Integrating Well Data with Velocity-Depth Modeling: A Case Study from Upper Assam Basin

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Summary

In the nineties, the Pre-stack Depth Migration (PSDM) technology was limited mostly to imaging below salt in the Gulf of Mexico, where time imaging could not produce any meaningful image below salt. With the more and more availability of cheaper computing resources this technology is now progressively being employed in relatively simpler geology with rewarding results in providing focused image with more accurate positioning of image in the sub-surface.

To achieve this, we need to build data driven Velocity-Depth model taking into account the heterogeneity and anisotropy of the sub-surface. The other challenge is the velocity-depth ambiguity, which results due to limited band width and aperture during data acquisition. Using well data helps to minimize this ambiguity at seismic scale.

In the present paper, we show a case study from Upper Assam basin, India where anisotropic effect is not significant from imaging point of view and isotropic velocity depth modeling using seismic data and proper integration of well data has brought out focused and accurately positioned image in the sub-surface, circumventing partially the problem of velocity-depth ambiguity. We have also shown a method to extract compaction gradient from seism data during velocity depth modeling, in the portion where well data is not available.

Introduction

Velocity-depth modeling is one of the crucial exercises for successful completion of a PSDM project. To get a focused and positioned image we need to account for heterogeneity and anisotropy of the sub-surface in the velocity-depth model. Determination of these parameters, if only P-wave data is available, is a challenge and requires well data along with good seismic data (S/N ratio and sufficient offset-depth ratio). Apart from this velocity-depth ambiguity [Archer, (1982), Toldi, (1985, 1989), Bickel (1990), Stork (1992)], is a serious problem and again well data is required to minimize its effects.

In our area of study, sub-surface is characterize by alternation of sand and shale sequences Fig.1 (Stratigraphy) deposited in fluvial environment. The clay in shallow section and Girujan clay (Oligocene) are expected to show anisotropy and heterogeneity and may affect the imaging. The S/N ratio of the data is good and offset-depth ratio is more than 2 at these shallower levels, and sufficient no of wells are presen in the area, therefore we can determine the anisotropy due to these formations if it is significant . Sonic logs are not present in the shallow section therefore gradient can not be determined from the well data.

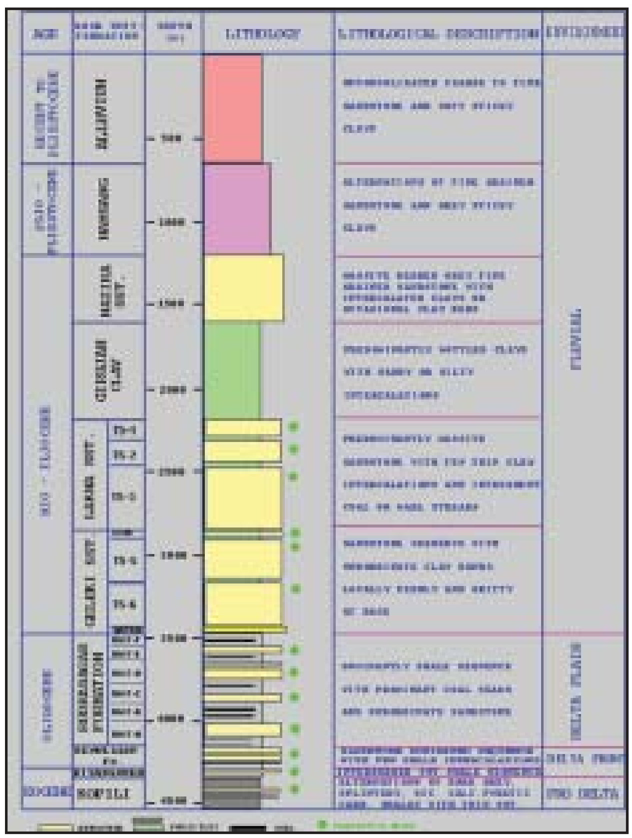

Fig. 1: Generalized stratigraphy of the area

In the present study we have shown that there is no significant anisotropic effect of the clay formations present in the shallower section. We have also shown how to estimate compaction gradient during velocity modeling using seismic data though it may suffer from resolution. But our result show that it is matching with the well data in portion where sonic logs are available. Theses observations regarding anisotropy and compaction gradient are also supported by the fact that Isotropic PSDM images are well focused and giving good match with well tops within seismic resolution.

