Comparative Study of Imaging Approaches In Indian Basins: A Case Study

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Keywords

PSTM, PSDM, Migration , Ray tracing, opening angle, directional angle, pencil distance, CRAM

Summary

Migration is a process which removes the effects of wave propagation from seismic data. The output of seismic migration in which seismic events are geometrically re- positioned in either space or time to the location the event occurred in the subsurface rather than the location it was recorded at the surface, thereby creating a more accurate image of the subsurface. The position of horizontal reflector in depth will appear as a horizontal reflector on the time section whereas a dipping reflector is always incorrectly positioned on the seismic section. It is the task of migration to correct the mispositioning. Migration moves dipping reflectors to their true subsurface positions and collapses diffractions resulting in a migrated image that typically has an increased spatial resolution and resolves areas of complex geology much better than non-migrated images. Now-a-days, depth imaging is the need of the industry to address the imaging issues. In this study, Kirchhoff's time/depth migration technique is used to process the seismic data and compared the images obtained with new technology (CRAM) which is performed in angle domain and images so obtained are better than the most frequently used Kirchhoff's images in different Indian basins.

Thou RTM, Gaussian Beam migration and wave equation migration are available for seismic imaging but could not compare with KPSTM, KPSDM and CRAM imaging techniques because of non availability of software for processing of the seismic data which are shown in this paper

Introduction

First seismic reflection data were migrated in 1921 with limited resources but with intensive data acquisition with large no of channels, the migration technique needs to be reviewed to get the better image quality. In modern times, the machine power – in terms of computation efficiency has increased many fold to cater the present ned of handling large sized data sets. Migration can be classified in different categories based on domain of operation or Algorithm of operation. 2D and 3D operation, Post and Pre-Stack as well as Time and Depth operation. Now days, Processing Geophysicists are involved in 2D/3D Pre-Stack time/depth migration. Time Migration is applied to seismic data in time coordinates. This type of migration makes the assumption of only mild lateral velocity variations and this breaks down in the presence of most interesting and complex subsurface structures, particularly salt. Some popularly used time migration algorithms are Stolt migration, Gazdag, Kirchhoff time migration and Finite-difference migration.

Depth Migration is applied to seismic data which require a velocity model, making it resource-intensive because building a seismic velocity model is a time consuming and iterative process. The significant advantage to this migration method is that it can be successfully implemented in areas where large lateral velocity variations exists, which tend to be the areas that are most interesting to petroleum geoscientists. Some of the popularly used depth migration algorithms are Kirchhoff depth migration, Reverse Time Migration (RTM), Gaussian Beam Migration, Wave-equation migration and Common Reflection Angle Migration (CRAM) and Full Azimuth Angle Domain Imaging**.** Kirchhoff's migration is traditionally well accepted migration tools in Industry for time and depth domain , with well known efficiency, ability to image steep dips and over hanging dips. The disadvantage with this migration technique is that it does not handle the multi arrivals and artifacts are caused due to swinging action.

Methodology

Seismic data is generated by wave propagation through a subsurface and image obtained by this process is distorted and does not correctly reflect the true geometry of the subsurface structure. However, a geological model can be transformed after wave propagation into seismic section and after migration. This can be demonstrated in Fig1 below.

The true position of the reflector in depth differs from its position on the time section. The lateral and vertical positions are different, as well as the dip of the images reflector is not true.

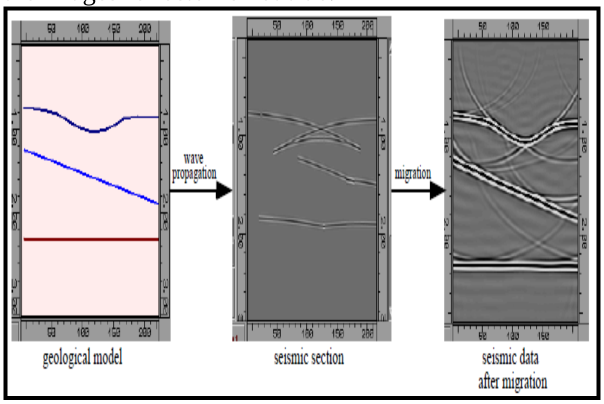

Fig1: Geological model and seismic data

The apparent time dip of the reflector is smaller than true dip, and the reflector itself appears longer (Fig2). Generally migration steepens dips, shorten dipping events, and moves events up dip, therefore anticlines decrease while synclines increase.

