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**PSDM as Diagnostic Tool to validate the Existence of Shallow Lime Stone  
in Palk Bay Area.**

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### Summary

*Determination of the precise interval velocity field for subsurface imaging is a major challenge in pre-stack depth migration (PSDM). The ability to define an accurate interval velocity model and economically perform pre-stack imaging in depth provides the opportunity to more fully exploit the critical subsurface imaging. However, the PSDM method is more demanding of the data requirements than conventional time techniques to deliver the degree of velocity model accuracy required for optimal spatial positioning of target reflectors.*

*This present study deals with a multi-line 2D seismic survey in Palk Bay area. The survey was conducted over an area with shallow and deep complex velocity distributions. Recently, the data were reprocessed making use of velocity-depth model building procedures and pre-stack depth migration to clarify the subsurface geologic model and improve the resultant seismic image. A critical component of this procedure was the use of 2D seismic horizon based tomography to facilitate the building of a velocity depth model that incorporates both the shallow and deep velocity variations.*

*Due to the presence of very thin shallow wrecked calcareous sedimentations in few well data surrounding the study area, the interpreters expected a shallow limestone high velocity layer in the study area which could not be replicated by the conventional PSDM results using coherency inversion. Subsequently as it was expected, in order to accommodate the shallow subsurface velocity distribution, a forced “limestone” layer was included in the velocity model and the iterative horizon based tomography could “set right” the near surface velocity errors in the second stream PSDM.*

### Introduction

An economic & feasible Kirchhoff pre-stack depth migration and velocity model-building solution was selected for accurate Velocity Estimation & refinement of Subsurface Imaging. Once near-surface refraction modeling and careful pre-processing were satisfactorily completed, attention turned to defining an accurate velocity model for the Kirchhoff PSDM solution justifying the subsurface complexity.

The results obtained from the pre-stack depth migration could have two improvements by: (i) the improved imaging of the seismic data, and (ii) the more geologically correct velocity field. The depth conversion requires the use of an average velocity vs. time function, which requires knowledge of the interval velocity vs. time. The latter was estimated using the

DIX conversion formula on the assumption that the stacking velocity closely approximates the rms velocity.

An iterative tops-down workflow was adopted to progressively establish the upper layer velocities and horizon positions before moving deeper to define the next series of formations. The workflow used the pre-stack time migrated velocity volume and a series of mapped horizons to provide key interval velocity boundaries. The initial velocity model would be high-graded using Kirchhoff PSDM image gather and residual curvature (velocity) estimates from semblance analyses for subsequent and deeper iterations.



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Initially, first stream of Pre Stack Depth Migration was done in the conventional way using the Time migrated mapped horizons & updated interval velocities through horizon based tomography. Later, in the second stream, a forced synthetic interval velocity model was build up by incorporating the high interval velocity in the shallow limestone layer as it was expected by interpreters. Then this postulated interval velocity model was repeatedly iterated and updated through horizon based tomography and Pre Stack Depth Migration to get the refined final interval velocity model. In this later case as well, we obtained the same interval velocity model as earlier which validates the flattening of the PSDM image gathers nullifying the pre- conceived notion of existence of shallow lime stone.

## Geological Background

The vicinity under study is the Palk Bay sub-basin comprises the northern continuity of Ramnad sub-basin into the offshore (Figure-1). It is delimited in the northwest by Pattukottai-Mannargudi ridge and in the southwest by Mandapam-Delft ridge. The sub-basin contains sedimentary fill contiguous to the Cretaceous – Tertiary succession encountered in the Ramnad sub-basin. The typical stratigraphic succession encountered in the well data indicates the development of two arenaceous packages below Cretaceous top boundary viz. Nannilam and Bhuvanagiri Formations. However, the well data encountered thick arenaceous sequence called Palk Bay Formation representing undifferentiated Pre Albian to Turonian sequence, followed by mainly shale and sandstone with minor limestone development in the Upper Cretaceous and major limestone interludes during Eocene and Miocene periods.

