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Target oriented enhanced seismic imaging in Upper Assam basin: a case study

Summary

The basic objective of re-processing of a particular seismic dataset lies in extracting and bringing out more information in terms of both structural as well as stratigraphic elements. The growing emphasis and requirement of reservoir geophysics studies in the field of seismic interpretation and location proposal, have increased the requirement for gathers which are AVO friendly and amenable for reservoir geophysics studies. Advancements in seismic processing techniques and algorithms have been occurring at an rapid rate and thus it has been possible to extract missed/ meaningful information from vintage datasets as well as use processes to prepare, treat and generate deliverables which are more amenable for interpretation.

The area of study is located in the Assam Arakan Basin, situated in the state of Assam in north East India. The decade old 3D seismic campaign in the area was acquired with reasonable parameters, however the processing at that time was carried out to resolve the shallower horizons, which were the main producing reservoirs at that time, however there was a significant scope of improvement of the deeper targets.

Advanced statics algorithms and adaptive noise attenuation schemes have been used to achieve the aforesaid challenges. Special emphasis was given to pick accurate velocities at deeper levels by using horizon-guided methods. 3D regularization & interpolation was used not only to reconstruct shallow offsets but also to improve mappability and resolution at the deeper stratigraphic horizons. Special multiple attenuation techniques were used to make the gathers multiple free. All methods used were surface consistent in nature to preserve original nature of amplitudes and make the final gathers ready for reservoir geophysics studies.

Final results compared with vintage datasets show significant improvements in general and more so specifically met the objective of imaging the deeper stratigraphic horizons with better structural continuity and resolution, that could either not be imaged earlier or those which lacked sufficient coherence to be confidently picked up for mapping during seismic interpretation.

Introduction

The study area is a part of the Assam Arakan Basin with most of its area lying in the foreland part of the basin. Towards the south of the block, runs the Naga thrust, and its manifestation is clearly visible in the raw shot records characterized by poor S/N ratio, noise trains and dispersion of energy in this part of the block. This part of the basin where the block lies, has been in production for quite some time now from the Oligocene reservoirs, however Eocene reservoirs were discovered later and added to production. The vintage seismic image is constrained by poor illumination of the deeper target formations in terms of structural details and confident mapping. The challenges are three fold. Firstly, the imaging near the thrust was quite obscure, leading to ambiguities in interpretation. Secondly, continuity in reflectors and structural details in mapping required substantial degree of improvement in the deeper Eocene levels. Third, was the need for amplitude preserved processing of the gathers and de-multiple in order to carry out reservoir studies. Fig 1 & 2 show vintage stack and gathers through which it is evident the need for reprocessing. The boxes in the figures show areas where improvement is desired.

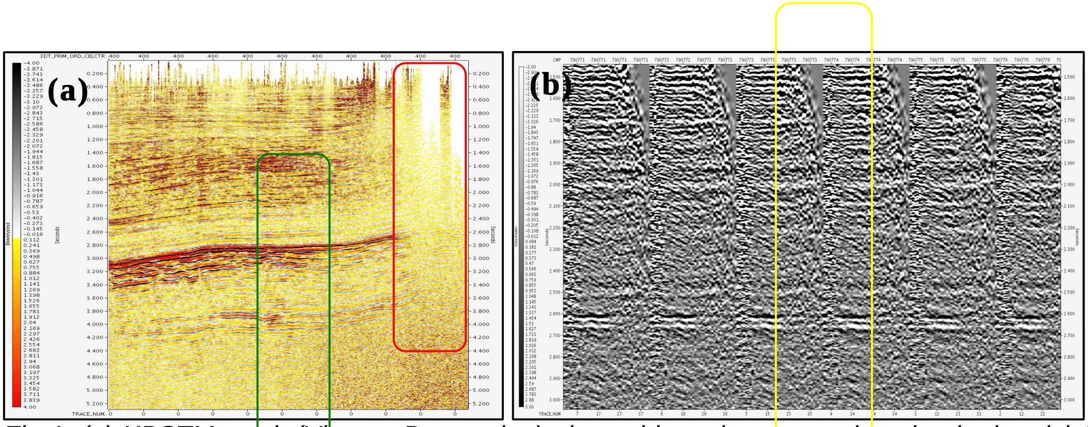

Fig 1. (a) KPSTM stack (Vintage Processing); the red box shows poor imaging in the vicinity of thrust, green box shows poor illumination in the deep reservoirs & (b) Migrated CMP gathers (Vintage Processing) showing presence of multiples (yellow box)

Methodology

All processes used were amplitude preserved in nature. Special emphasis was given to derivation of statics by computation of accurate near surface velocity model through Tau-P refraction tomography using first breaks. Specially designed adaptive noise attenuation techniques were used in various domains to treat noises in a phased manner. Multiples were removed in Tau-P domain using parabolic radon transforms.

