What Happened to Depth after Pre-SDM ?

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ABSTRACT : True amplitude preserved seismic image, located in its correct spatial position in the sub-surface is essential for success of any E&P activity. Recent advances in Pre-SDM technology with their capability to include heterogeneity and anisotropy, essential for producing amplitude preserved image in its true spatial position, hold great promise. Images produced by isotropic PSDM generally do not match with well tops and mis-match can be of the order of 5%-10% in presence of anisotropy. To match the isotropic PSDM image with well markers the velocity field used for focusing needs to be scaled in the light of well velocity in the area to obtain a new scaled velocity field. This however is no trivial exercise. The most appropriate solution perhaps is to do Anisotropic PSDM (APSDM). In the present paper we show some examples of 2D/3D APSDM from western offshore to demonstrate that inclusion of anisotropy and vertical heterogeneity reduces the depth uncertainty drastically. We also discuss the issue of offset-depth ratio, which is crucial to achieve the vertical positioning accuracy of the order of seismic resolution; which may be one of the major PSDM objectives for deciding step-out wells in producing fields.

INTRODUCTION

Presenting the seismic section in depth has always been a challenge in seismic imaging. Most important issue in accomplishing this goal is the estimation of correct sub-surface velocity distribution. Early attempts involving NMO velocity analysis and Dix conversion (Dix, 1955) were applicable to the isotropic and homogeneous Earth. Soon it was observed that presence of even a mild lateral velocity variation could cause wild swings in Dix converted interval velocities (Lynn and Clarbout, 1982). Bickel (1980) and Archer et al. (1982) also showed that certain long wavelength variation in velocity field could not be determined accurately and caused velocity depth ambiguity. This velocity depth ambiguity is a feature of sub-surface geometry and is not caused by any particular algorithm (Hans J. Tieman, 1994).

Incorporation of heterogeneity (vertical and lateral) and anisotropy (Thomson L., 1986) leads to more realistic description of the earth. To derive the accurate velocity depth model in such situations, numerous methods (Bishop et al. 1985, Tarantola, 1986, Williamson, 1986, Bording et al. 1987, scales 1987, Kennett et al. 1988, and Stork and clayton, 1991) have been proposed. Most of these methods fall in the category of reflection tomography and involve, deriving an initial velocity-depth model and updating the same iteratively by observing residuals measured on CRP gathers or traveltime curves. The accuracy of thus obtained final velocity depth model depends largely on the quality of the input data. The other major factor to reckon is actual determination & incorporation of anisotropy and vertical heterogeneity for which depth-offset ratio also becomes a key factor.

METHODOLOGY

We have carried out present work first on a 2D profile in an offshore area. Coherency inversion was used to obtain an initial interval velocity model. Using surface and well seismic data a credible velocity model was prepared incorporating vertical velocity gradients and estimated anisotropy parameters. Tomographic method was used to iteratively update the interval velocity. Anisotropic PSDM was then carried out and depth gather and stacks were obtained. A comparison has been made between isotropic PSDM and APSDM outputs.

This study was further extended to a 3D data set covering 1200 Sq Km in the same area. The mismatch with well-markers for map-migrated (using updated interval velocity model) horizons has been studied to draw inferences.

Thereafter we have also tried to investigate qualitatively, the effect of factors like quality of data and offset-to-depth ratio on the depth accuracy of stack. Some perturbation was introduced in the final velocity to study its effect on flatness of gathers and residual semblance plots.

DISCUSSION

Isotropic PSDM images generally do not match with well markers and the mismatch may be more than 5% (Fig 1) To match with well markers, these images need to be scaled, which is not an easy exercise. This mis-tie is a direct evidence of the presence of anisotropy in the overburden which also manifests as the hockey stick effect at far offset on PSDM gathers (Fig 2) Vertical velocity gradient however needs to be accounted before estimation of anisotropic parameters (δ &