Cretaceous reservoirs of Nannilam Formation ranging in age from Santonian to Campanian constitute the main exploratory target in Ramnad Sub-basin. Arenaceous reservoirs of Bhuvanagiri Formation of Coniacian to Turonian age is the other exploratory target on structural culminations. The Nannilam reservoirs have been deposited in this area through mass transport mechanisms, viz., debris flow and high density turbidity currents. The Kamalapuram reservoirs occur as marine channel fill or slope fan/ basin floor fan overlaying the Cretaceous unconformity. The structural configuration of sub-basin has been delineated by detailed mapping of four levels corresponding to Basement, Andimadam top, Bhuvanagiri top and Nannilam top levels.

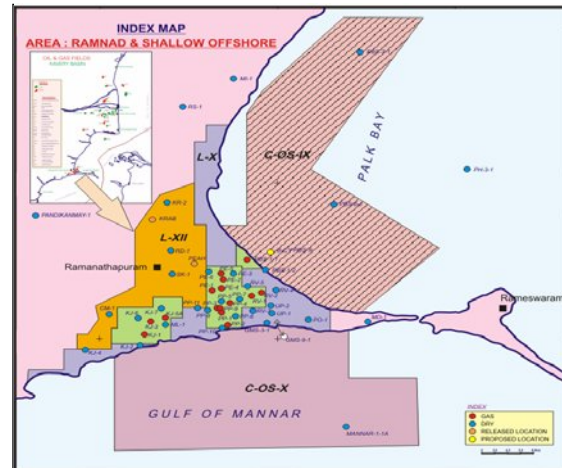


Figure-1: Index Map of the Palk Bay area

## Theory and Methodology

The initial velocity field in PSDM is often described as a layered model where the interval velocities are derived from stacking velocities or normal moveout velocities by Dix conversion. During PSDM the initial interval velocity model is iteratively updated, starting by perturbing the shallowest layer and progressing downwards. Common image gathers are made when all offsets have been migrated and are used to verify that the seismic is migrated with the optimal velocity field. The criterion for an optimal interval velocity in a layer is that the events corresponding to the base of the layer are flat in each Common image gather (CIG). If a wrong velocity model is applied in the migration, the traces in a CIG will not be located at same depth and not be a common reflection point gather. At the outset, to generate the meticulous time migrated map and the RMS velocity model, Pre Stack Time Migration (PSTM) was carried out using the conditioned CMP gathers. Then to convert the time migrated map into depth domain, interval velocity analysis was attempted in the study area using the RMS Velocities derived after PSTM from the seismic data.



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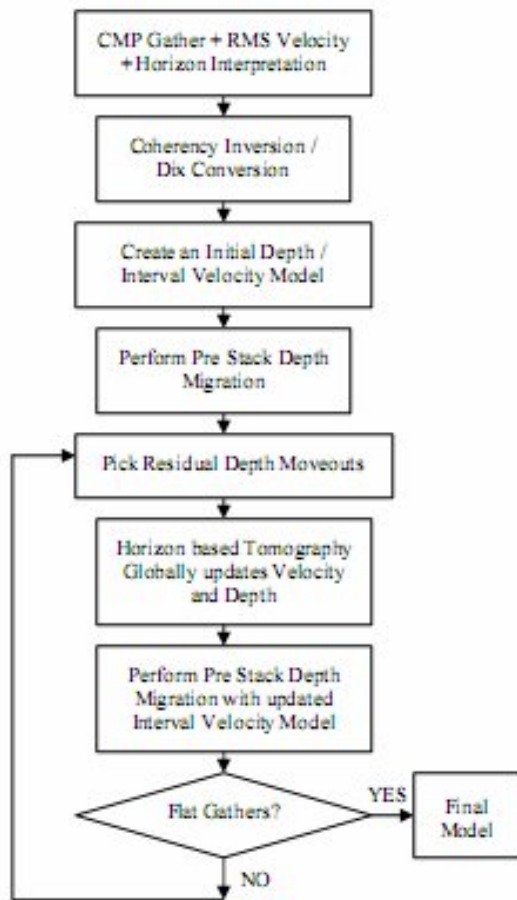


Figure-2: PSDM workflow using Horizon based Tomography

Effective pre-stack depth migration processing requires good quality preprocessed data. A robust PSDM processing flow with Horizon based Tomography using residual depth moveouts was adopted for refinement of both interval velocity & depth model (Figure-2).

