.4). Since acquisition coordinates generally do not coincide with the natural coordinates, the radial and transverse receivers record projections of S1 and S2 (fig.5).

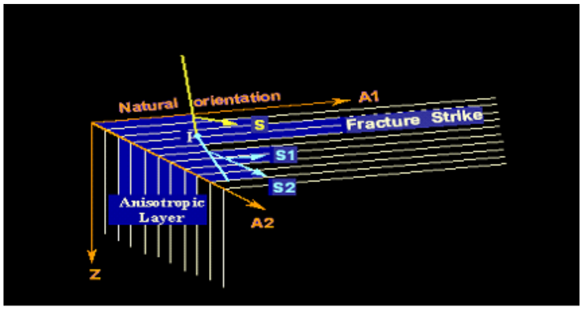


Fig.4 Shear wave splitting

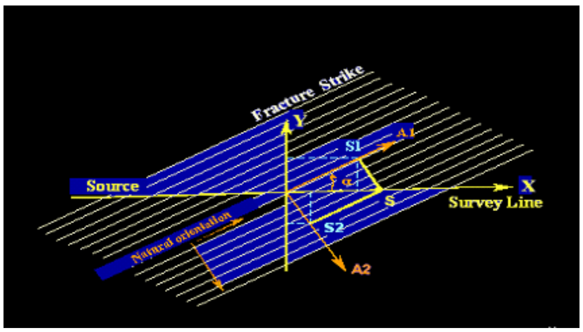


Fig.5 Survey Oblique to axes of anisotropy

Some of the characteristics of Shear waves are:

- They carry different information to P waves
- They respond to different physical properties of the rock viz. solid, liquid and gas
- They travel slowly compared to P waves
- They are polarized

Processing

The present study is related to processing of radial and transverse components of Converted Wave data along with vertical data acquired with digital sensors (SVSM). As the 3D data is acquired with end-on geometry as shown in fig.2, it may not have full azimuths in the data. For C-wave processing, azimuths and its distribution is a important parameter for azimuthal stack, required for the study of rotational analysis in presence of azimuthal anisotropy. The inline and x line azimuthal distribution observed in the area are shown in fig.6 and fig.7

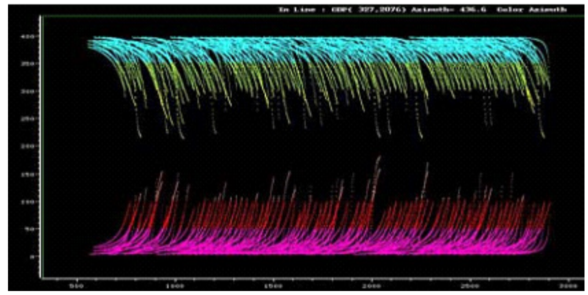


Fig.6 Azimuth along In line direction

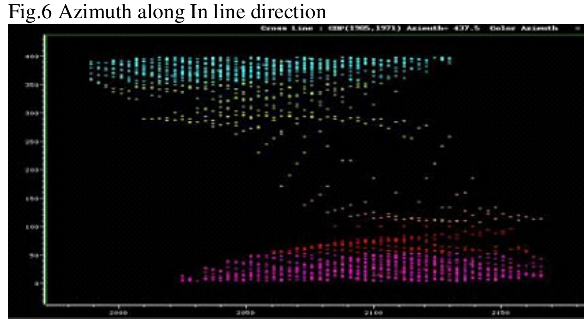
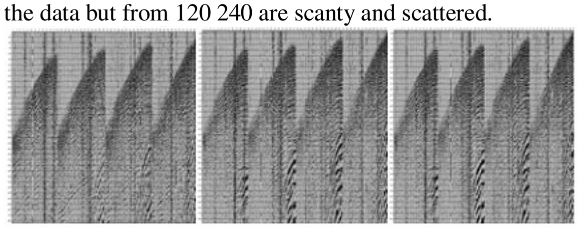


Fig.7 Azimuth along X line direction

This shows that although 0 to 360 azimuth are present in the data but from 120 240 are scanty and scattered.



