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Land Multicomponent Seismic Survey: PS Binning Approach – A Case study

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Summary

Compressional Wave (P-Wave) technology dominated the oil industry for the last 80 years, and majority of hydrocarbon finds have been made using this technology. It is also well established that the P wave is not panacea for every seismic imaging problem. In the recent years, shear wave technology has been proved to be quite useful as a complementary tool capable of providing a better and more realistic reservoir characterization of the subsurface.

Acquisition of compressional waves and P converted shear wave can be achieved by converted-wave recording using the same source and receiver array simultaneously and no need to design the P-P and P-S surveys independently. For any multi component 3D survey, a survey design that provides uniform PP-fold data may not provide uniform PS-fold for the converted wave. Therefore, while designing, due care needs to be taken to analyze the PS fold is critical, with respect to the adequacy of the fold and to avoid of any acquisition foot print without sacrificing the basic objective of the survey. For any Multicomponent seismic surveys Asymptotic or Depth specific binning methods are usually applied during survey designing stage to analysis the PS-fold in Common Conversion Point (CCP) domain.

The present case study deals with the pre in-depth analysis of PS-fold with the available binning options namely depth specific / asymptotic, for optimizing the geometry for Land multicomponent survey by analysis of both methods and establishing the method which gives more realistic information and can be relied upon with more confidence.

Introduction

Number of reservoirs discovered with the help of the conventional P wave technology basically used in 2D, 3D seismic surveys. Three dimensional surveys provide better signal to noise ratio and an accurate subsurface imaging. It increases confidence in reservoir delineation and estimation of hydrocarbons, hence reducing the drilling risk. Primary goal of 3D Surveys is to achieve the desired frequency and better S/N ratio at the target depth to meet the objectives. Although 3D seismic established its superiority over 2D seismic in terms of improved subsurface imaging and helped in mitigating the drilling risk, it is well established that all seismic imaging problems cannot be fully solved using 3D seismic. Multi component 3D seismic has started gaining the ground for better subsurface imaging by addressing numerous applications such as lithology and fluid discrimination, better fault definition, imaging through gas zones, anisotropy analysis and reservoir monitoring.

P-S data is recorded in addition to the PP-data as part of the 3D3C surveys. The P-Wave propagates downwards and gets reflected as the PP wave and also as the PS wave after getting converted to the S wave from the acoustic boundary (*Fig-1*). Simultaneous acquisition of shear and compressional waves by using the same source and receiver pair is an added advantage in 3D3C data acquisition. Ideal Geometry should produce a Smooth Mid-Point distribution for P-P Data and also smooth CCP distribution for the converted wave Data (P-S data).

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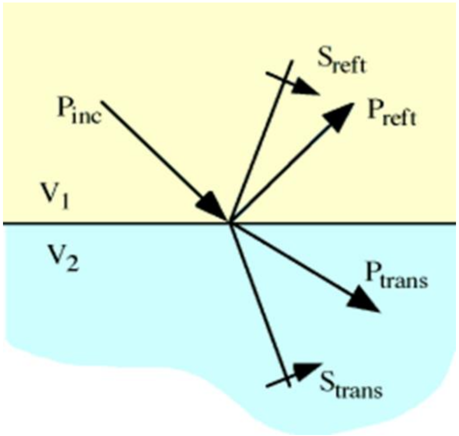

Fig 1: Propagation of compressional and shear waves

Designing the multi component 3D survey is complex in nature, as the ray paths of PS waves are different from the PP wave. For any Multicomponent seismic surveys, the PS-fold study based on two binning approaches (Asymptotic and Depth Specific) is an important part of the survey design. The Common Conversion Point (CCP) is not the same as Common Mid Points (CMP) as in the conventional 3D survey. The CCP, where the incident P-wave is converted to be reflected as S-wave, does not lie at the midpoint position between source and receiver as CMP. Acquisition design for converted wave seismic surveys in the early 90's was based on the assumption of Asymptotic Conversion Points (ACP) at the reflector. The ACP is independent of the reflector depth and represents the asymptote to the actual conversion point trajectory as the depth to offset ratio approaches infinity (r*ef-1)*.

The distance of conversion point from source is Xc given by the equation

$$Xc = r/(1+Vs/Vp)$$ ……(*Ref-4* by *Cordsen*)

Where

r is the distance between source and receiver,
Vs is the average S-wave velocity, and
Vp is the average P-wave velocity.

The conversion point offset from the source position is a function of Vp/Vs ratio which varies with depth and the petro- physical properties of the rock. In general the Vp/Vs ratio is higher at a shallower depth and lower at a deeper depth. Due to this the conversion point (CCP) follows an asymptotic path and shifts towards the receiver (*Fig-2*) when it comes to shallower levels.