In addition to the Migration technique used for seismic migration in offset domain, another migration technique is available in angle domain. As the Kirchhoff's migration adversely affects the reservoir properties, therefore a reconstruction of common image angle gathers are needed (Xu et.al.2001, Koren etal.2007. This is a multi arrival, ray based migration technique that uses the entire wave field within a controlled aperture named as CRAM and was developed by Koren et.al 2008. This is a bottom up Ray tracing method which is performed from image points up to the surface, forming a system for mapping the recorded surface seismic data into the local angle domain at the image points (Fig3). CRAM imaging process combines a number of ray pairs representing the incident and reflected/diffracted rays from the subsurface. The procedure is based on a uniform illumination at image points from all directions, ensuring that all arrivals are taken into account while amplitude and phases are preserved. These two migration techniques have been studied and implemented on different data set for comparison purposes.

Generalized Seismic Processing flow for Kirchhoff's PSTM/PSDM Migration and Common Reflection Angle Migration is given below in Table1 &2.

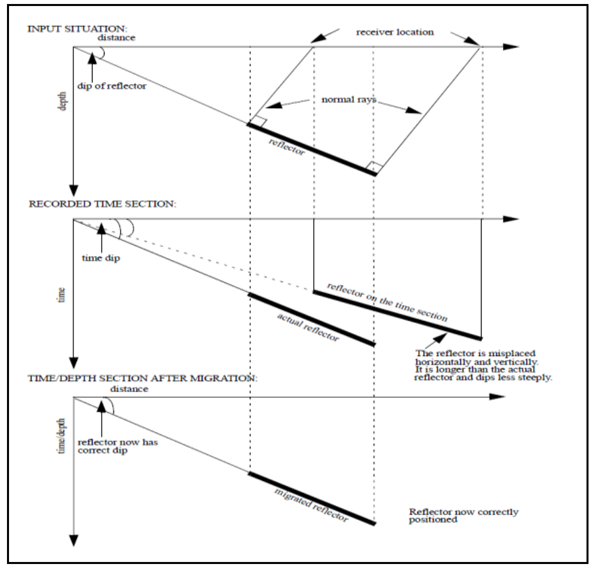

Fig2: True position of the reflector in depth differs from its position on time section (courtesy Paradigm Migration Manual)

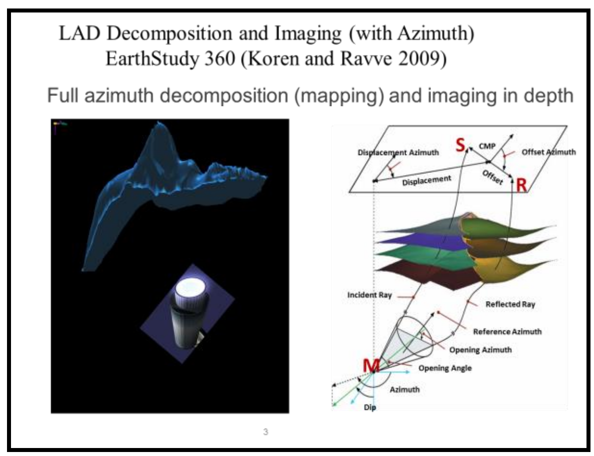

Fig3: Imaging in local angle domain. Fig demonstrate an example of a selected ray pair incident and scattered at a given subsurface point M and four angles associated with the LAD (Local Angle Domain) dip and azimuth of the ray pair normal, opening angle and opening azimuth. Four angle describes the direction of the incident and reflected rays.

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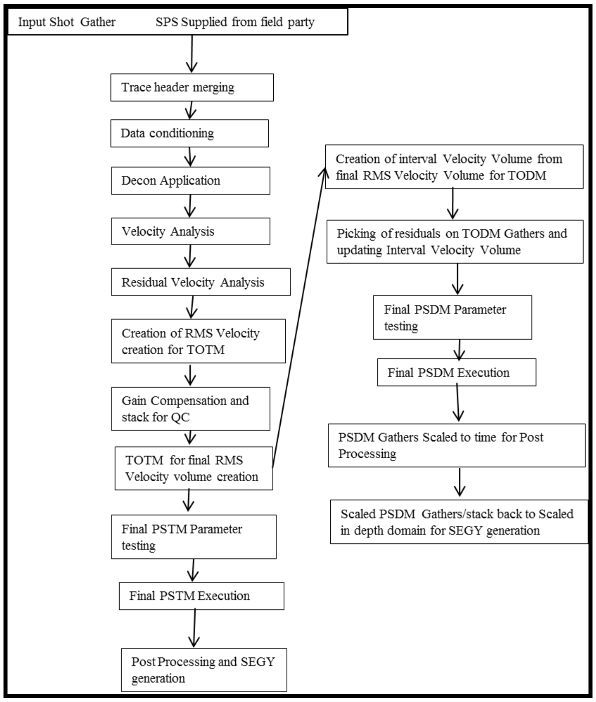