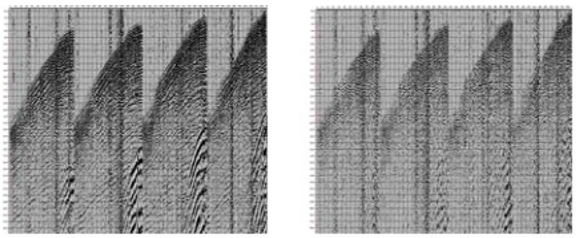
Z X Y

Fig.8 Raw data of three components

Processing of Z (vertical) component: The first step of multicomponent time processing was to process conventional P wave data up to the optimum stack. Therefore the 3D data was processed after reconditioning of the raw data and finalization of processing parameter for vertical component. The P wave image itself is very helpful to guide PS processing. The raw data of all the three components are shown in fig8.

Processing of X & Y component: Processing of X & Y component of 3C data involves various steps of processing and QC, that are different from Converted wave processing.

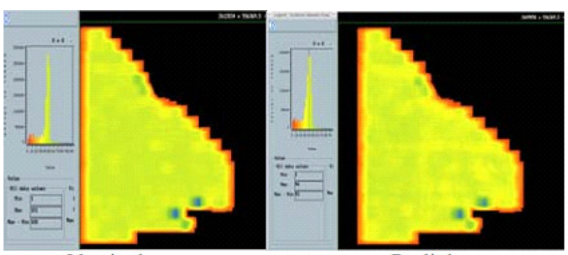
The first and important step is to do orientation QC to verify that the orientation of X, Y,& Z data provided by the field crew is correct. After orientation QC, the acquisition coordinate i.e X,Y are rotated to processing coordinates i.e R(Radial) and T(Transverse).



R T

Fig.9 Raw data after rotation to R and T

The raw data after rotation to R & T is shown in fig9. The raw data of R shows that maximum energy has been transferred from X to R and T indicates minimum energy. This R & T raw data is subjected to denoising and reconditioning for use in subsequent processing steps. Initial PS velocity estimation is done on this denoised data for stacking of data in common receiver mode and ACP mode. The foldage map of Vertical and Radial components Shown in fig10 shows that both the components are having uniform foldage except at some location, which is high due to recovery plan.



Vertical Radial

Fig.10 Fold Map of the area

In the case of C-wave propagation, the down going wave is compressional wave and the upcoming reflected wave is Sv part of shear wave. Therefore, for the down going P wave, shot statics is same as for P wave but for upcoming Cwave, receiver statics is to be computed, which is called shear statics. This shear statics computation is done in common receiver mode after correlating the same events on PP and PS data. The data before and after computation of shear statics is shown in fig11 and fig.12.

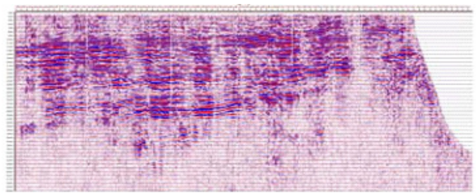


Fig.11 Receiver stack before shear statics

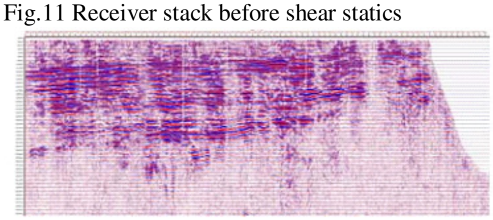
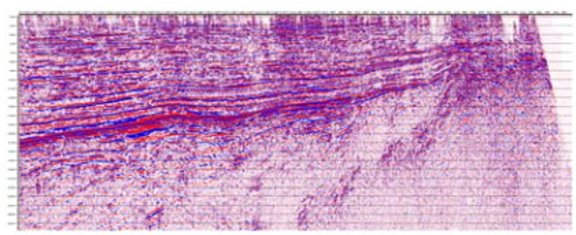
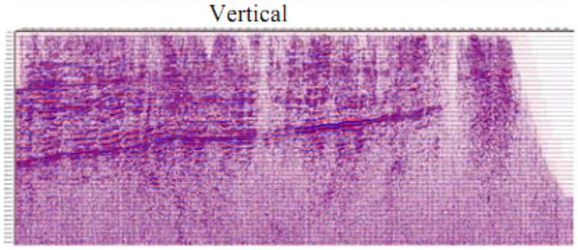


Fig.12 Receiver stack after shear statics

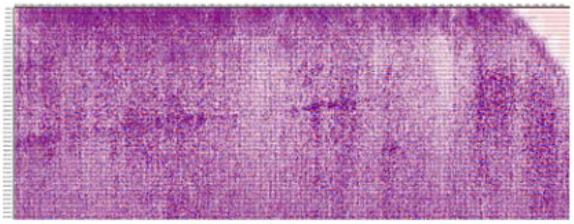
After computation and application of shear statics on the data, the PS velocity is again refined for better quality of ACP stack. At this point, the effect of azimuthal anisotropy in the area is studied and if present, processing is carried out for S1(fast) and S2(slow) component after rotational analysis else, emphasis is given to Radial component.



