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Improved Imaging through Pre-stack Trace Interpolation for missing offsets of OBC data – A case study from North Tapti area of West Coast, India

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Summary:

The inadequate coverage of seismic data in congested/ logistically constrained areas often result in data gaps/low foldage due to missing offsets (traces) . This affects the data processing and noise elimination becomes challenging due to introduction of footprints as well as aliasing of the noise band resulting in poor imaging through PSTM. The offset regularization through pre-stack interpolation as a precursor to pre-stack migration helps us to improve seismic image. In this paper, the impact of Pre-stack interpolation is analyzed and used to interpolate the missing traces for regularize the data gap within a gather. The interpolation appears to be a viable solution pertaining to foldage enhancement and adequate noise elimination before imaging. This is enunciated in present case history pertaining to OBC data acquired using orthogonal shooting geometry. In the orthogonal acquisition, the azimuth-offset distribution has a more even distribution in the azimuth domain whereas the conventional parallel acquisition geometry has a more restricted azimuth range. However, significant acquisition footprints/noise is expected from the orthogonal acquisition due to low foldage/missing offsets at shallower level. The problem becomes more severe in the presence of obstacles. Adequate fold recovery of missing offset/traces is mandatory to achieve a good image. The present study shows that the Pre-stack interpolation can lead to a considerable improvement in the final processed image of 3D seismic data acquired using orthogonal shooting geometry.

Introduction:

In seismic imaging our main goal is to yield an artifact-free image of the subsurface with optimal resolution with true amplitude preserved seismic event. Artifact-free seismic imaging requires perfect surface and subsurface sampling in the common shot, receiver, offset, azimuth, and CMP domain, which is difficult to achieve in practice. A compromise is often required for cost reduction. The CDP technique was introduced by Mayne in 1962 (Mayne, 1962) with the assumption of regular distribution of offset within a CDP gather, it leads to many advantages like enhancement of S/N ratio by out of phase stacking of multiples and in phase stacking of primaries.

In the orthogonal acquisition, the azimuth-offset distribution has a more even distribution in the azimuth domain whereas the parallel acquisition on average has a very limited azimuth range (Jan H. Kommedal, 2002). With the increased azimuth distribution in orthogonal pattern of acquisition, the imaging of the reservoir should improve because seismic rays illuminate the reservoir from different azimuthal orientation. Increased azimuth distribution is also advantageous for analysis of azimuthal anisotropy and velocity estimation but the foldage variation also affects the stack quality at sporadic location.

The OBC survey is designed with orthogonal shooting i.e. source and receiver line to orient orthogonally from one another is very common in seismic industry for better subsurface imaging. Some of the other advantages of OBC over towed steamer surveys are the flexibility of acquisition geometry, greater surface consistency, more convenience in working around logistically constrained areas and , the use of dual sensors adequately remove ghosts and layered reverberations etc (Noel Zinn,1999).

For obvious reason, in OBC data the near offset will be missing on the subsurface line generated from the source away from the receiver line. This may introduce

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artifacts/noise (FIG. 1) in the pre stack gather and foldage loss is also eminent. Adequate fold recovery is mandatory to achieve a good image. We may have two types of distinct problems in any data – first is presence of more than one trace per offset class and second is absence of some offset classes in 3D bins. The problem of missing data/offsets may be effectively handled by pre-stack interpolation.

Pre-stack interpolation:

Pre-stack Interpolation estimates the coherent components for the traces in the gate centered at the output interpolated trace location along a moving window of the size of the spatial gate at each of the dips specified by maximum dip and maximum frequency used in the data analysis. The two neighboring input traces are then used to interpolate or extrapolate the output trace along the coherent dips. Interpolation is used when the new output trace lies between two neighbouring input trace. Extrapolation will be used if there are not traces on both side of the output trace but at least two traces exist on either side of the output trace.