Near Surface Modeling

Determination of Near Surface velocity model was carried out with the help of Tau-P tomography. It involves two steps, first decomposes the first arrival picks to a best-fit 3D Tau-P representation using linear inversion that does not require explicit ray tracing or an initial model, the second step is an integral transformation that builds the 3D velocity-depth model from tau-p representation.

Following is the procedure for calculation of statics at any particular station:

1. The first term is the vertical traveltime through the velocity model from the station elevation down to an intermediate datum.
2. The second term is the vertical traveltime from the intermediate datum up to the final datum using a replacement velocity. These statics are long-period as they correspond to the smoothed velocity model.

The final statics is the result of difference between the above two terms.

Fig 2. (a) shows the derived near surface velocity model. It is pertinent to note that towards the south of the block there is a sharp increase in velocity and this trend matches fairly well with the surface imprint of thrust. Modeling these velocities were very crucial as these contributed in proper calculation and resolution of statics in the supra-thrust portion of the block.

The statics is then derived from the near surface velocity model as discussed above. The correctness of the derived statics solution can always be judged by looking at the stack volumes. Refraction statics is derived correctly must deliver a better stacking response in comparison to elevation statics as it compensates both for the surface elevation as well as the near surface velocity variation. Fig 2 (b) & (c) show a comparison between the stack with elevation statics and refraction statics applied respectively.

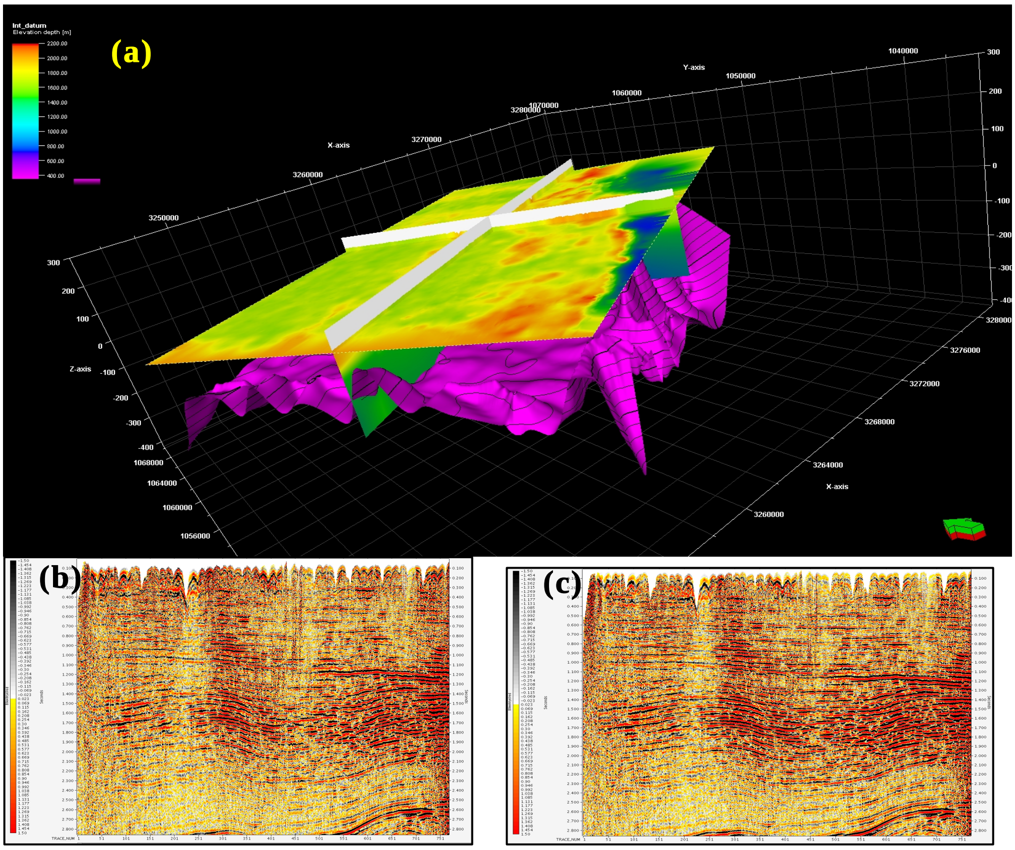

Fig 2. (a) Near Surface Velocity Model; (b) Stack with elevation statics; (c) Stack with refraction statics