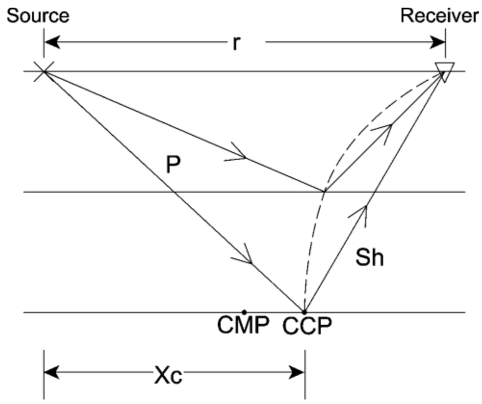

Fig 2: Converted wave ray path P-Wave and Shear wave

PS-fold study

CMP and CCP Scattering

The CMP scatter (*Fig3a*) clearly indicates that midpoints fall at the center of the bin, whereas in the conversion points are scattered within the bin as shown in CCP bin scatter (*Fig*-3b).

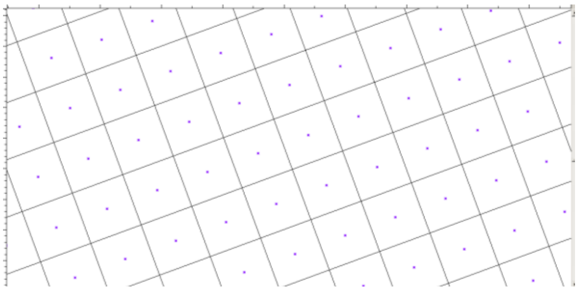

Fig 3a: CMP bin scatter

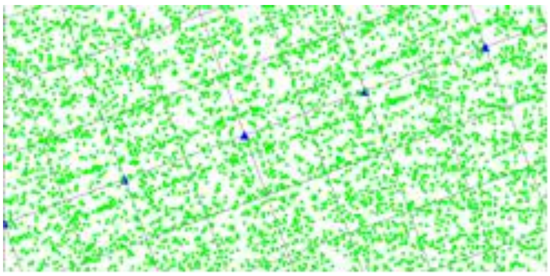

Fig 3b: CCP bin scatter

This results in a uniform PP-fold coverage for a simple model whereas converted wave binning results in non-uniform CCP fold coverage. The CCP scatter area is elongated parallel to the receiver line direction, causing the subsurface coverage toward the receiver lines with high and low fold stripes, and lower fold stripes perpendicular to the receiver lines. It is observed that the CCP fold area is larger than the CMP scatter area (Fig 4 & Fig 5) may be due to the receiver surface area is bigger than the source area.

Fig 4: CCP bin scatter area

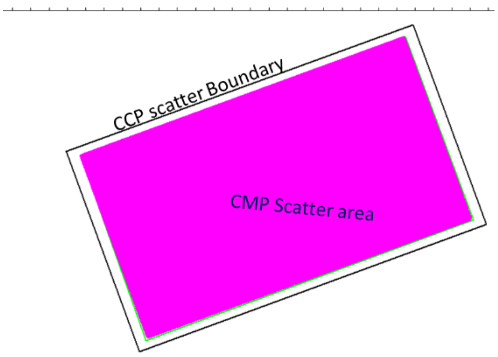

Fig 5: CMP and CCP bin scatter diagram

Depth specific binning Vs Asymptotic binning

Depth specific binning accounts for the depth - variance of the conversion point trajectory. The source and receiver midpoint satisfies the fourth order polynomial equation (ref-2). The solution of the exact single layer formula is used to reposition to its correct conversion point to each sample point to depth. The depth specific binning algorithms mapped the true depth variant position of the conversion point. Whereas the asymptotic binning is not depth variant and assumes that the reflector is very deep, thus each shot receiver pair is binned into a proper subsurface location taking a global Vp/Vs value

Symmetric split spread configuration with 162 fold, single swath roll over, having good offset distribution and with wide azimuth was shortlisted for acquisition in the study area. The acquisition parameters shown in *Table-1* were considered for the PS fold study with both the binning methodologies.

Table: 1: Survey design Parameters

Parameters	Study area Geom
Zone of Interest	2500-3000m
Shooting Type	SSS
Bin size	17.5m x 17.5m
GI / SI	35m
RLI / SLI	280m / 245m
Fold	(18 X 9)=162
Receiver lines	18
No. of channels	252 /line
Total active #s	4536
Shots / salvo	8
Swath roll over	Single
Minimum offset	25m
Maximum offset	5055m

The PS fold study was carried out with *asymptotic approach* in the study area with different values of Vp/Vs ratios. The fold distribution with Vp/Vs as 2.0 varies from 72 to 288, specifically 72,144,288 fold are observed in the bins (*Fig: 6*).

Whereas with Vp/Vs. 3.5 (*Fig-7*), the variation is 0 to 331 with Zero and very low fold strips were predominant in the bin grid. It is observed that large variations of PS-fold with neighboring bins within the bin grid.