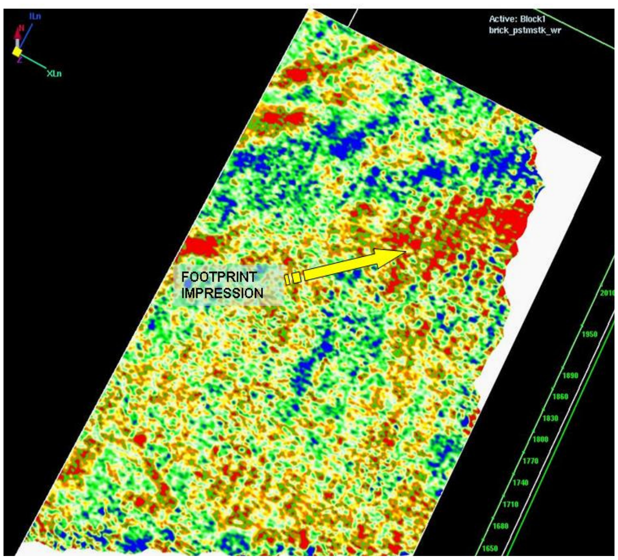

Figure 1: Time slice at 800 ms shows the footprints before interpolation

To obtain the interpolated traces, the coherence function is evaluated for all dips, the peak coherencies are found and interpolated to their exact dip values, and then sorted from largest to smallest coherency values. By examining the coherency and its ratio to other picked coherencies, the module then determines how many dips should contribute to the interpolation for the corresponding output sample. The two nearest traces then used to interpolate along the automatically picked dips to create the output sample value. This process is repeated for each output sample.

Real Data Example:

In the present study, a 3D OBC shallow water seismic data volume from offshore India (FIG. 2) , is used to demonstrate the effect of missing traces in the CDP gather using pre-stack interpolation on the stack and subsequent pre stack migration. This survey was designed for the source and receiver lines to lie orthogonally from one another. This allowed for good overall fold and wide azimuth, but left for an unequal distribution of fold in the four offset ranges of interest (Table 1). The amount of fold per depth point increased as offset increased, which is standard for this design of survey. The near offset quarter had the lowest fold of the four offset groupings, leading to a slight acquisition footprint in the shallower part of stacked data.

The detailed acquisition parameters are given in Table 2. The survey area was shot merging two designs (design 1 and design 2), in order to get a better bin fold coverage in the near offset ranges. The second design improved greatly the fold coverage in the near offsets domain to enhance the seismic data quality.

Table 1: Fold Offset Distributions

OFFSET RANGES	FOLD COVERAGE	TOTAL FOLD COVERAGE
0 – 1250	7	
1250 – 2500	13	
2500 – 3750	10	
> 3750	12	42

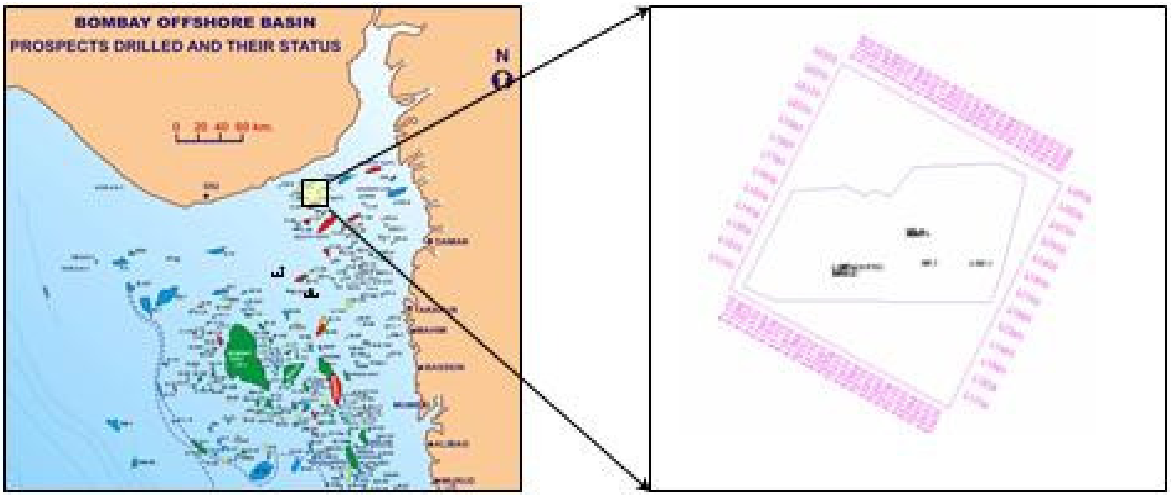

Figure 2: Prospect map of study area

Table 2: Acquisition Parameters :