Adaptive Noise Attenuation schemes

Noise attenuation was carried out in different domain to treat specific types of noises. Adaptive schemes were aimed at deriving the noise model from the data based on certain characteristics and then adaptively subtracting it from the dataset. Suppression of coherent noise was attempted in frequency-space (F-X) domain and is provides control over both the frequency as well as velocity range of the coherent noises. This is accomplished by azimuthally binning each gather prior to filtering. Each azimuth was then filtered independently using f-x domain fan filters and a least-squares optimization scheme. Noise is then estimated for a specific range of apparent velocities and then subtracted from the input data. Fig. 3 shows the application of coherent noise suppression on gathers.

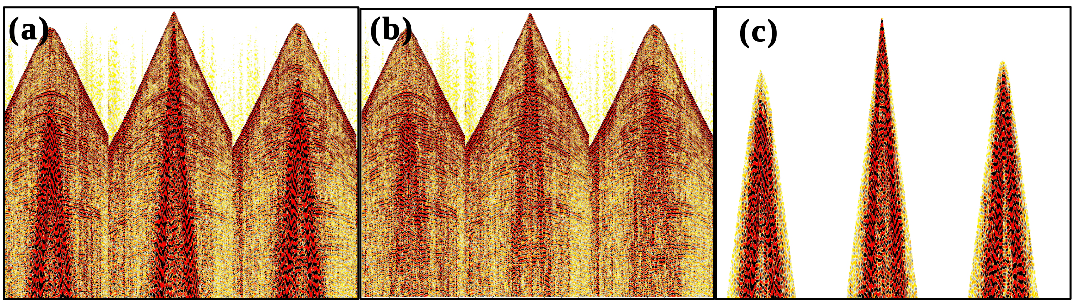

Fig 3. (a) Shot gather before; & (b) after application of adaptive coherent noise attenuation; (c) Difference plot

Noise attenuation in cross spread domain was another effective method for suppression of linear noises in the data. An areal group allows better control over the data in 3D sense as offsets and azimuths of proper distribution can be grouped into one gather.

Horizon Guided Velocity Analysis

Conducting horizon guided velocity analysis at incremental steps during the entire sequence ensure accurate picking of velocities and preservation of geologically conformable nature of the derived velocity volume. Four(4) major horizons interpreted from the vintage data were loaded to conduct velocity analysis. This was a crucial step in mapping details in the deeper layers as the velocity consistency not only at the target level, but in an aggregate is required for successful imaging at any level. Fig 4 shows horizons superimposed on semblance panel and velocity superimposed on stack.

