MINING INFORMATION FROM VINTAGE 3D SEISMIC DATA BY LEVERAGING THE PROCESSING ALGORITHMS: A CASE STUDY FROM ASSAM SHELF

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ABSTRACT

Seismic data acquisition in Upper Assam shelf region has always been challenging owing to socio-environmental issues. These challenges are now coupled with fast infrastructure development in the region such as the building of roads and housing constructions. Hence, it is imperative to extract maximum benefits out of the vintage datasets through re-processing as it is time-effective, efficient and lower-cost strategy. The objective of this study is to illustrate the extent of benefits possible through reprocessing of legacy seismic data through the application of current seismic imaging algorithms. This work showcases a case study from Upper Assam Shelf Basin, where re-processing was carried out on 3D seismic data acquired in the 1990's. It also highlights how a significantly enhanced subsurface image can be achieved through an improved processing workflow, leading to a remarkable insight for the seismic interpreter even in an already explored region. The re-processing workflow used for mining the information included steps such as refraction statics, noise modeling and attenuation, robust surface consistent deconvolution, regularization and 4D interpolation, 3D Kirchhoff Pre-Stack time migration. Together, these algorithms helped generate a superior sub-surface seismic image in a highly explored area which shall help develop newer insights for future exploration and development avenues in the region.

INTRODUCTION

The survey area is located in the south bank of river Brahmaputra in the upper assam shelf (Figure 1). The 3D seismic dataset used in this study was acquired in the late 1990's in the shelf part of the upper Assam basin with a humble bin size of 25m X 50m, symmetrical split spread with a total of 80 active channels and a nominal fold of 24 (8IL X 3XL). Seismic data acquisition is not only challenging but also expensive to record; This legacy data comprises of areas that are now fast becoming urban centres with limited open areas, thus making the seismic data extremely valuable. The seismic dataset presented in this study was originally processed in early 2000's when computing power was relatively lower and when current processing algorithms were limited or unavailable. By utilizing modern techniques, coupled with software capabilities and High Performance Computation power, this dataset has been transformed to provide geo-scientists gain new geological and geophysical insights.

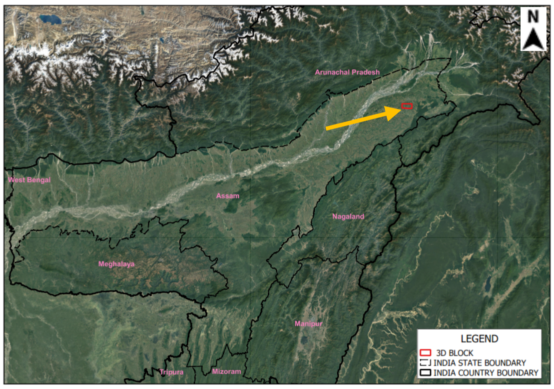

Figure 1. Location of the Study Area

GEOLOGY OF THE STUDY AREA

The Upper Assam shelf, a southeast dipping shelf is the foreland part of Assam-Arakan Basin and is a well-known petroliferous province of India. It is bounded in the north by Eastern Himalayas, in the east by Mishmi Massif, in the south by Naga-Patkai Hills and in the west by the Mikir Hills and Shillong Plateau. A thick pile (about 7000m thick) of sediment ranging in age from Cretaceous to Pleistocene has been deposited in the Basin. To date, commercial hydrocarbon production has been successfully established from Paleocene to Mio-Pliocene sedimentary deposits (Wandrey, C.J.). The present study area is a faulted anticlinal structure bounded by two major faults trending ENE-WSW direction which separates it from the neighbouring hydrocarbon bearing structures. The study area is an elongated dome like structure at Oligocene level with the major axis trending in NE-SW direction. The area has multi-stacked reservoirs within Miocene and Oligocene level.