Parameter	**Design 1**	**Design 2**
Receiver Station Spacing	50 m	50 m
Receiver Line Spacing	400 m	400 m
Source Station spacing	25 m	25 m
Source Line spacing	400 m	350 m
No. of source per line	192	128
Total channels active	208 x 2 x 2 = 832	210 x 2 x 2 = 840
Source pattern	Orthogonal to receiver line	Orthogonal to receiver line
Nominal Fold	42 – 50	42 – 50
Bin Size	12.5 x 25 m	12.5 x 25 m
Maximum offset	5000 m	5000 m
Source	Airgun	Airgun
Sample Interval	2 ms	2 ms
Record length	6 ms	6 ms

Processing effort:

The conditioning of data for removing the ghosts was carried out. The hydrophone and geophone information for each channel was summed, random and coherent noise was minimized, and correction for the tidal conditions of the area applied. The receiver-side ghost multiple due to the free-surface in the hydrophone data was attenuated by choosing appropriate receiver weights for the geophone data, weighting the geophone data, and then summing the hydrophone data with the weighted geophone data by dual Sensor Summation (DSS) (Barr F.J. 1997) .

In addition to the receiver ghost, there is a source ghost present in the hydrophone and geophone data as well. The source ghost adds constructively during DSS and its effect on the data is handled in deconvolution. Using the source signature, an operator was derived to convert the source signature into its minimum phase equivalent. This operator was then applied to the data prior to surface consistent Deconvolution.

Pre-stack interpolation is used to interpolate the missing traces to regularize the data gap within a gather. The results are compared visually on CDP gather, stack section and PSTM Stack section & time slice. The output was also compared with earlier processed volume. It was felt that missing trace interpolation technique on pre stack gather is helping to eliminate some of the problems encountered.

Analysis:

Impact of Pre-stack interpolation is analyzed on gather, stack section and on pre stack migrated data. Pre stack time migration of CMP gather with and without interpolation is carried out. Fig. 3 shows a CDP gather with and without pre-stack interpolation. The interpolation has filled the missing offsets and has also improved the signal to noise ratio on the gather. The reflection events look more coherent and considerable improvement is visible at the shallow part of the gather where the near offsets were missing. The effectiveness of Pre-stack interpolation is very well evident on the seismic section illustrated in (Fig. 4). Appreciable improvement in the overall signal to noise ratio and improve of continuity of the events in the section is achieved with Pre-stack Interpolation. Missing data gaps get filled up after interpolation and reflection events look more coherent. More appreciable improvement is observed in PSTM gather, section and Time slice. Reflection events look more coherent in PSTM gather with interpolation as shown in FIG. 5. Signal to noise ratio has improve appreciably. FIG. 6 show the comparison of PSTM section with (b) and without (a) interpolation. Image has become more sharper and the reflection event looks more focused and continuous after Pre-stack trace interpolation. Fig. 7 shows amplitude time slice at 800 ms taken from 3D PSTM volume before (a) and after interpolation (b). Appreciable improvement in S/N ratio is also visible in slice. Footprints/noise visible in the earlier section, may result in incorrect interpretation, have been significantly dropped.