Table1: Processing flow for Kirchhoff's PSTM/PSDM

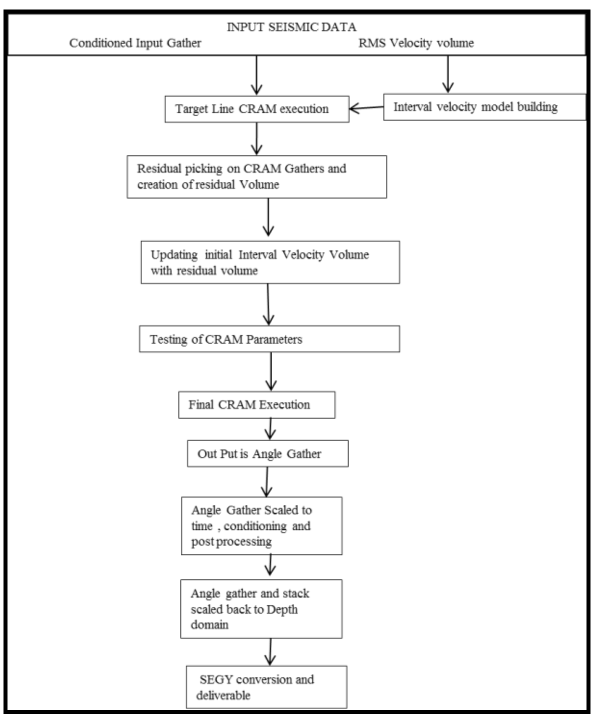

Table2: Processing flow for CRAM

The input data for PSTM/PSDM is subjected to different type of processing steps to get the CDP sorted data which is used as input for migration. RMS velocity volume is prepared by picking the velocities on target line migrated seismic data and this RMS volume is used for PSTM. Interval velocity volume is obtained by transforming RMS velocity volume. This interval velocity volume was used as initial velocity for target line depth migration through Kirchhoff PSDM and CRAM Residual velocity volume is prepared by picking RMOs on these depth gathers and used to update initial interval velocity model to generate a final Depth-Interval velocity volume for final depth migration. Optimization of parameters e.g. migration aperture, Frequency to be migrated, offset in InLine/ XLine direction , Depth cut, stretch factor for PSTM/PSDM are carried out.. In case of CRAM, the critical parameters involved are opening angle, directional angle which are decided through ray tracing that gives the number of failed and successful ray counts, final values are decided by taking into account the more successful rays, pencil Distance, Azimuth, Aperture, frequency and Reference Depth for defining the angle at top and bottom. Proper optimizations of these parameters result in best possible subsurface image.

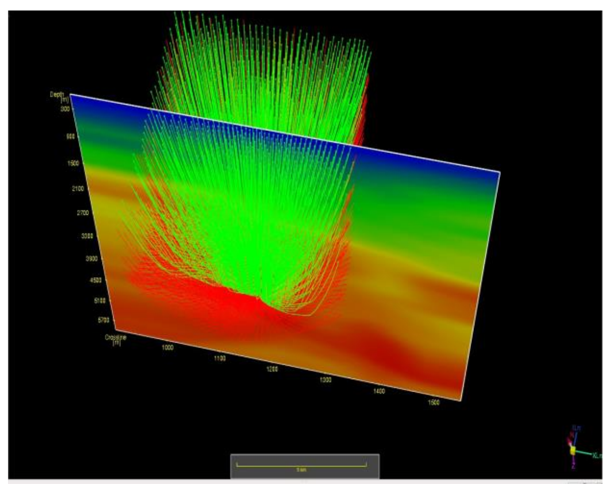

Fig4: Ray trace modeling for optimization of CRAM parameters. Pictures demonstrate the ray tracing from image point to the surface taking interval velocity volume as background. Rays in green colour are successful rays which received on the surface for a given offset, aperture and Lad Parameters.

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Area of studies

The data sets for study were taken from Western Offshore, KG, Cauvery and Assam Arakan Basin from the North East India having different exploration objectives.The results are shown below in Case-1 to Case-5.