PROCESSING OF SEISMIC DATA

Seismic data processing and imaging have undergone major upgradations, in part due to exponential increase in computing capabilities and in part due to algorithmic advancements. These advancements have now enabled possibilities to mine hidden details in the legacy seismic datasets. Seismic imaging for land data is a multi-faceted approach for tackling multiple dataset issues such as ground roll and random noise, velocities, data gaps and correct repositioning of seismic reflectors (migration). As the effectiveness of each processing step is connected to the other processing steps, significant attention was focused on noise attenuation, robust deconvolution, multiple passes of velocity analysis, regularization and 4D interpolation and pre-stack time migration. Improved imaging and availability of additional deliverables viz. migrated CMP gathers for quantitative interpretation (AVO/inversion studies) (Malajczuk, S. et. al.) culminates into opened avenues for future exploration and development in the region. The main target for processing of this seismic dataset was to carry out relative amplitude preserved (RAP) pre-stack imaging, to provide geologically conformable seismic image of geological structures, to improve the quality of interpretation of tectonic lines and to enable detailed interpretation of the target horizons (especially the Oligocene age sands).

The major processing steps carried out on this dataset are elaborated below:

A) Surface Consistent Deconvolution

Surface Consistent Deconvolution (SCD) has been carried out to remove source wavelet from the reflectivity. In the present study, SCD was used with a gap of 4 msec which helped in major improvement in vertical resolution of the dataset (Figure 2a). The advancements in the deconvolution algorithms today help us in mitigating the noise already present and generated during the process while increasing the vertical resolution (Figure 2b & 2c).

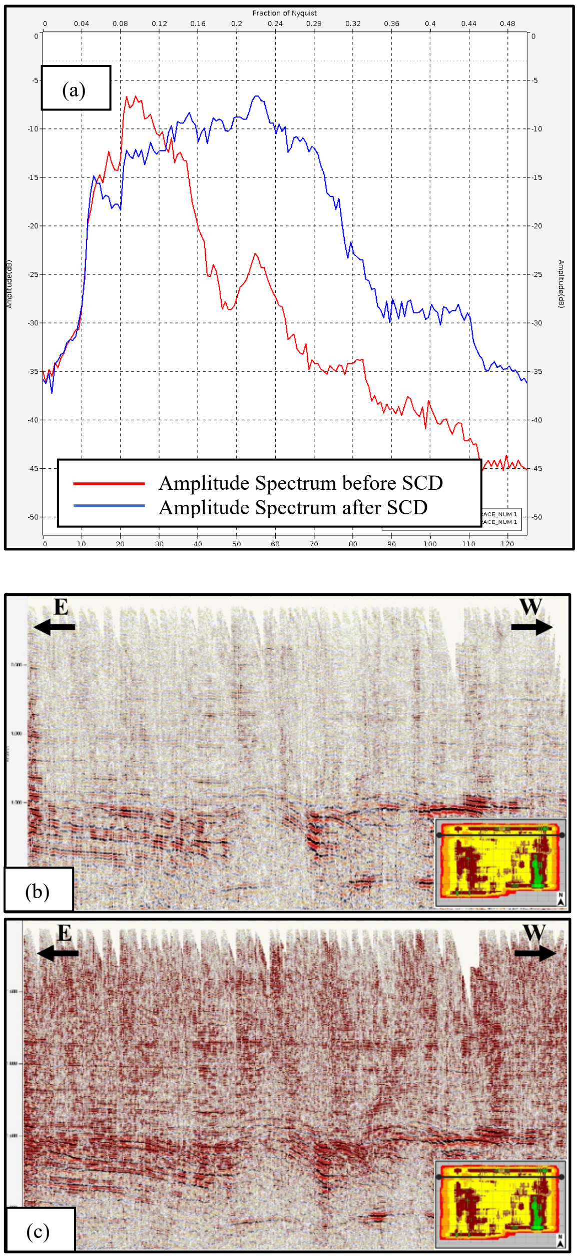

Figure 2. (a) Amplitude Spectrum before & after SCD
(b) & (c) Stack before & after SCD

B) Regularization and Interpolation:

Seismic dataset today is being extensively utilized for carrying out AVO and pre-stack inversion studies leading to improvement in confidence for drilling well locations. However, land datasets generally comprise of irregular offset distribution, low fold/data gaps and significant noise even after

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deconvolution. This in turn compromises the imaging capability of pre-stack migration algorithms (Al-Gain, M. et. al.). Regularization of seismic dataset is thus needed for mitigating the above mentioned challenges. The dataset has a nominal fold of 24 with erratic distribution (Figure 3a). Thus, in order to improve imaging, the dataset was regularized through distribution of CMP gathers in offset classes (a total of 40 offset classes of 100m each). Thereafter, 3D and 4D regularization was thoroughly tested and subsequently 4D interpolation was found to provide better result (Figure 3b). This helped in filling gaps in various offset classes (Figure 4), increased the fold to 40 and helped in significant improvement in subsequent imaging. When applied on the dataset, the improvement was distinctively visible (Figure 5).

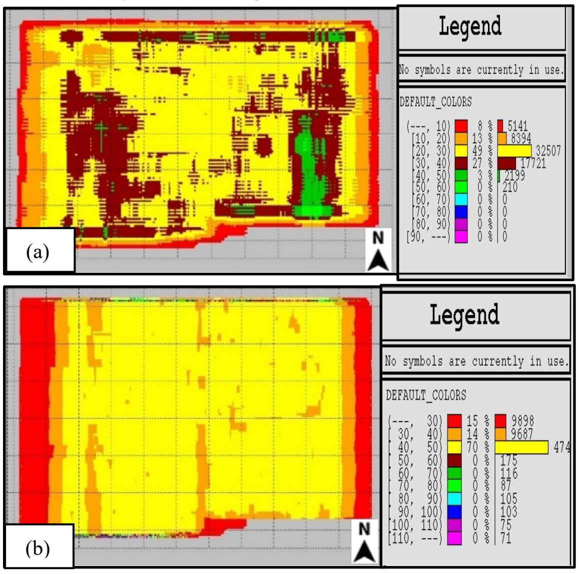
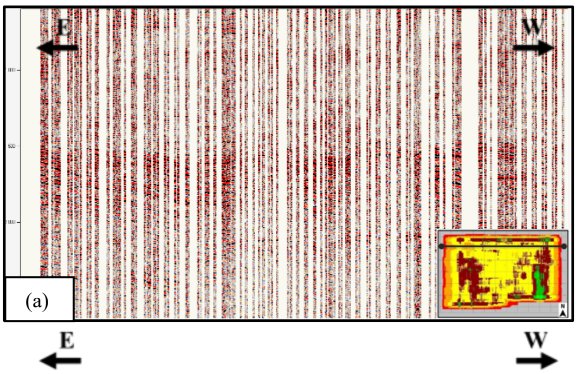