Theory and/or method

Velocity-Depth Modeling

For initial velocity-depth modeling we have divided the whole section into seven sequences Fig. 2. First sequence base is at Namsang (Mio-pliocene to recent) and consist of un-compacted sand stone, alluvium and boulder alluvium. The second sequence correspond to upper sand stone (Miocene). The third sequence Girujan clay (Miocene) forth and fift sequences are upper tippam and lower tippam (Miocene). Sixth is barails (Oligocene) and seventh is Kopili shale(Eocene).

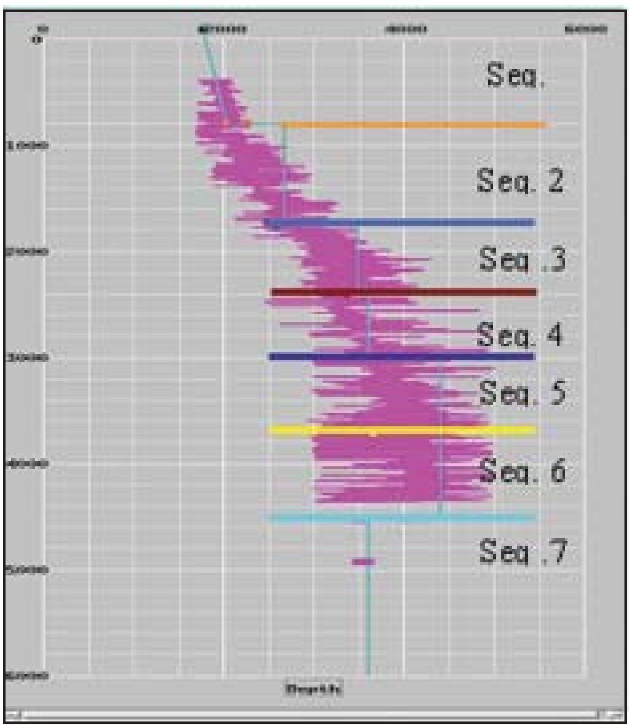

Fig. 2: showing the sequence boundaries along with sonic log and interval velocity model derived from seismic data, Note the match of seismic derived gradient to sonic gradient in the first sequence.

A: Estimation of gradient

Interval velocity for the first layer varies according to the structural trend indicating a mild gradient Fig.3. By trial method along different profiles we have found a gradient value of $0.3s^{-1}$ which removes the compaction effect Fig.4. and also matches with sonic log Fig.2. Interval velocity for second layer does not show any appreciable velocity dependence on structure Fig.5, though in the upper part of the layer gradient can be seen from the log. Large scale facies variation is expected in this layer and we can not use gradient information from limited well control, there fore in thick layer approximation we have not taken any gradient in this layer Fig4. The other layers are compact sand stone no appreciable gradient is present Fig2.

B: Anisotropy

Layered earth depositional model can be approximated by vertically transverse anisotropic (VTI). In such medium P-wave imaging requires the estimation of **ε, δ** (Thomson, 1986; Singh, 2004) and vertical velocity (along the axis of symmetry). The presence of anisotropy in