Subsequently, the initial postulated model of the interval velocity incorporating the forced shallow limestone (Figure-3) and the corresponding PSDM gathers migrated with this postulated interval velocity (Figure-4) replicate that the events are not flat and requires more slower velocity. With this modeling strategy, after each iteration of tomography, interval velocities and PSDM Gathers were assessed for image quality with a horizon review/update of the model before the next iteration. With this strategy in place, the PSDM process proceeded rapidly through a series of iterations to produce the final interval velocity model & PSDM volume.

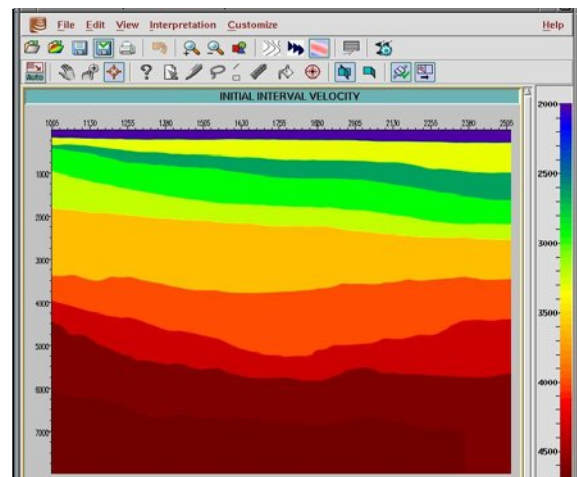


Figure-3: The initial postulated model of the interval velocity incorporating the forced shallow limestone.

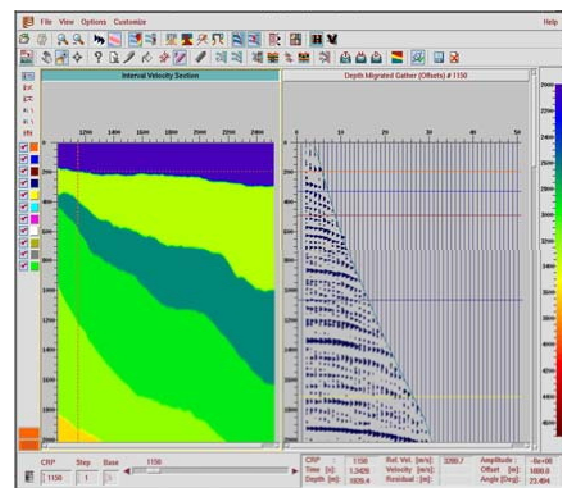


Figure-4: The initial postulated model of the interval velocity incorporating the forced shallow limestone and the corresponding non-flat PSDM gathers (zoomed section)

Tomography is an imaging technique that attempts to correct errors in the velocity depth model by analyzing the residual delays after PSDM. An important feature of tomography is that it is a global approach as compared to layer stripping. Tomography can attribute an error in time at one location to an error in velocity and depth at another location. These errors are solved simultaneously by making changes to the velocity and depth model across the entire section. Layer stripping may result in accumulation of error at the deeper parts of the section when there are errors at the shallow parts. Tomography updates the shallow and deeper portions simultaneously. Horizon based tomography updates the interval velocity and horizon depth using a residual moveout analysis along the each picked horizons by picking the residual moveouts where the semblance value is maximal (Figure-5).