Figure 3. (a) & (b) Fold map before & after interpolation



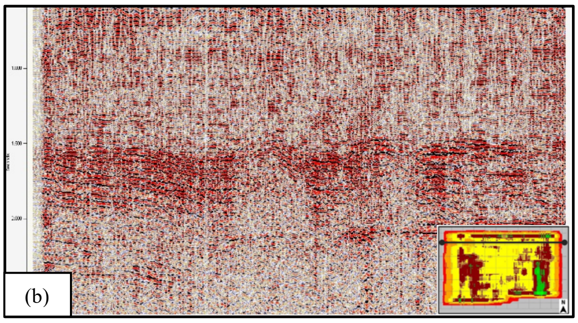


Figure 4. (a) & (b) offset class (1400-1500m) before & after interpolation

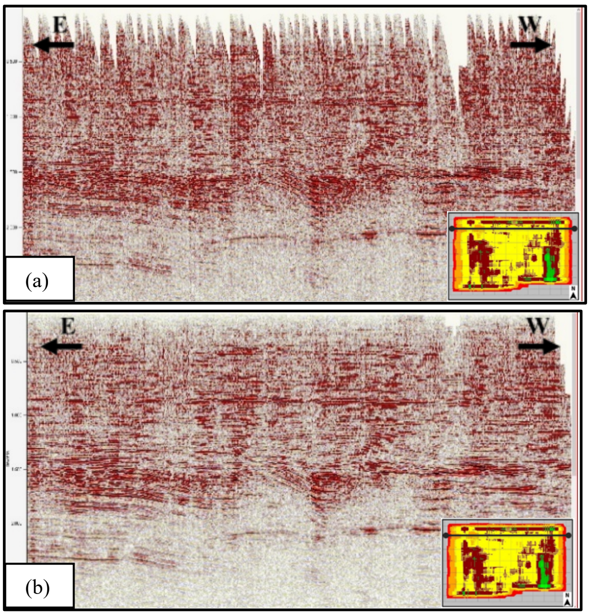


Figure 5. (a) & (b) Stack before & after interpolation

C) Pre-Stack Time Migration:

The vintage dataset was processed with post-stack time migration (Figure 6a). However, the new processing was carried out in pre-stack domain, so was the imaging. The pre-stack time migration brought out subtle details and structural features present in the dataset (Figure 6b) which was not seen previously and helped in carrying out post-migration velocity analysis which provided a detailed sub-surface velocity model necessary for future depth imaging projects on the dataset.

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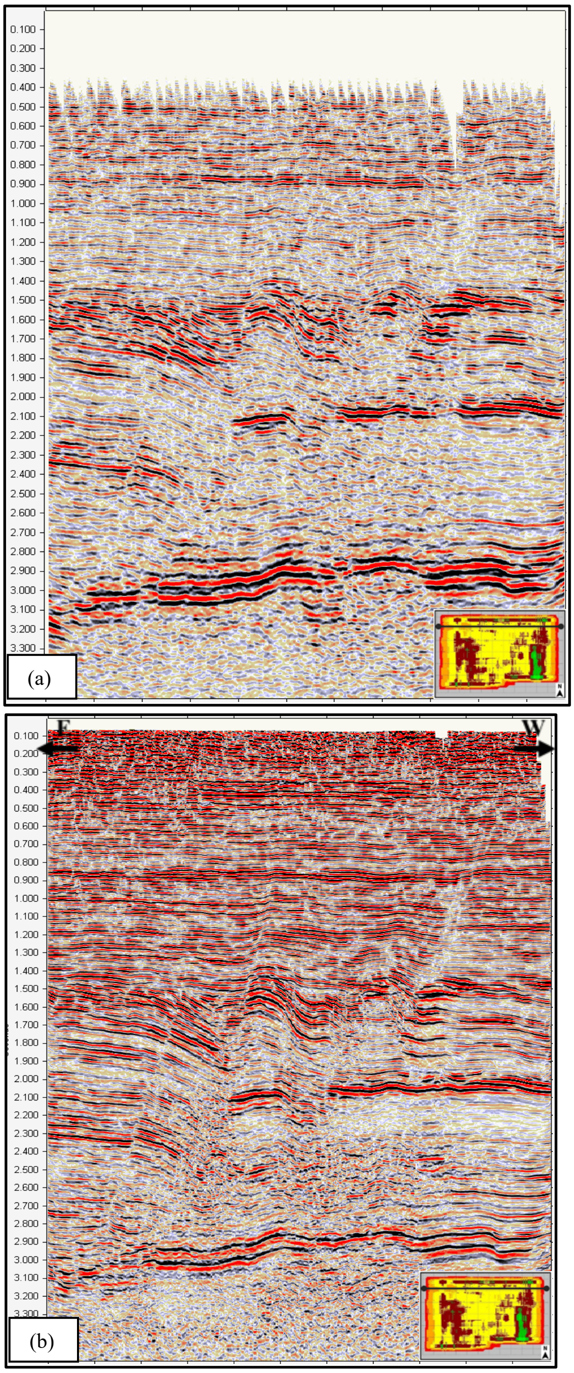