Vertical



Radial

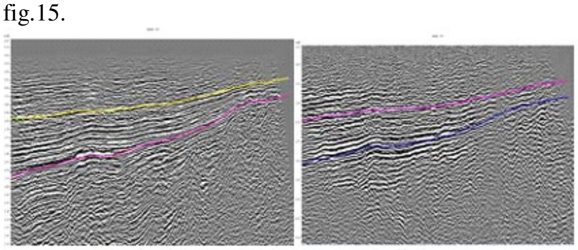


Transverse

Fig.13 Stack section after residual statics of three comp.

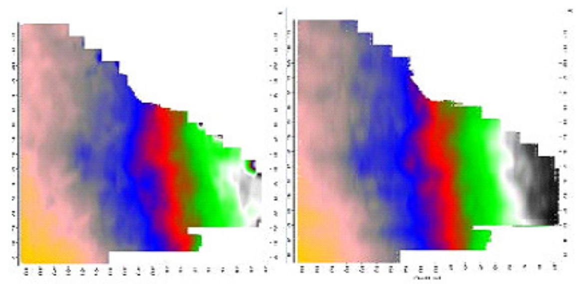
In our area of study, the effect of azimuthal anisotropy is not seen as shown in fig.13, therefore, rotational analysis is not attempted, while processing Radial component and Decon parameter is tested and applied on Radial and Transverse component to generate decon stack sections. Residual statics is computed and applied on decon data after further refinement of PS velocity field. The residual stack sections are shown in fig13.

After processing the C-wave data in ACP domain with single Gamma value, estimated earlier. Now horizons are picked on PP and PS data, corresponding to same geological boundaries, which may be two or more depending on our data quality. In our study two horizons H1 and H2 are picked at two different prominent markers. These horizons H1 and H2 are picked on selected in lines and cross lines and then interpolated and propagated to entire 3D volume to generate combined smooth horizon map for PP and PS data respectively as shown in fig14 and fig.15.



Vertical Radial

Fig.14 Horizons on vertical and Radial section



Vertical Radial

Fig.15 Time structure map of H2 of PP and PS data.

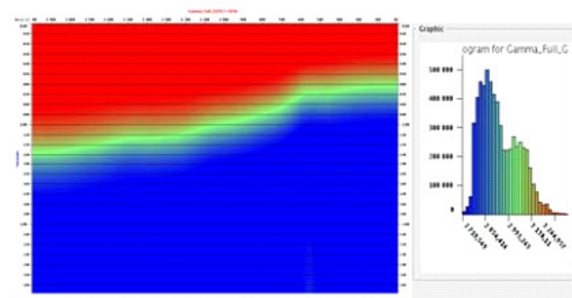


Fig.16 Gamma section along the line IL1

Time and space variant gamma velocity is computed for full 3D volume with the help of these horizon maps and then smoothed for use in CCP stack. This gamma volume is refined after few iteration as obtained from two horizons H1 and H2. Gamma section, which is a important attribute for interpretation of lithology is shown in fig16.

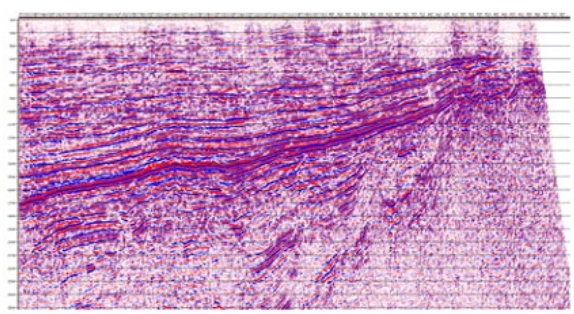


Fig.17 PSTM section along Inline IL1 of Vertical comp

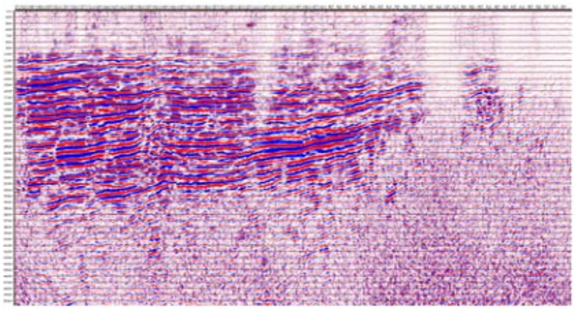


Fig.18 PSTM section along Inline IL1 of Radial comp.