CASE-1

In this case , the Areas under stdy fall in the western Part of India. The Imaging is a problem below 1000 ms in the Western Part of the area with the kirchhoff's Time migration (The objective of the survey was to *explore* Tertiary and Mesozoic formations, 500-2200 ms), therefore Kirchhoff's Depth migration was carried out using The results show improvement in the imaging quality (fig5 and fig6).

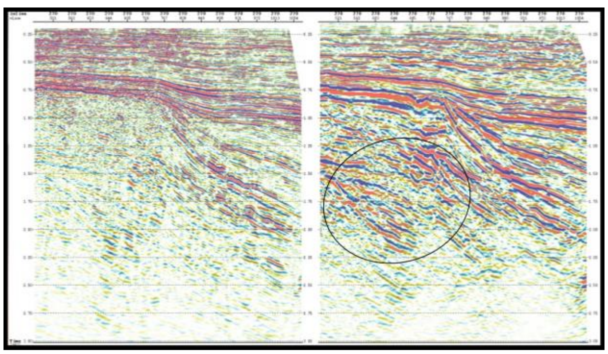

Fig5:Comparision of PSTM Stack and Scaled PSDM Stack

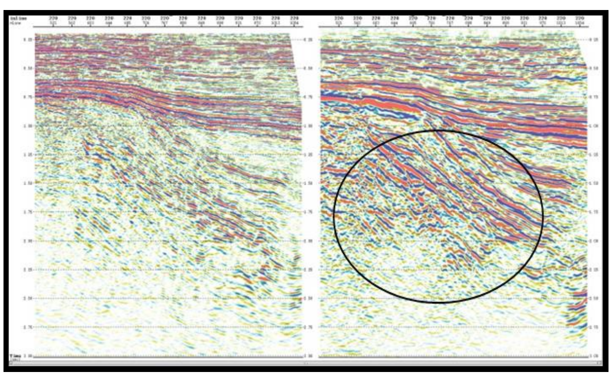

Fig6: Comparision of PSTM Stack and Scaled PSDM Stack

CASE-2:
In this case, the again is from western Part of India. This area was assigned with specific objective to delineate Synrift (Olpad & OCS) as a primary and Rift fill (YCS & Kalol) as secondary pay with Zone Of Interest between 1200 – 3800 ms TWT. In Fig7, the left is obtained from kirchhoff's migration and right one from CRAM migration scaled in time domain. The result shows appreciable improvement in the reflections from deeper section. Quality of CRAM image is clearly seen in Zoomed version (fig8)

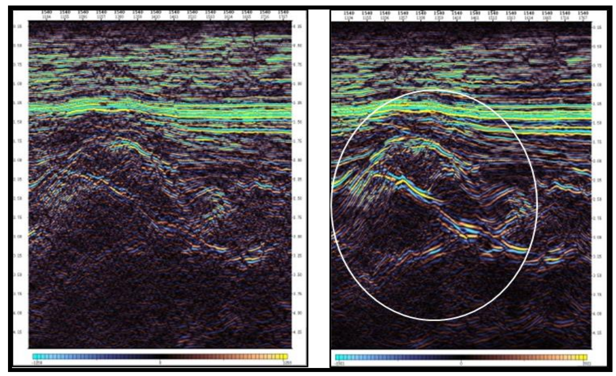

Fig7:Comparision of PSTM Stack and of Scaled CRAM Stack

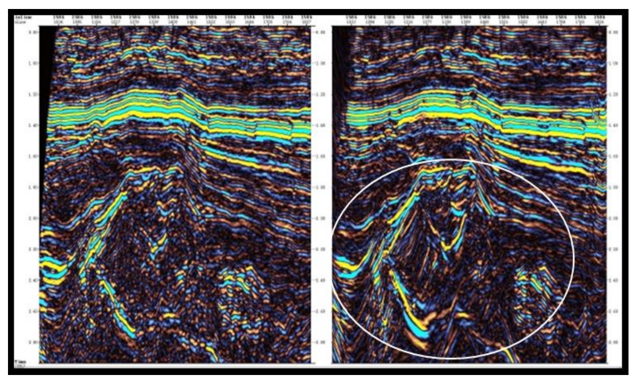

Fig8: Comparision of PSTM Stack and of Scaled CRAM Stack (zoomed).

CASE-3

In this case, the data is taken from Krishna Godavari Basin of southern India. The objective is to evaluate hydrocarbon prospects in Cretaceous sediments and identify structural / strati-structural entrapments. The zone of interest is 1500 m to 4500 m (depth) and 1200 ms to 3200 ms (time). The objective could not be achieved through Kirchhoff's migration shown in Fig9 &10. Whereas the CRAM results show marked improvement in imaging in terms of continuity and reflection strength.