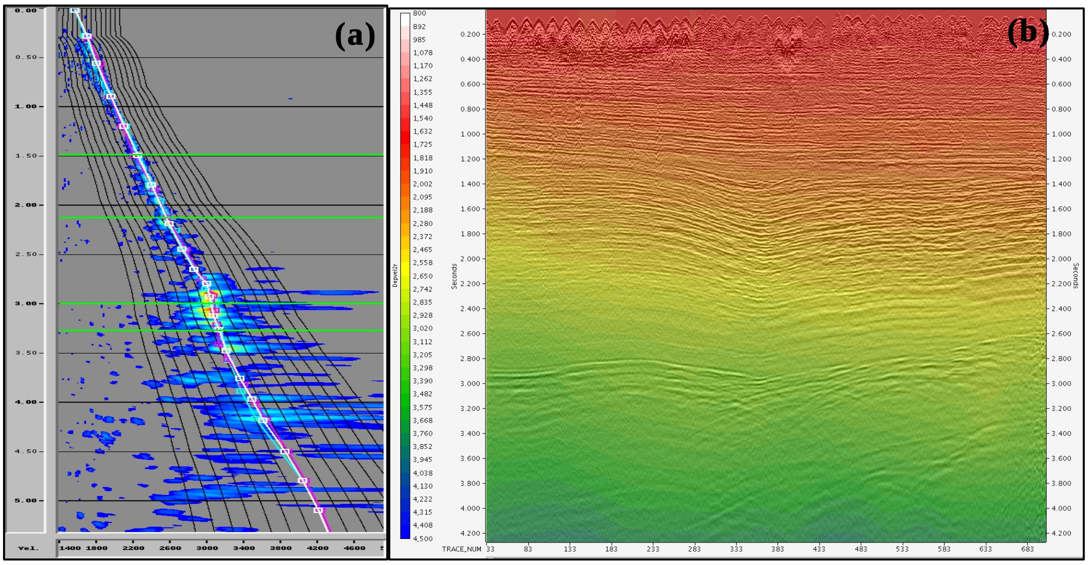

Fig 4.(a) Horizons (green) overlay on semblance panel; (b) Velocity overlay on stack

Interpolation & Regularization

3D interpolation of the dataset was carried out which ensured better illumination of the deeper levels as well as reconstructed the missing shallow offsets. The regularization method uses an iterative procedure for computing the spectrum of irregularly sampled data. For every iteration, a discrete Fourier transform is performed. Then, the maximum Fourier component is selected and transformed back to the irregular grid. The component is subtracted from the input data, and the result is used in the next iteration. Fig 5 shows effective reconstruction of shallow offsets in stack.

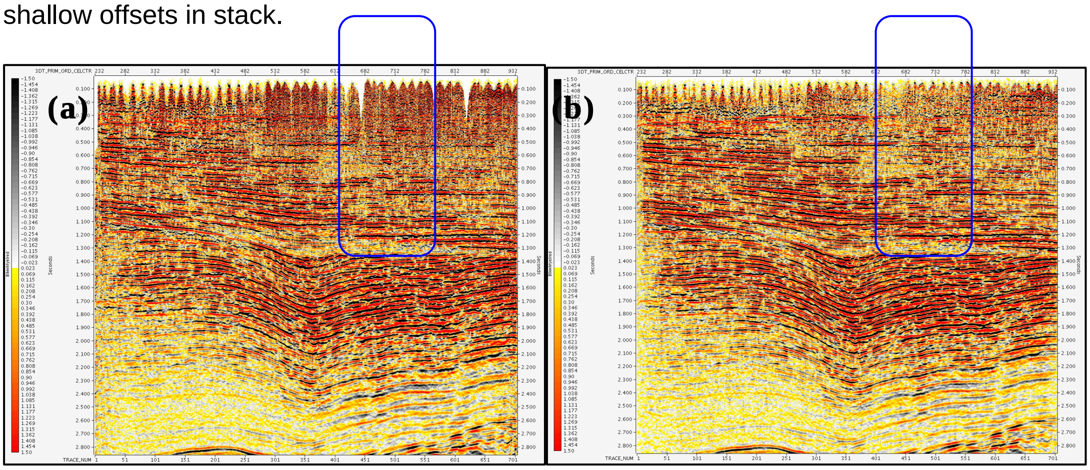

Fig 5. (a) Stack before & (b) after interpolation showing reconstruction of shallow offsets

Demultiple

The data consisted of several distinct long period multiples at the reservoir level. The distinguishing characteristics of the long period multiples are the moveout difference compared with the primaries at the same level. The property was used to eliminate mutiples using Parabolic Radon transform thus making the gathers more favourable for any kind of reservoir studies.Parabolic Radon transforms seek to improve the focusing of events in the Radon domain over that provided by conventional transforms. This improved resolution is achieved by including prior information about desirable characteristics of the model into the transform. The prior information usually takes the form of weights in the model domain, chosen to improve the sparsity of the model whilst still modeling all of the data. Improved focusing in the Radon domain improves identification and separation of signal and noise trends, with reduced artifact levels. Fig 6 shows the effect of Parabolic radon demultiple on CMP gathers.