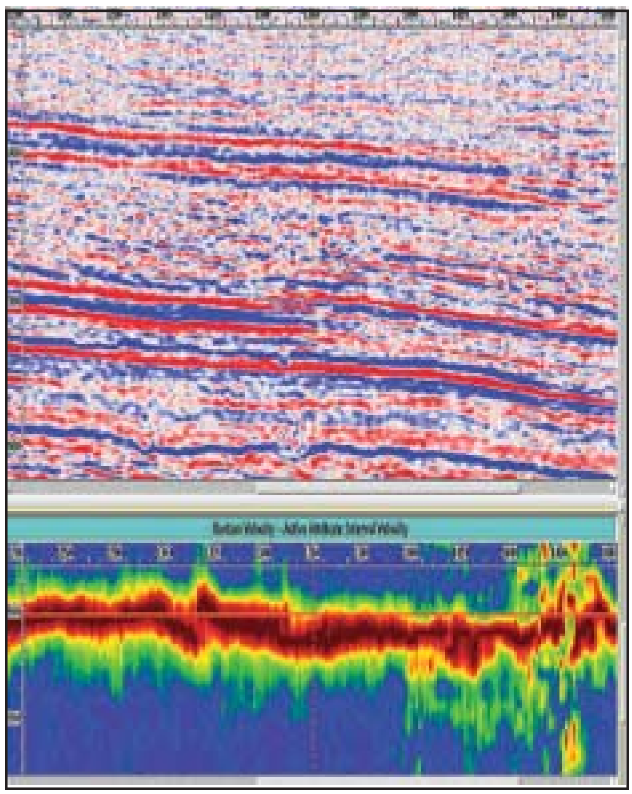

Fig. 3: showing the dependence of interval velocity on structural trend Note the increase in interval velocity with depth.

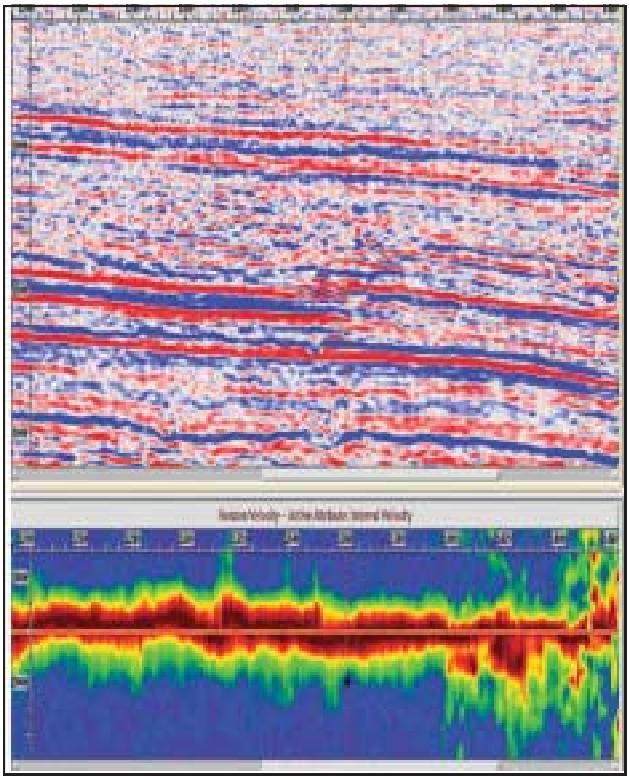

Fig. 4: Showing the removal of compaction effect by using a gradient value 0.3 sec^{-1}

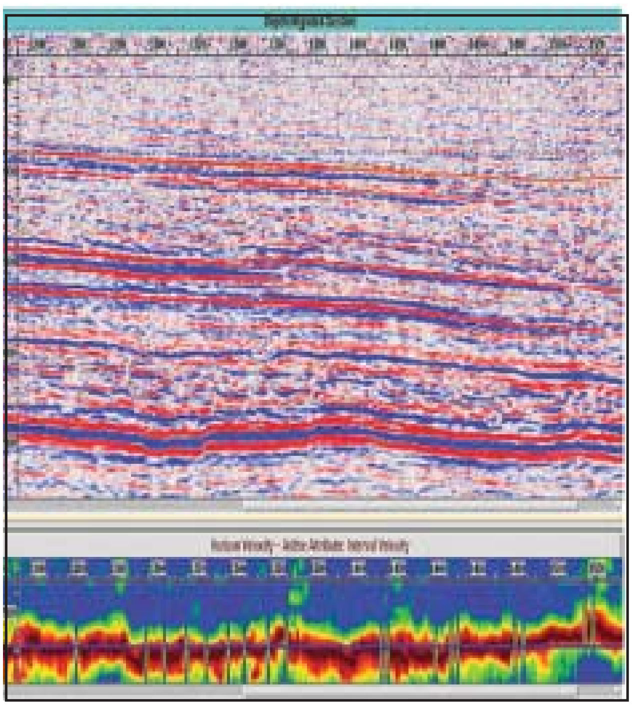

Fig. 5: Showing that velocity is not following structural trend for this sequence