Figure 6. (a) Migrated Vintage Stack (Post Stack Migrated)
(b) Migrated re-processed Stack (Pre-Stack Migrated)

D) Seismic Attributes: Seismic attribute analysis can extract information from seismic data that is, otherwise, hidden in the data and has been frequently used to identify different structural and stratigraphic features and prospects (Koson, S. et. al.). Two (02) attributes were generated on both vintage stack data and re-processed stack data for a detailed comparison on the improvements obtained from this re-processing. These are elaborated as below:

i) RMS amplitude: The RMS Amplitude is a volume attribute which computes the Root Mean Square (RMS) of single-trace samples. The RMS is a popular statistical measure of reflectivity or energy in a dataset. RMS can help in mapping direct hydrocarbon indicators, such as bright spots or channels, in the seismic data. It can also highlight other geologic features which are isolated from background features by the amplitude response.

The Figure 7 (a) and (b) shows a comparison in the time slices of the seismic volume in the present study as compared to the vintage data. The increase in sharpness of the events along with improvement in spatial resolution were seen which shall contribute to yield a better interpretation with a higher degree of confidence.

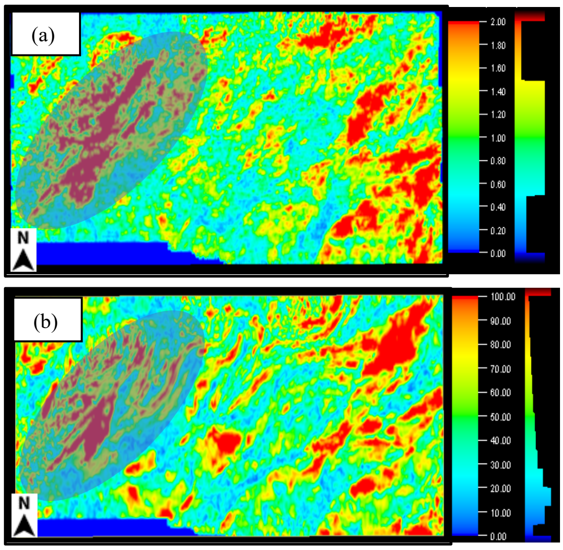


Figure 7. RMS amplitude attribute of (a) Vintage Stack & (b) Re-Processed Stack

ii) Variance: The variance is a powerful tool used to enhance the edge imaging of a seismic dataset. The Variance attribute can be used to isolate edges (discontinuities in the horizontal continuity of amplitude) in the seismic data set. The variance is commonly used for the detection of faults, fractures, discontinuities etc. as reflector terminations. These are better viewed in time slice.

The variance attribute has been generated for both the vintage (Figure 8 a) and the re-processed data (Figure 8 b). The figures show significant improvement of subtle discontinuities viz. faults & fractures. This will eventually help structural interpretation in delineating different structural features with higher confidence.

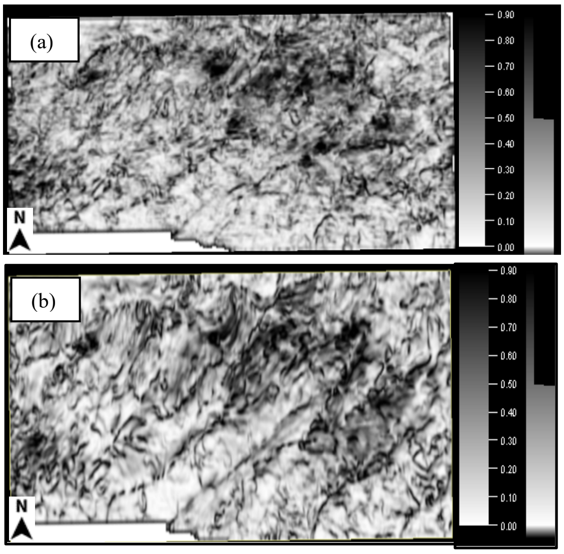
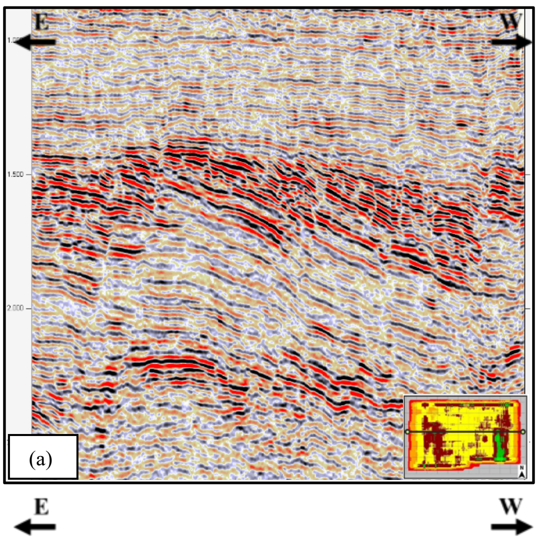