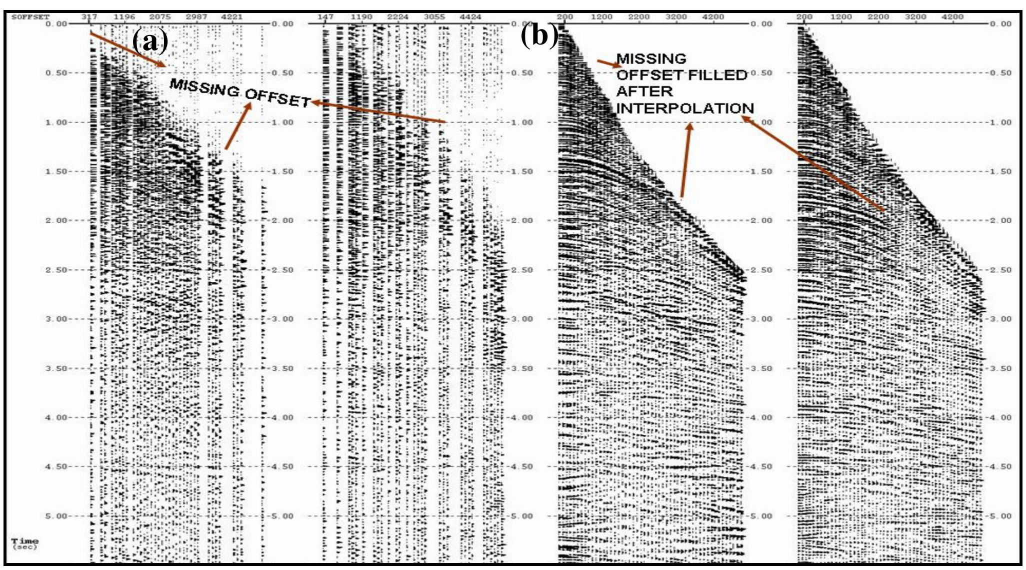

Figure 3: CMP Gathers before (a) and after (b) pre-stack interpolation. Missing offsets are filled after interpolation and the S/N ratio is improved

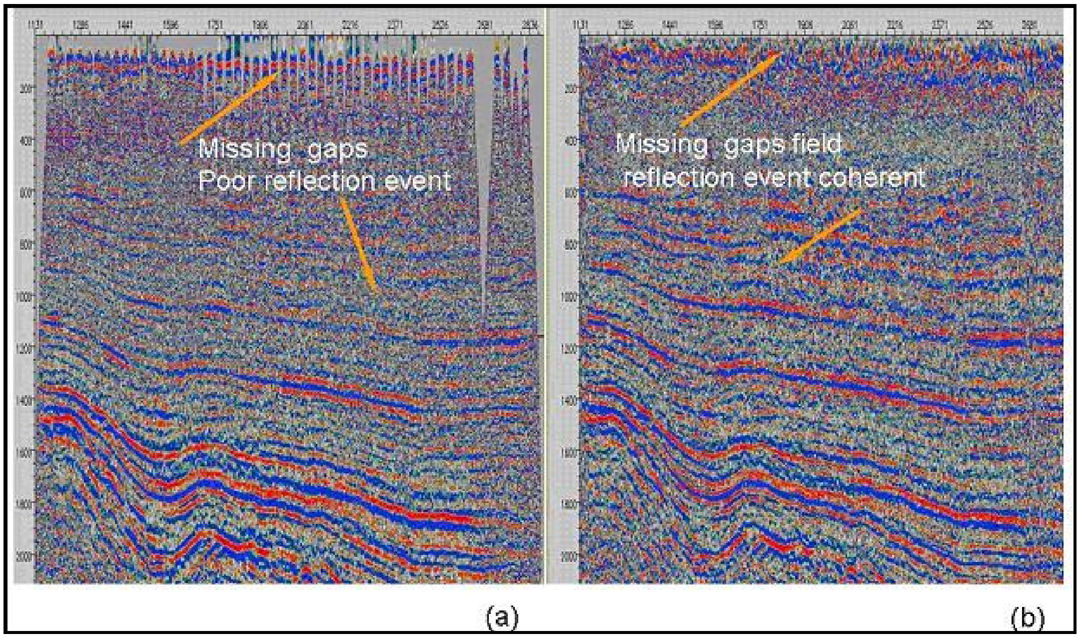

Figure 4: Inline stacks before (a) and after interpolation (b). Missing data gaps get filled up after Pre-stack interpolation and reflections look more coherent.