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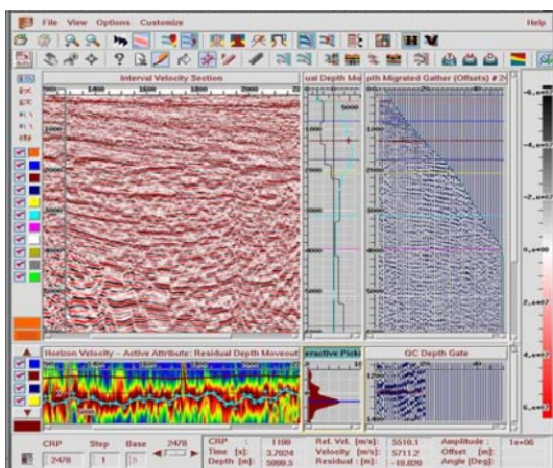


Figure-5: Semblance computation of the limestone horizon and the residual moveout analysis for horizon based tomographic updates

After repeated iterations and updating through horizon based tomography, the tomo-updated true interval velocity and depth model was generated and consequently final pre-stack depth migration was performed. In fact, from the final tomographic updated interval velocity model, it is well analyzed that the corrected interval velocity in the postulated shallow limestone layer has drastically lowered down as a result of global tomographic updates, which nullifies the existence of the shallow limestone as it was proposed in the study area.

Finally, the resultant interval velocity map (Figure-6) shows that the high velocity trend in the shallow prospect of limestone is not observed in areas around the study area. The resulting depth gather were found to be faithfully flat (Figure-7) and the corresponding depth section showed improved structural features with better understanding of the events (Figure-8).

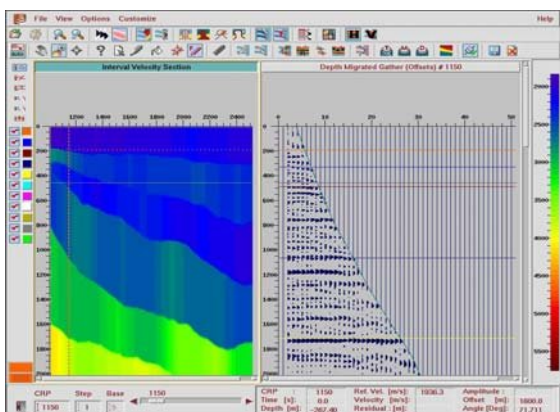


Figure-6: Tomographic updated velocity model & corresponding depth gathers (zoomed section).

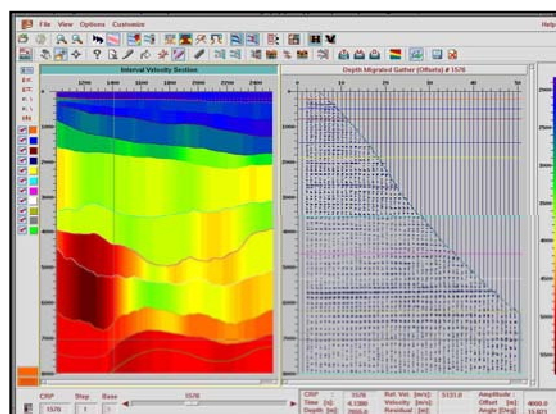


Figure-7: Final Tomographic updated interval velocity model with the flat depth gathers (Full section).

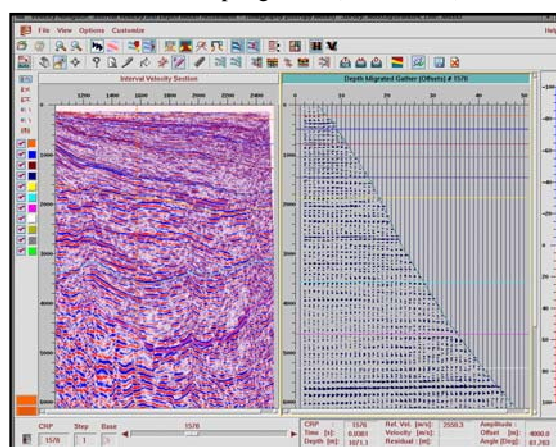


Figure-8: Final PSDM section showing the depth horizons along with the flat depth gathers.

A comparison of the PSDM sections with the initial postulated model of the interval velocity incorporating the forced shallow limestone (Left) and with the successive tomographic updated final interval velocity model (Right) is shown in Figure-9. It is clearly observed that the final PSDM section shows significant improvement in structural imaging with better subsurface definition.