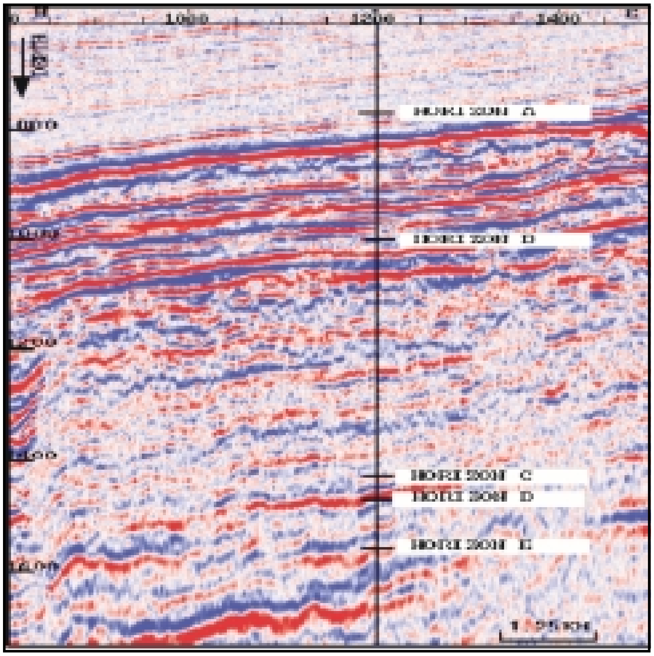

Figure 1: Isotropic PSDM image using best focusing velocity. Note the mismatch of seismic events with well tops.

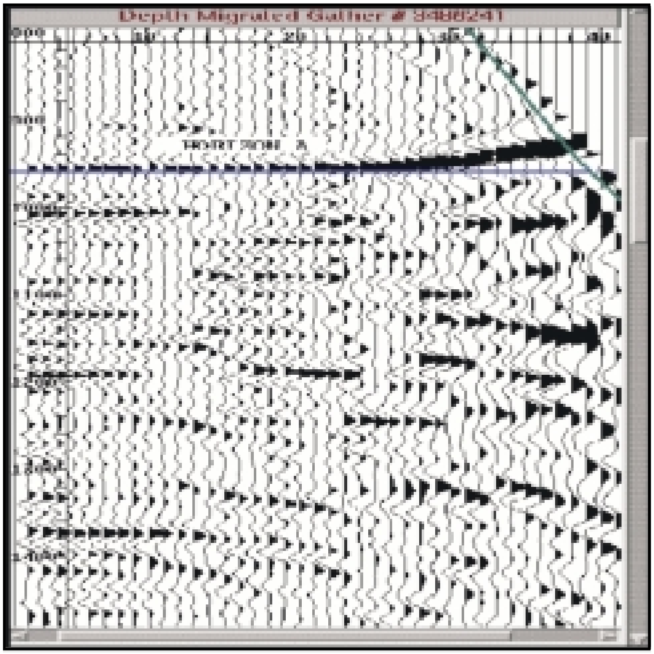

Figure 2 :Isotropic PSDM Gather showing non hyperbolic effects attributable to both heterogeneity and anisotropy.

ε) as it manifests as anisotropy (Alkhalifah, 1986). Good quality long offset (offset-depth ratio more than 2) seismic data is required for reliable estimation of Thomsen parameters in addition to well data i.e. sonic, check shot and VSP. In this work the offset-depth ratio used is close to 3 for the reflector corresponding to the base of anisotropic formation. The estimate of these parameters has been further refined by analysis of APSDM gathers; shown in Fig 3. In this area of study, the overburden responsible for anisotropy exists as a thick (700-1000m) shale layer. The APSDM stack section shown in Fig 4 shows a match with well markers within seismic resolution.

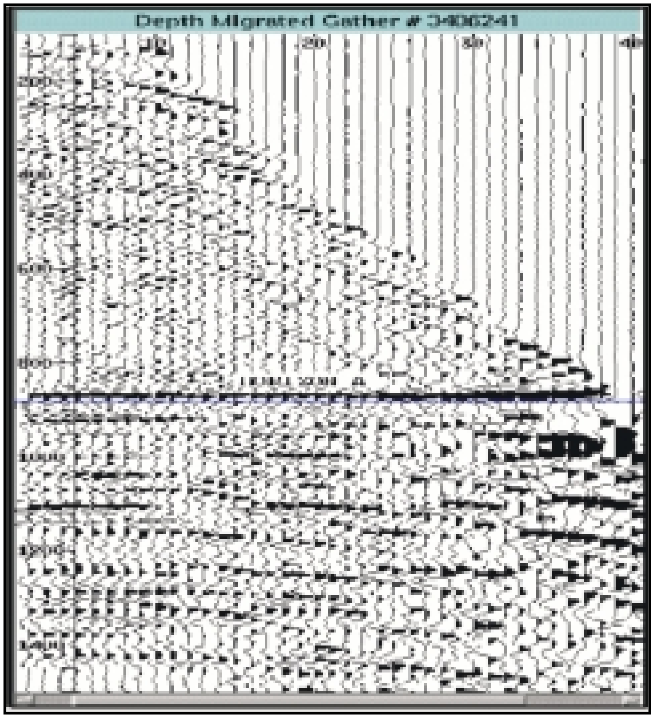

Figure 3 : An APSDM Gather. Note the flatness of event at farthest offsets (depth/offset ratio ≈ 2.4) 5Km N