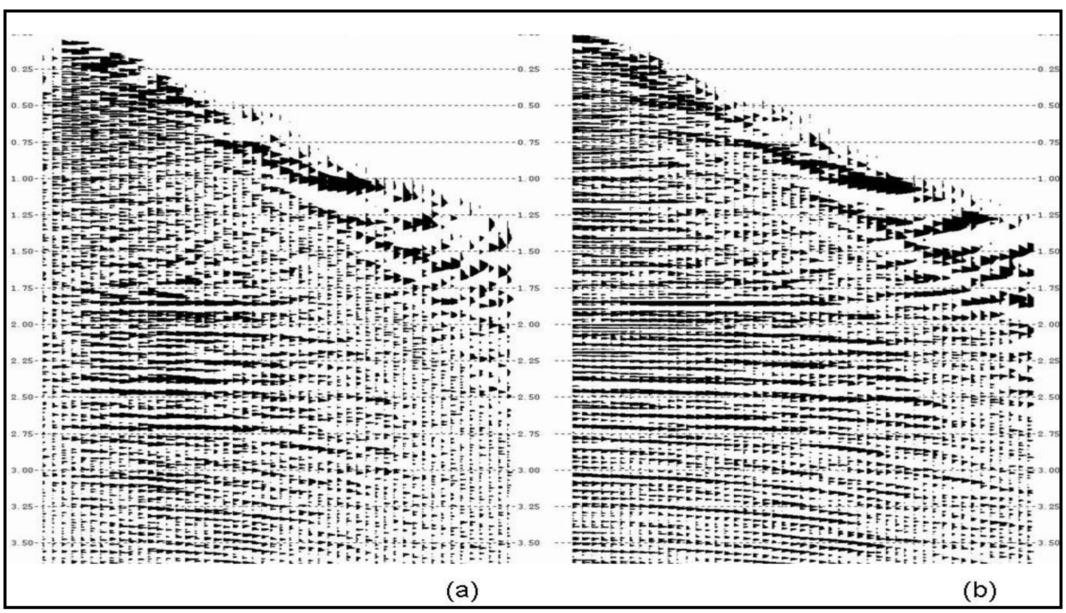

Figure 5: PSTM gathers before (a) and after interpolation (b) improves the signal to noise ratio and reflections look more coherent.