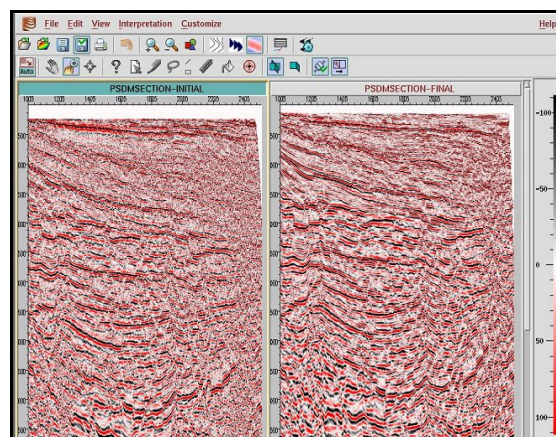


Figure-9: Comparison of PSDM Sections with initial postulated velocity model (Left) and with the successive tomographic updated true velocity model (Right)



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Moreover, the non-hyperbolic nature of moveout of the events in time domain, caused by the lateral velocity variations might have caused the time migration to produce a poor result. Comparison of time migrated section and final PSDM section scaled to time (Figure-10) clearly shows improvement in structural delineation through depth domain imaging.

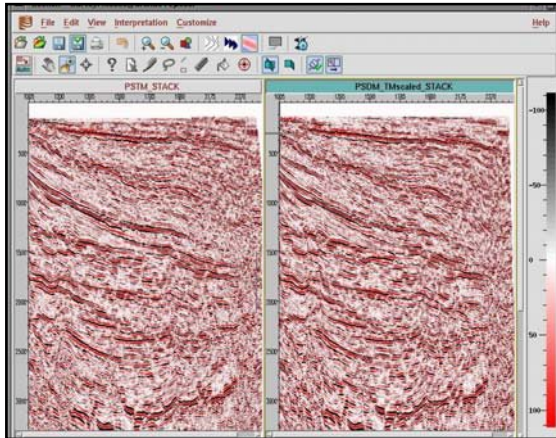


Figure-10: Comparison of the final PSTM Section (Left) and the final PSDM section scaled to time (Right)

## Conclusions

- The data in the Palk Bay area is processed through two streams of Pre-stack depth migration.
- Initially, Conventional Pre-stack depth migration using coherency inversion without the shallow limestone layer definition.
- Later, the model forced PSDM by including the postulated shallow layer of limestone as it was expected by the interpreters and iterated the model through successive tomography runs to correct for the layer velocity model.
- The model forced PSDM actually converged to the original velocity with which the first PSDM was done.
- The results demonstrated that the postulated layer is not limestone.
- Depth processing based on iterative velocity model building and tomographic updating can produce reliable results in complex geologic settings that include both near surface and deep subsurface velocity anomalies.

## References

Andy Furniss, "An integrated Pre-stack depth migration workflow using model based velocity estimation and refinement", Geohorizon, July 2000.

Uwe Albertin et al., "The time for depth imaging", Oil field review, Spring 2002.

Landa E. et al., "A method for determination of velocity and depth from seismic data, Geophysical Prospecting, 1988'April.

Versteeg R. et al., "Sensitivity of pre stack depth migration to the velocity model, Geophysics vol. 58, 1993.

Online help of Geodepth software, Epos 3.0 2<sup>nd</sup> edition, Paradigm Geophysical, 2005.

Yilmaz, O., "Seismic Data Analysis, Vol-1 & 2 (Text), SEG Publication, 2001.

Arjeesh Gupta et al., "PSDM using model based velocity estimation & Refinement for Enhancement of subsurface imaging", 5<sup>th</sup> Conference & Exposition on Petroleum Geophysics, Hyderabad-2004, India.

Tian-when Lo et al., "Fundamentals of Seismic Tomography, SEG monograph series, 1994.

Ning Guo et al., "Becoming effective velocity model builders and depth imagers", The Leading Edge, Dec'2002.

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