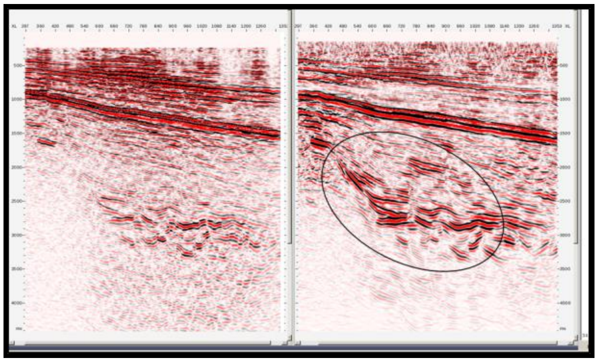

Fig9: Comparision of PSTM Stack and of Scaled CRAM Stack

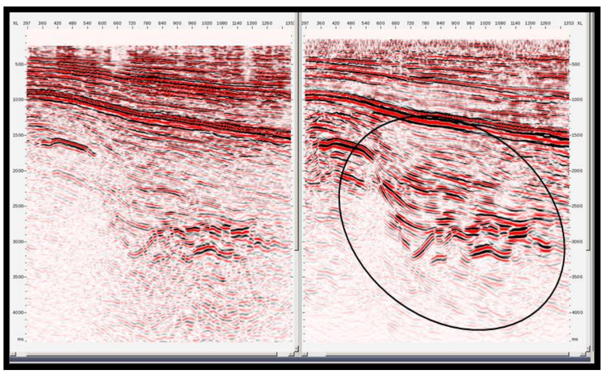

Fig10: Comparision of PSTM Stack and of Scaled CRAM Stack

CASE-4:

In this case, the data is taken from Cauvery Basin of southern India. The objective of the survey was detailed mapping of the reservoirs within Eocene, Oligocene and Miocene. Structural and strati-structural entrapment models are envisaged in the area. Zone of interest lies between 720 -1850 ms in time& 700 -2200 mts in depth. The exploration interest in the deeper sections (~ 4000 m) has gained momentum with the discovery of hydrocarbon from basement. The Seismic data, after pre-processing and conditioning, was migrated using Kirchhoff's migration algorithm and Common Reflection Angle Migration (CRAM) in depth domain to study the feasibility ~~to~~ for bringing out the desired images from deeper parts of the area. The subsurface image brought out by CRAM has shown better reflection continuity along with bringing out subtle stratigraphic features in the area as shown in the fig11 & 12

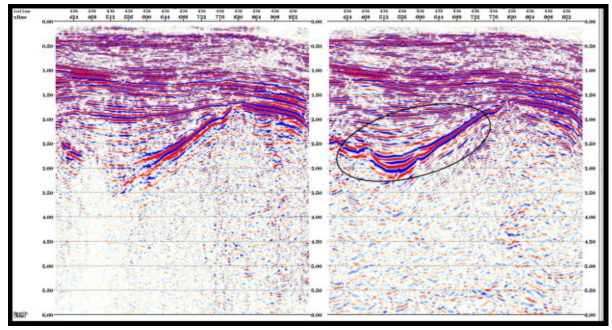

Fig11: Comparision of PSDM Stack and of CRAM Stack

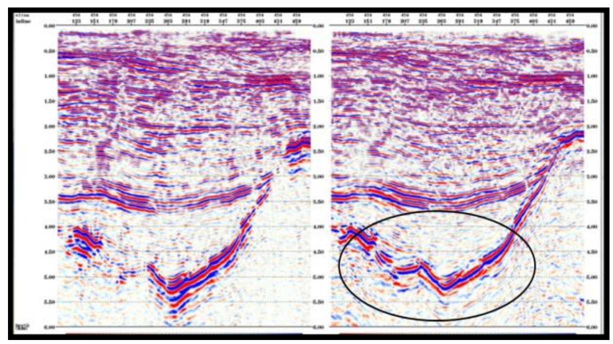

Fig12: Comparision of PSDM Stack and CRAM Stack

CASE-5:

This is a 3D data set from the North-Eastern part of the India where reservoir sands within sylhet limestone and kopli shales, could not be properly resolved with available PSTM images. was attempted to bring out the desired results as shown in Fig13,14,15,16.