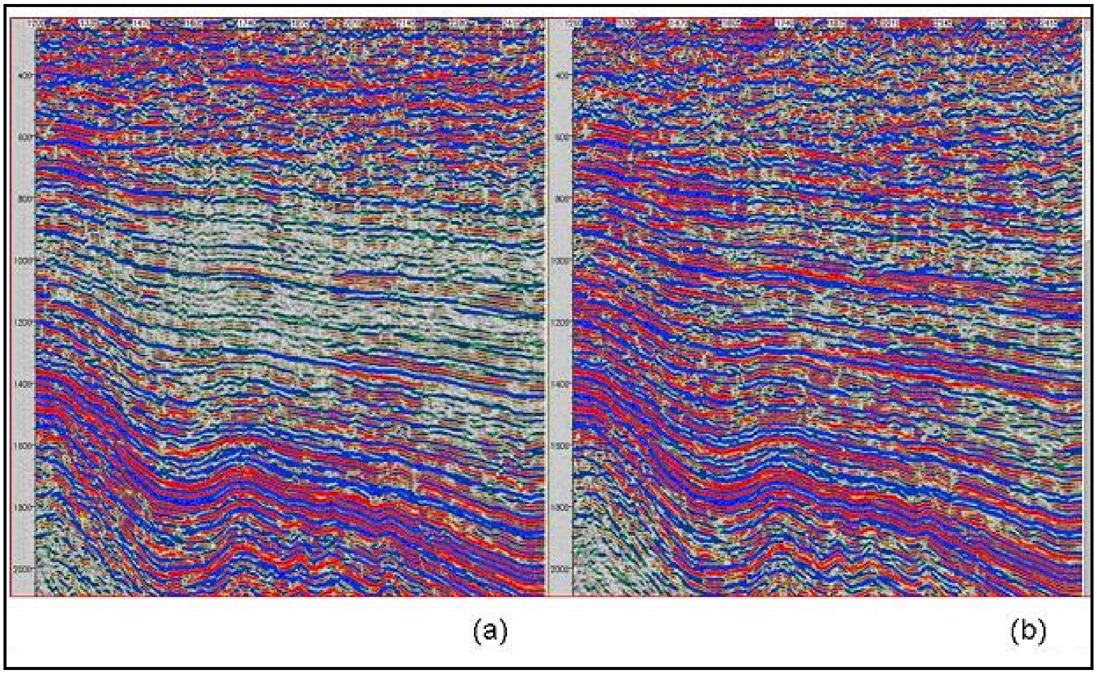

Figure 6: Inline PSTM section before (a) and after interpolation (b). The reflection event looks more focused and continuous.

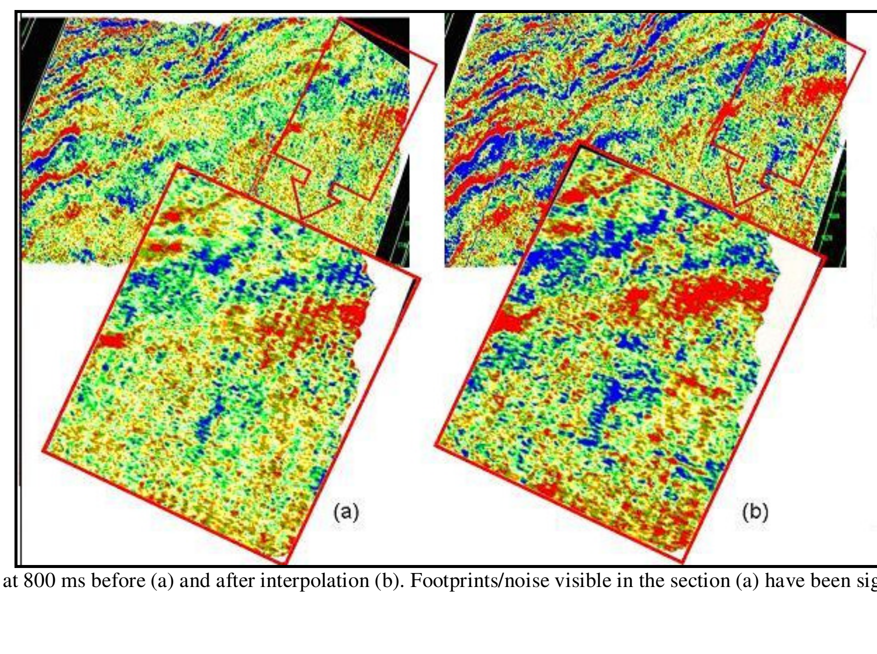

Figure 7: Time slice at 800 ms before (a) and after interpolation (b). Footprints/noise visible in the section (a) have been significantly dropped (b)

Value Addition:

The present PSTM volume has been compared with earlier processed output of the area and significant value addition has been achieved. FIG. 8 & 9 show the comparison of a inline and crossline sections with earlier processed sections. FIG. 10 show the time slice at 1500 ms. From these figures it can be concluded that:

- Reflection events look more focused and continuous with enhanced strength.
- The fault patterns are more clearly seen which are crucial from the entrapment point of view.
- Resolution & S/N ratio is appreciably improved.
- Events between Mahim and H4 (Panna) which are prolific producing are better developed.

Conclusion:

The pre-stack trace interpolation technique used for filling the gaps and missing offsets has appreciably improved the processed image thereby leading to a meaningful interpretation. In addition, it has effectively removed acquisition footprint which may be a hindrance to subsequent attribute analysis.