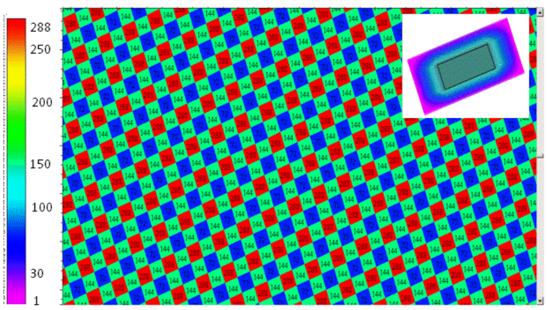

Fig 6: Ps fold map with Vp/Vs 2.0 Asymptotic

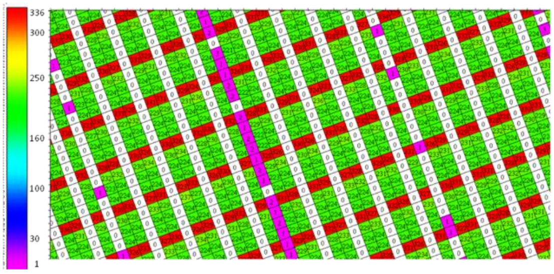

Fig 7: Ps fold map with Vp/Vs 3.5 Asymptotic

Similar studies were carried out with *depth specific* approach and the depth of the reflector at the zone of interest was specified as 3000 m. Generated PS fold maps are shown in *Fig 8 and Fig-9* for the Vp/Vs 2.0 and 3.5 respectively. The PS fold distribution shows minimum variation within the bins in the bin grid as compared to asymptotic approach. It is also observed that the fold distribution is smoother and does not have any zero fold strips and high fold strips.

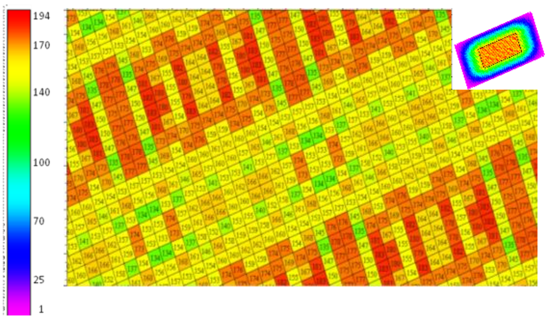

Fig -8 : Ps fold map with Vp/Vs 2.0 depth specific 3000m

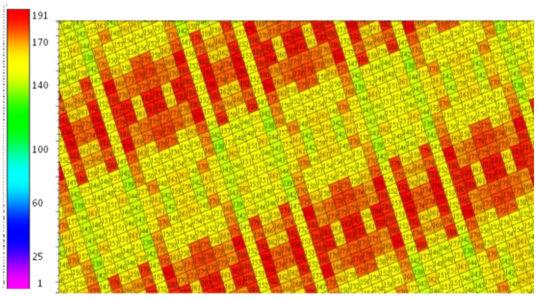

Fig-9: Ps fold map with Vp/Vs 3.5 depth specific 3000m

Application

The multi-component Survey was carried out in the study area for identifying prospective reservoir and the fluid distribution in tertiary sediments. The shortlisted geometry which was specified in *Table-1* was selected for 3D3C data acquisition in the study area and its attributes like offset, azimuth, and fold were shown in *Fig-10*.

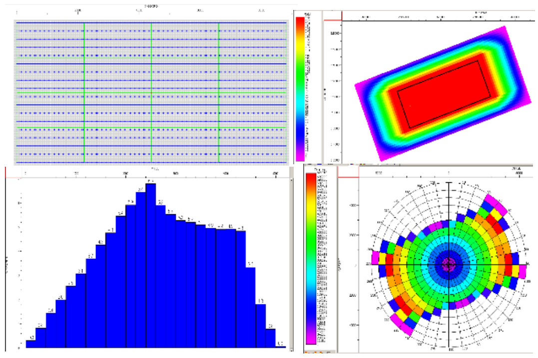

Fig 10: Layout and Design attributes of the study area.

After the completion of multicomponent data acquisition in the study area PP and PS fold analysis was carried out with the help of field data (SPS) by generating various fold maps. The the nominal PP fold as per the geometry is 162 and it is observed that uniform PP fold distribution was maintained in the field data *(Fig-11)*. However, very few high and low fold patches are visible in the PP fold map are as a result of recoveries carried out in inaccessible area.