Figure 8. Variance attribute map of (a) Vintage Stack & (b) Re-Processed Stack

DISCUSSIONS

Any re-processing project focuses on generation of outputs leading to improved confidence in structural and stratigraphic interpretation and carrying out of AVO/Inversion studies. The outputs generated in this project shall significantly aid in structural and stratigraphic interpretation mainly due to the following reasons: application of refraction statics instead of elevation statics, better vertical resolution (due to 04 msec prediction gap in deconvolution), 4D gap filling and regularization, Pre-stack time migration. Moreover, availability of near surface velocities (from refraction statics solution) and seismic velocities picked using CMP gathers post-migration shall facilitate carrying out PSDM on this dataset.



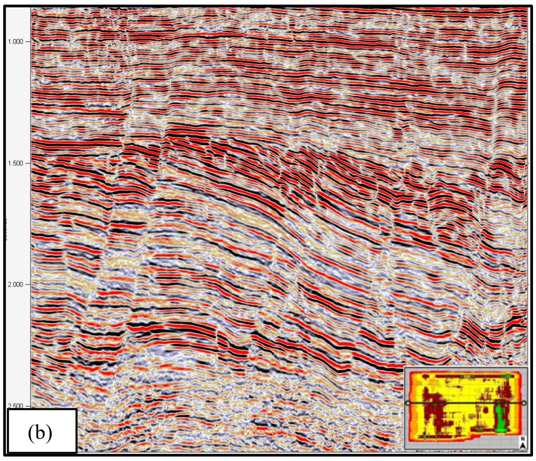


Figure 9. (a) & (b) Vintage vs Reprocessed Migrated Stack (zoomed at Oligocene level).

The comparison stacks shown at various levels, that is, at middle section (Figure 9) and at deep section (Figure 10) explicitly showcase the improvements in the stack sections.

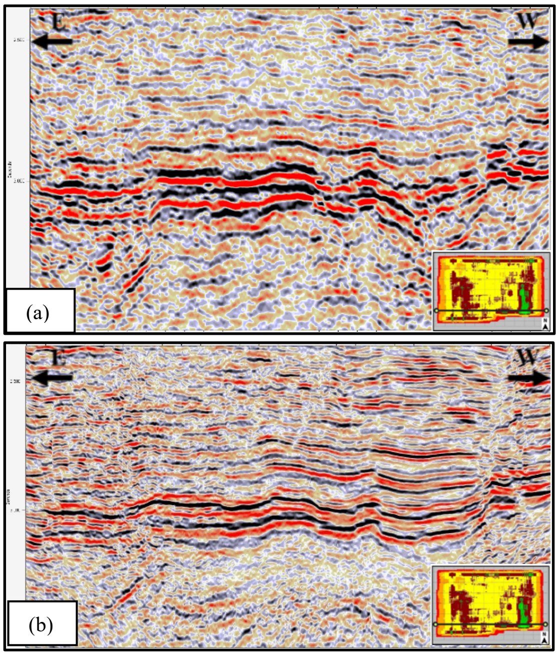


Figure 10. (a) & (b) Vintage vs Reprocessed Migrated Stack (zoomed at Eocene level)

Overall, superior imaging in terms of resolution enhancement and fault delineation has been achieved throughout the 3D volume (Figure 11). These deliverables shall generate fresh impetus to carry out future development studies in the region.