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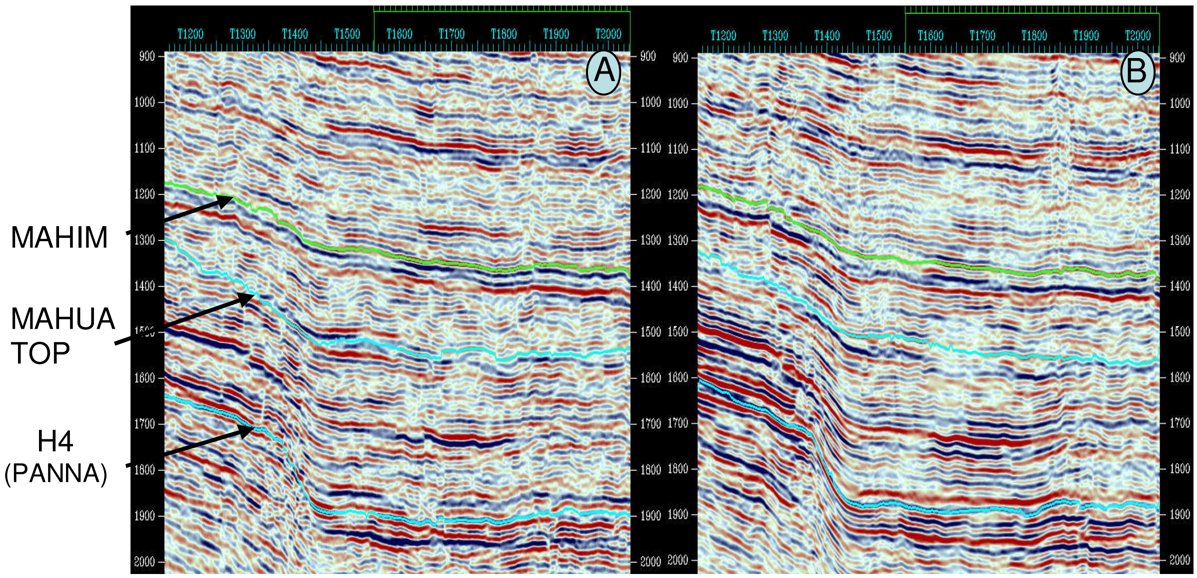

Figure 8: Comparison of Inline section between earlier processed (A) & currently processed (B). Events are Better imaged in (B).

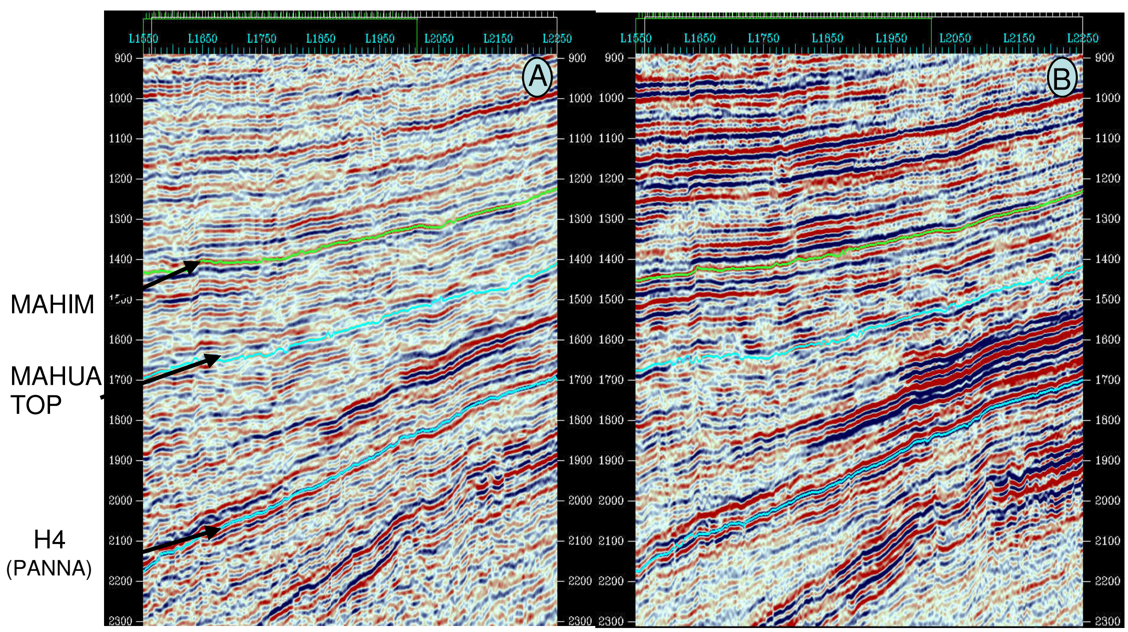

Figure 9: Comparison of Xline section between earlier processed (A) & currently processed (B). Events are Better imaged in (B).