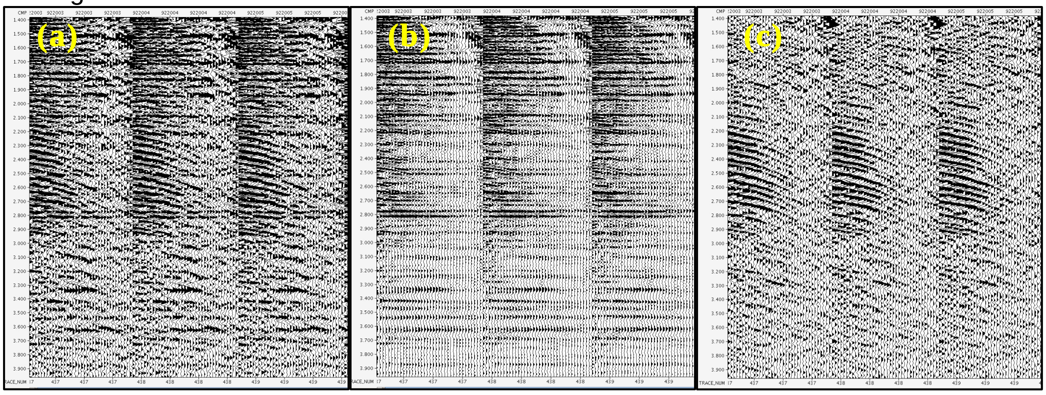

Fig 6. (a) CMP gather before (b) & after (below) demultiple; (c) Difference

Comparison of results

All the processes discussed previously in the paper helped in improvement of image quality as well as meeting the tagets originally chalked out for re-processing of the data. The final images of stacks, gathers and time slices have been compared against the vintage processing to demsonstrate the success of processes used in achieving the goals. Fig 7 to 10 show comparison of vintage & reprocessed data.