the sub-surface can be recognized on seismic image gathers at for offsets (offset-depth ratios close to two) in the form of hockey-stick caused due to some combination of **ε** and **δ** known as **η**parameter in time domain processing **$[\eta = (\epsilon - \delta)/(1-2\delta)]$** and at near offset in terms of mismatch with well marker (**δ, depthing parameter**). PSDM image gather (Fig.6) do not show any hockey-stick effect even up to offset-depth ratio more than 2.5 at shallower reflectors and PSDM section is showing very good match with well marker Fig.7. This clearly demonstrates that the effect of anisotropy is not significant in this area from the imaging point of view.

Discussion

The initial velocity-depth model was built through 3D-coherency inversion incorporating the gradient determined using seismic data for the first layer. Subsequently PSDM was run along every 10th inline (250m apart) for doing residual analysis. Global layer based Tomography was run taking all the layers together. It did not minimize the residuals at shallower levels. Therefore we did layer by layer Tomography and got encouraging

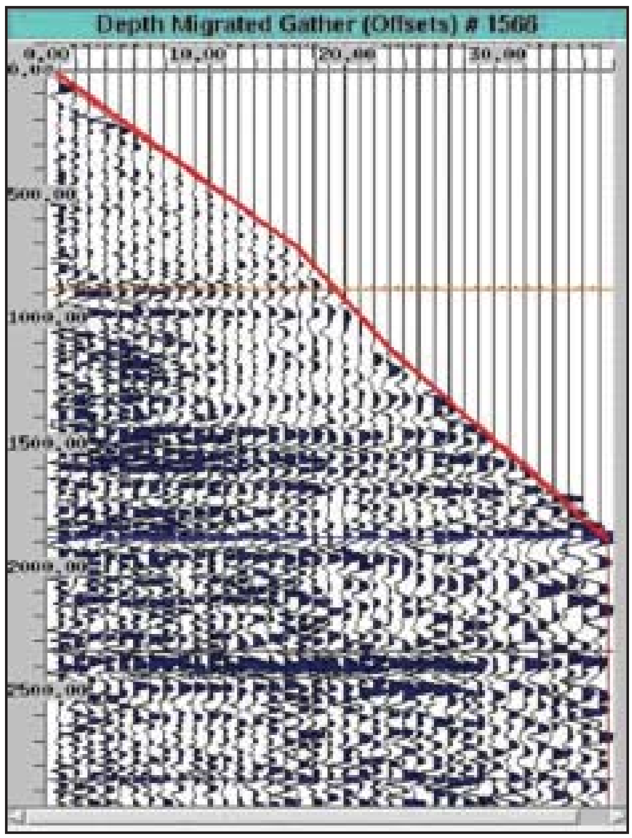

Fig. 6: Showing Flatness of gathers after PSDM

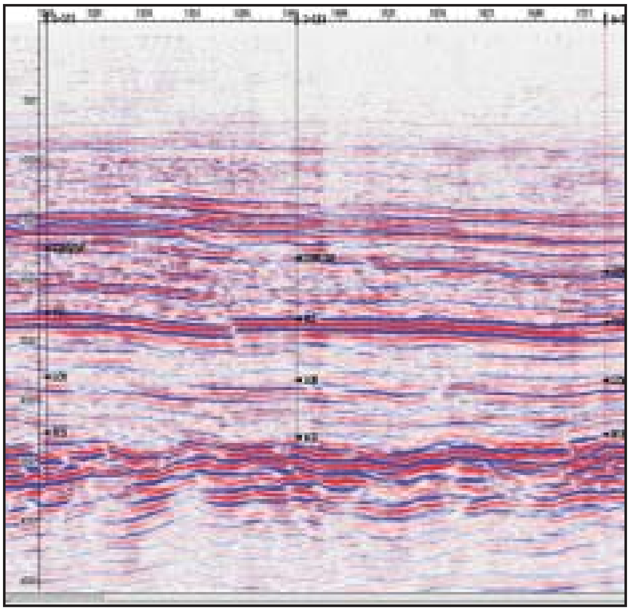

Fig. 7: Showing the well marker match with PSDM image.

results which helped to minimize the residuals as well as gave good tie with well marker.