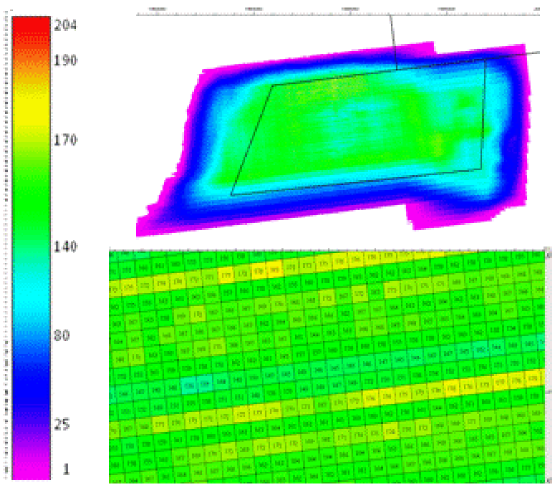

Fig11: PP fold map of the study Area

PS fold analyses with *depth specific* and *asymptotic* approaches were carried out on this data for Vp/Vs= 2.0 and 3.5 (*Fig: 12-15*) as specified in presurvey studies. For comparative study the parameters in both approaches were kept same as it is in design stage. The PS fold maps with Vp/Vs 2.0 and 3.5 with Asymptotic approach (Fig 13 and 14) showing high fold strips and non-uniformity in fold was observed.

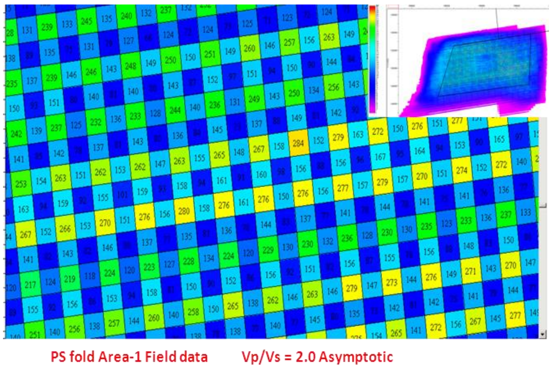

Fig 12: Ps fold map with Vp/Vs 2.0 Asymptotic

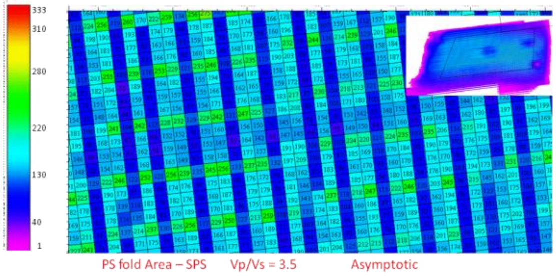

Fig 13: PS fold map with Vp/Vs 3.5 Asymptotic

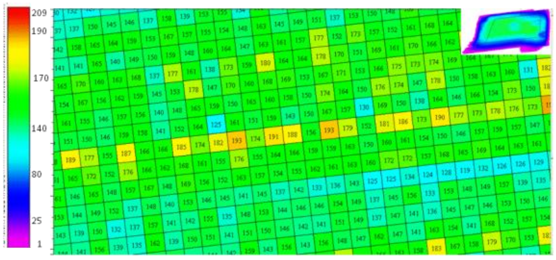

Fig 14: Ps fold map with Vp/Vs 2.0 depth specific(Depth 3000m)

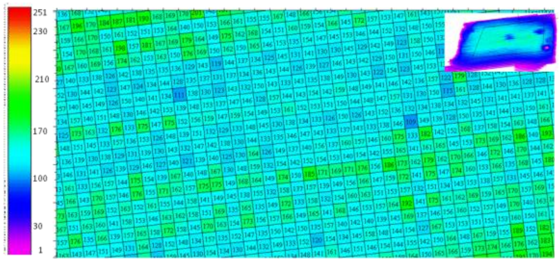

Fig 15: Ps fold map with Vp/Vs 3.5 depth specific (Depth 3000m)

Observations

In depth specific approach the PS fold maps were generated with the depth of the reflector at the zone of interest specified as 3000 m, same as in pre-survey design studies with Vp/Vs 2.0 and 3.5 (Fig 15 and 16) are showing a smooth distribution without Zero and high fold strips, and are in tune with the PS fold maps that were generated at the design stage. The depth specific binning methodology gave more realistic information and can be relied upon with more confidence for PS fold analysis in optimizing the geometry at time of survey design study. It is evident that the fold distribution at the planning stage is in tune with the actual data for 3D-3C seismic survey.

Conclusions

Multi-component surveys, one would like to find a field geometry that produces a uniform midpoint distribution in the compressional data and also a smooth CCP bin distribution in the converted-wave data.

To study converted wave (PS -wave) fold distribution at the survey design stage and optimize the best suited geometry for multicomponent survey is an important aspect. Depth-specific binning approach gave a more realistic picture.

The asymptotic binning is not depth variant and assumes that the reflector is very deep, thus each shot receiver pair is binned into a proper subsurface location by taking a global Vp/Vs value. If a single horizon is not in mind, reflector is very deep then Asymptotic approach may be considered.

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