Depth maps obtained by map migration of time interpretations, using 3D velocity model (incorporating the vertical gradient and anisotropic parameters for the thick shale layer) at two levels are shown in Fig. 5 and Fig 6. The mis-tie distribution in these figures depicts the vertical depth accuracy achieved in the variable data quality situation. For the shallow reflector in Fig 5 the data quality along the reflector is very good and offset-depth ratio is more than 2.5 hence the resulting match between seismic reflector and well markers are good i.e. within 5m. For the deeper reflector (1400-1500m) data quality being fair and offset-depth ratio in the range of 1.2 to 1.3, nearly 75% of well-markers match within 30m; with remaining 25% giving a mis-tie in the range of 40m-60m. Any larger deviation here is attributable to correlation error which is later verified on the depth section.

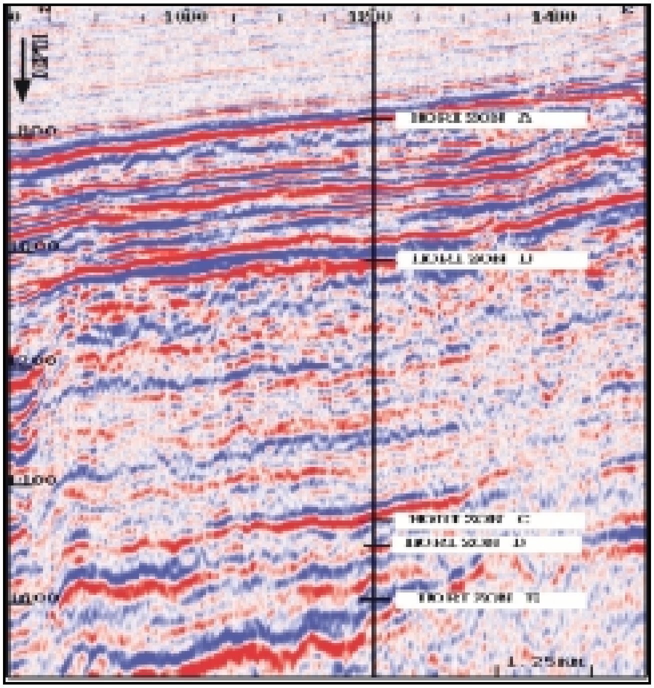

Figure 4 : The APSDM image along same profile showing focused image at all levels. Note the match with well tops

Figure5: Showing mis tie map corresponding to Reflector A after map migration using 3D velocity depth Model (including vertical gradient and anisotropy)

Figure 6:Showing mis tie map corresponding to Reflector C after map migration using 3D velocity depth Model (including vertical gradient and anisotropy)

We have also performed a sensitivity analysis for the given offset-depth ratio by changing the velocity by few percentage points and observing its effect on (i) flatness of gathers and (ii) residual velocity semblance plot (used for velocity updation). It was found that for a 5% change in velocity there was no perceptible change on flatness of gathers; (Fig. 7) and residual semblance plot; (Fig 8). However this velocity inaccuracy can cause an error of about 25m in depth estimates on APSDM stack. This has helped us to understand our observation that 75% well were within 30m match with well markers even after accounting for the anisotropy in the overburden.

CONCLUSION

1. Anisotropic PSMD (APSDM) immensely improves the match between seismic and well markers.

2. Good quality data with proper offset-depth ratio can provide PSDM image in its correct spatial position within seismic resolution and shall help achieve the important goal of producing seismic section in depth in coming years.

Figure7: APSDM gather using final velocity model obtained through coherency inversion and tomography.

Figure 8: APSDM gather using 5% higher velocity. Note The change in depth of reflector but no change in flatness.

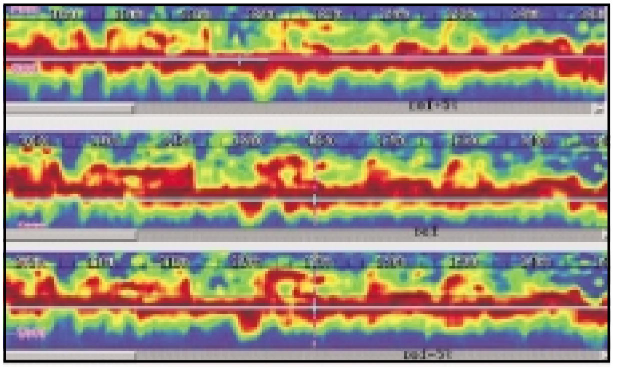

Figure 9: Showing the residual semblance on APSDM gathers along the target reflector using final velocity and 5% higher and lower velocity. Note there is no perceptible change in residual.

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