In this area there, Due to lateral facies changes there is some ambiguity in picking the well markers. Therefore to ascertain the capability of isotropic PSDM in this area we have selected Horizon three (base of third sequence) where picking ambiguity is minimum. Fig.8 clearly show that mis-tie at this level is (less that 20m and the average mis-tie is 3m) within the cycle (seismic

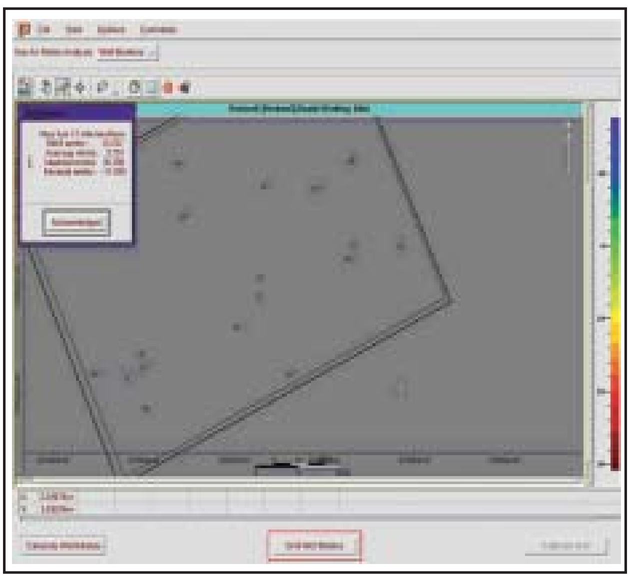

Fig.8. Showing mis-tie with well markers after 3D PSDM. (Note statistical table showing avg. mis-tie of 3 mts)

resolution). One well which is giving 30m mis-tie is at the edge of the survey and beyond the PSDM aperture and therefore tomography aperture and can be ignored. As a final comparison Fig.9 shows very good match with Time-depth (TD) curve of VSP and TD derived from seismic derived velocity-depth modeling.

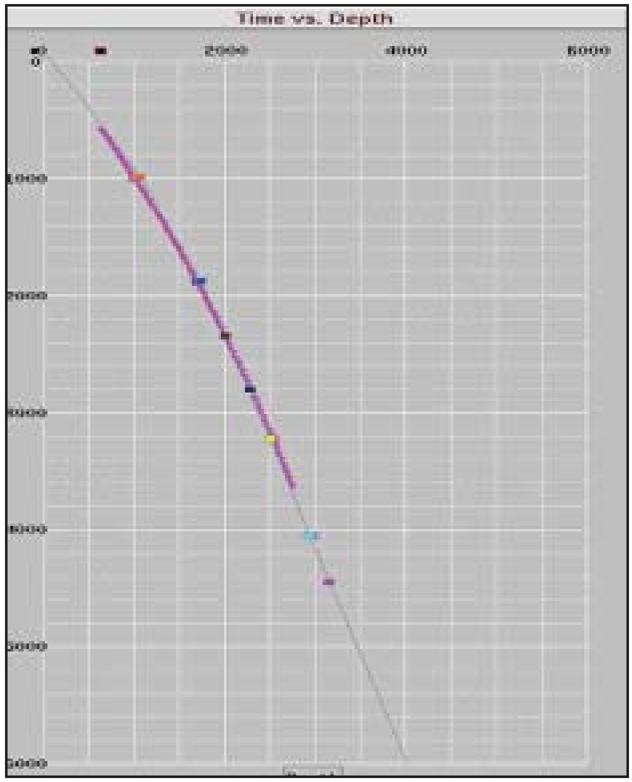

Fig. 9: Showing the match between the VSP time-depth curve and time depth curve derived from interval velocity volume. (Note the very good match between the two)

Conclusions

Proper integration of well data with velocity-depth modeling through seismic data requires the study of heterogeneity and anisotropy of the sub-surface

In the absence of anisotropy given good data quality (offset-depth ratio close to two and good S/N ratio) Isotropic PSDM provides well focused and accurately positioned image in the sub-surface

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Views expressed in this paper are those of the authors only and may not necessarily be of ONGC.

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