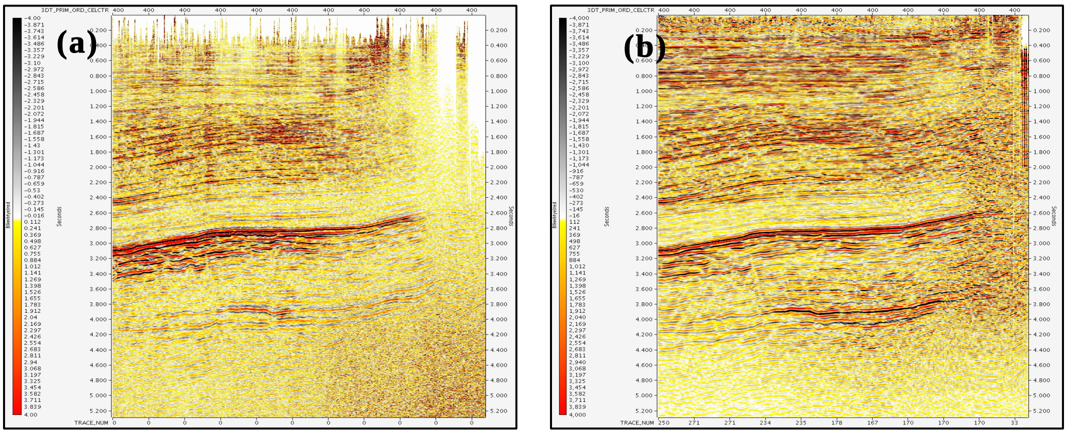

Fig 7. Stacks X-line comparison- (a) Vintage & (b) Re-processed

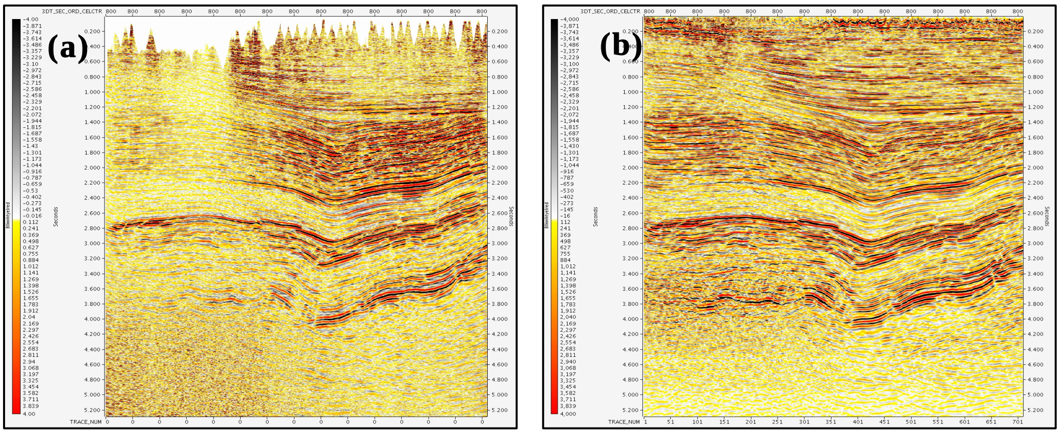

Fig 8. Stacks In-line comparison- (a) Vintage & (b) Re-processed

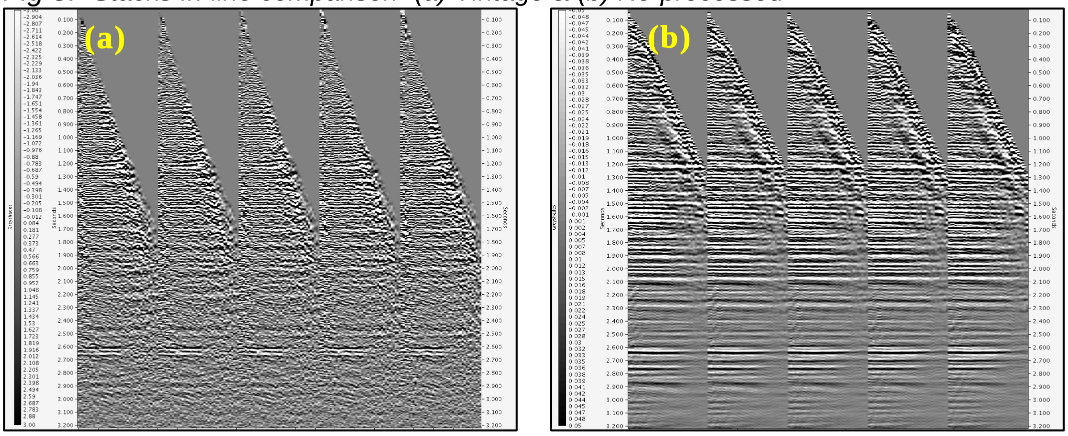

Fig 9. CMP gathers comparison- (a) Vintage & (b) Re-processed

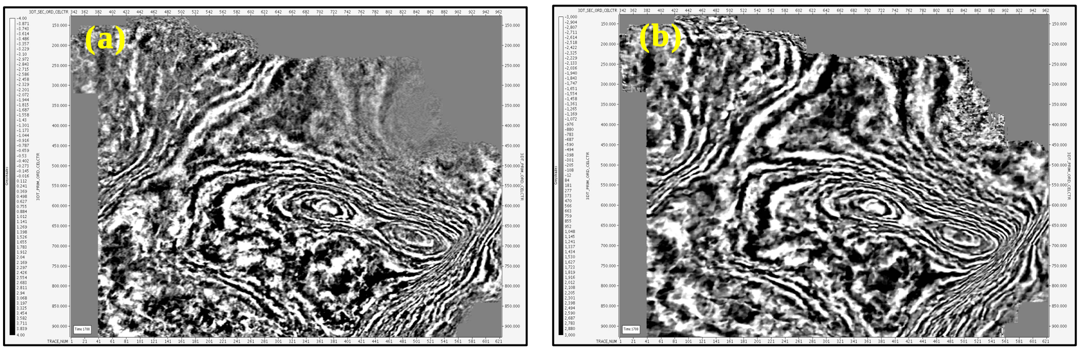

Fig 10. Time slice comparison- (a) Vintage & (b) Re-processed

Conclusion

The results presented in this paper clearly show the benefits of target oriented processing and proper planning and execution of steps towards achieving the goal. Within the ambit of the dataset, the results show enhanced quality and accuracy of the final gathers and stack images. The results of the study can be reliably used for better AVO and inversion results. In this study, the increase in mappability and resolution of the deeper Eocene horizons could be achieved through a cascade of processes, each having a significant contribution towards the final stack volume as well as the gathers.
After comparison with the vintage dataset, it can be concluded that the final images can be reliably used for better interpretation and shall provide more confidence in the Eocenes levels and in the vicinity of the thrust.
Therefore, from the study it can be inferred that, in seismic data processing, the processes and methodology to be applied must solely depend on the target we are trying to achieve.

Suggested Reading

Mathieu J. Duchesne, Virginia I. Brake,
Tom Brent, 2011, Making New with Old: Reprocessing Vintage Seismic Data from the Western Arctic Islands using Modern Methods, CSPG, CSEG, CWLS Convention

Acknowledgement

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