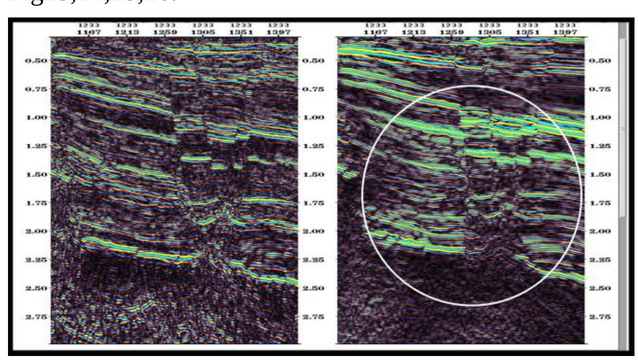

Fig13: Comparision of PSTM Stack and of Scaled CRAM Stack

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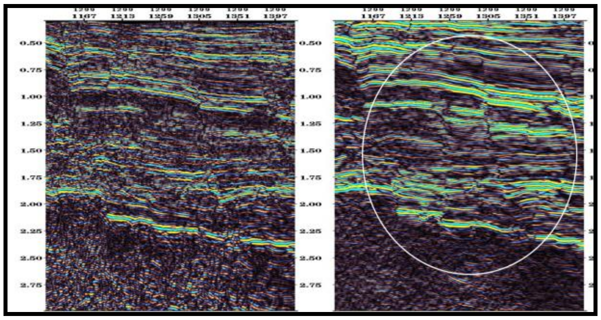

Fig14: Comparision of PSTM Stack and of Scaled CRAM Stack

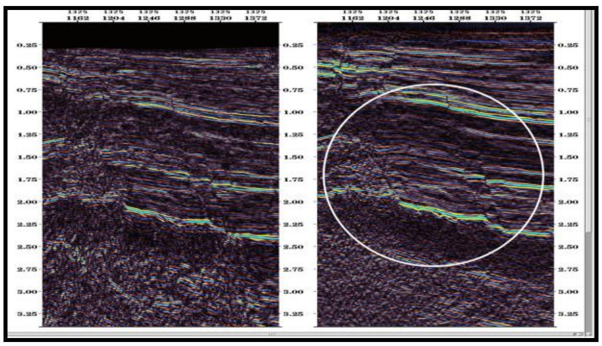

Fig15: Comparision of KPSTM Stack and Scaled CRAM Stack

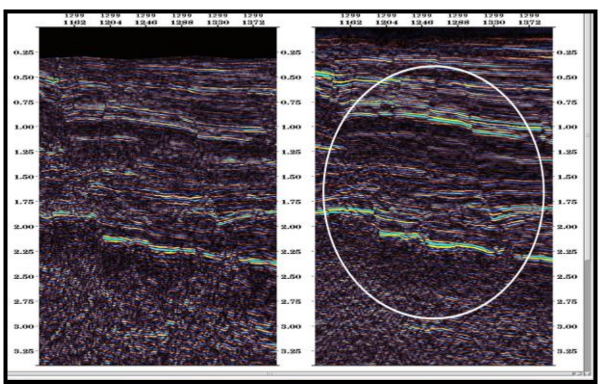

Fig16: Comparision of KPSTM Stack and Scaled CRAM Stack

Conclusion

- From the study (Case-4) it is clear that in Kirchhoff's Migration signal strength and quality of imaging is not adequate as compared to CRAM for mapping basement boundaries for the same interval velocity used in migration.
- The comparison of images obtained from CRAM migration scaled to time domain shows remarkable improvements over Kirchhoff's time migration for delineation of synrift (Case-2 and Case-3).
- CRAM images are more focused and crisp as compared to Kirchhoff's images. The fault planes and reflections from deeper section are better in CRAM images (Case-5)
- Comparison of KPSTM, KPSDM, and CRAM images with RTM, Gaussian Beam migration and wave equation migration could not be possible due to non- availability of images.
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References

Koren,Z.X Sheng. and D.Kosloff,2002, Target-Oriented Common Angle Migration:72nd SEG Exposition and Annual International Meeting, Expanded Abstracts, 1196-1199

D P Sinha , D K Visnoi et.al. A brief comparison of the efficacy of four migration algorithms- a sub basalt example

Koren.Z, and Ravve, I, Barttana ,A, and Kosloff,D(2007) . Local Angle Domain In Seismic Imaging, In Expanded Abstracts, EAGE, London.

Deregowski, S. M., 1990, Common-offset migrations and velocity analysis:
First Break, **8**, 224–234.

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