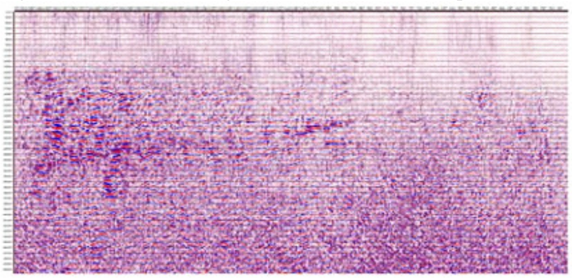


Fig.19 PSTM section along Inline IL1 of Trans. comp

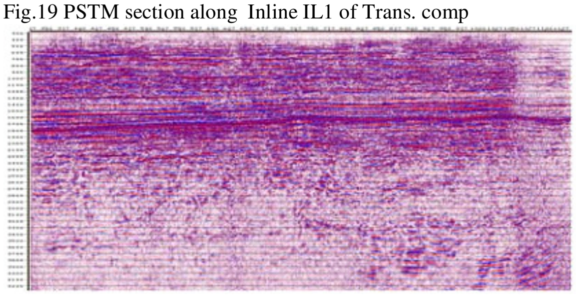


Fig.20 PSTM section of x line XL1 of Vertical comp

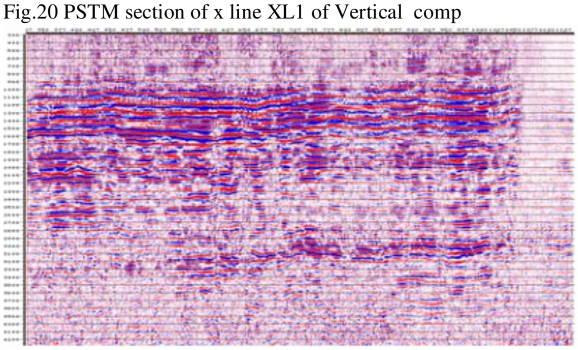


Fig.21 PSTM section along xline XL1 of Radial comp.

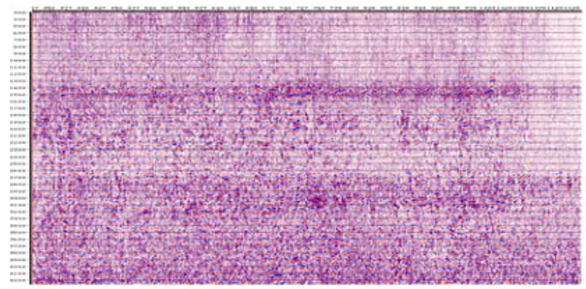


Fig.22 PSTM section along xline XL1 of Trans comp.

The final smoothed gamma velocity field and rms PS and PP velocity fields are used in PSTM of Radial and Transverse component in CCP domain. PSTM stack results of PP, Radial and Transverse components are shown in fig.17,fig.18&fig.19 The PSTM stack of PP, Radial and transverse along XL1 are shown in fig20, fig21 & fig.22

Discussion

An attempt was made to process C-Wave 3D seismic data acquired in the study area and with geometry discussed above. The study could have established the methodology of C-wave data processing. The events on processed output of Radial and Transverse Component indicate that mode conversion is taking place of down going P wave after reflection. Insignificant events on transverse component indicate the absence of azimuthal anisotropy in the area, however this could have been confirmed, if the data would have possessed better azimuthal distribution in the range of 120^o to $240\ ^o$. Well information with dipole sonic in the study area could have been helpful to calibrate Vp/Vs in the area. The Gamma section, which was created based on Horizons H1 and H2, indicate variation in Vp/Vs. More horizons in deeper part will further refine Gamma value, which may be helpful in the study of reservoir characterization.

Conclusions

The PSTM section of Vertical component shows good imaging within the zone of interest. The fault pattern is also well delineated, which is expected to fulfill the exploration objective in the area. The processed output of C-wave data i.e Radial component shows continuity of events and better imaging from shallower to Kalol level. This may add some value in exploration objective in the area.. The processed output of Transverse component does not show good events, which could be indicative of the absence of azimuthal anisotropy in the area.

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