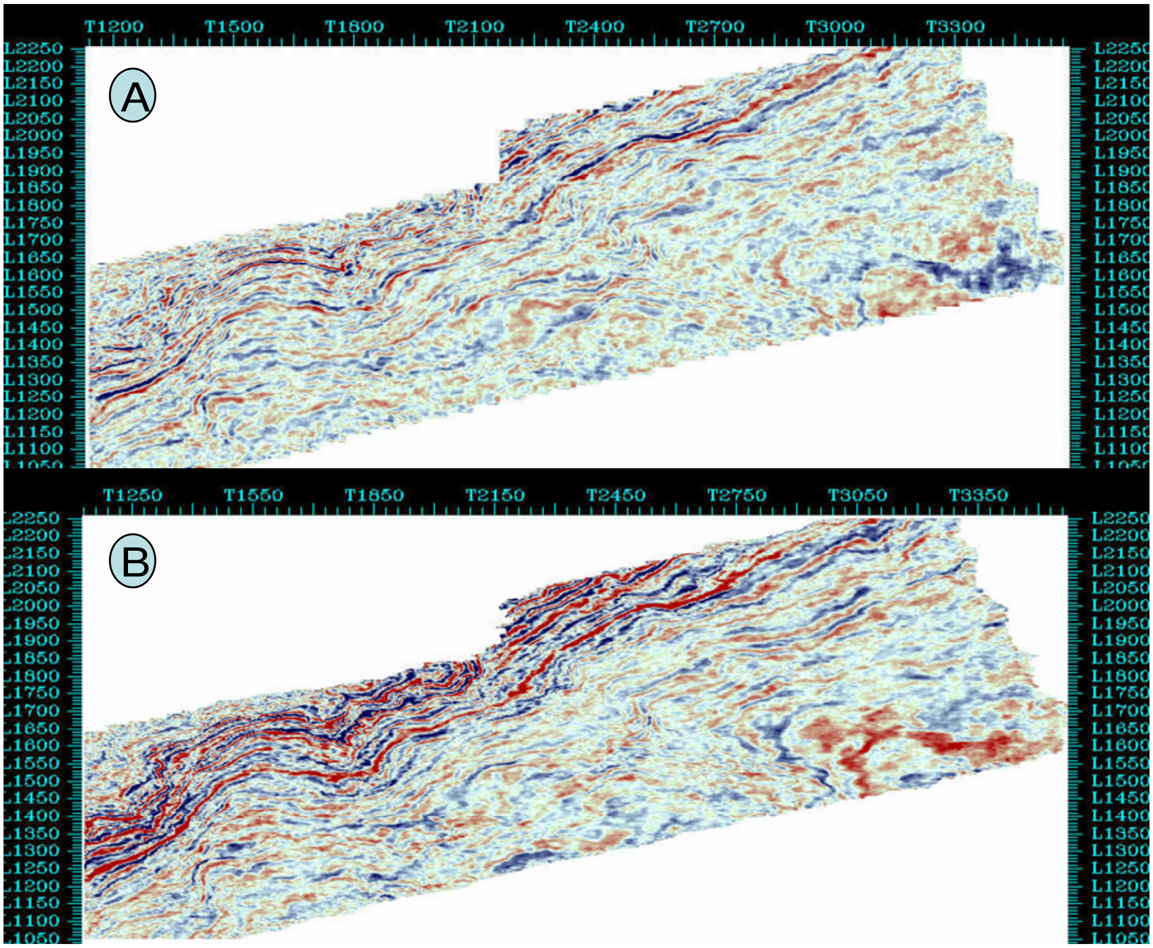

Figure 10: Comparison of Time slice at 1500 ms between earlier (A) currently processed (B).