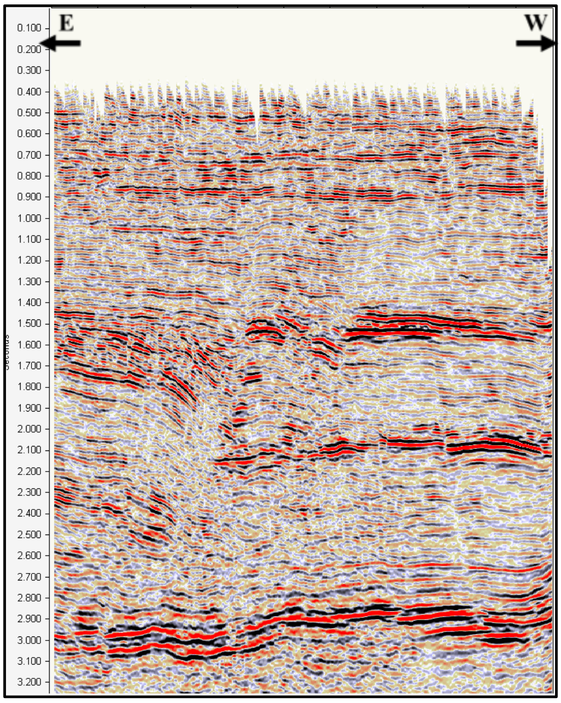


Figure 11 (a) Vintage Migrated Stack

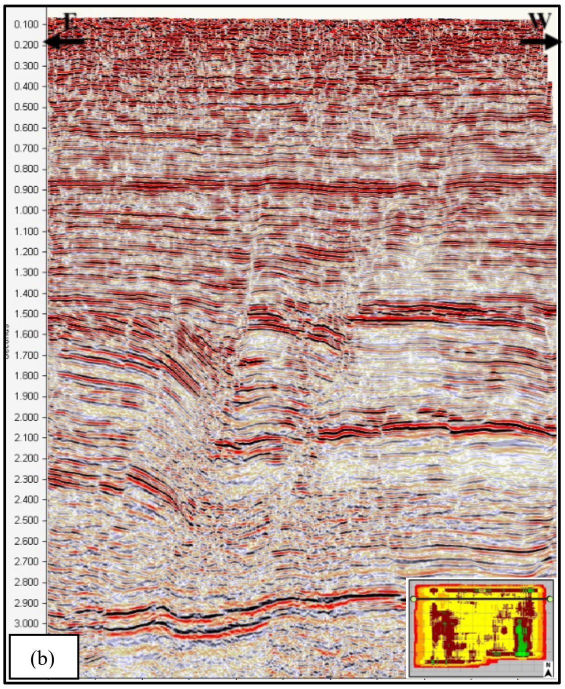


Figure 11 (b) Re-Processed Migrated Stack

CONCLUSION

New trends in seismic data processing shows that reprocessing of legacy seismic data can provide more accurate imaging of seismic events. Advanced processing workflows that include derivation and application of refraction statics from detailed near surface model, surface consistent deconvolution, advanced interpolation (4D), and pre-stack migration can mine more robust characteristics already present in the data. Most of the case studies highlight improvements in seismic image of a particular sub-surface region that occur in part, through improvement in acquisition parameters of acquired seismic data and in part, through utilization of advanced seismic processing algorithms. However, we highlight a scenario wherein a vintage seismic dataset acquired decades ago can be leveraged solely using currently available processing algorithms to generate superior seismic image. Seismic data acquisition in Assam shelf region has always been challenging, more so now due to faster urbanisation of the rural landscape, so it is imperative to extract maximum benefits out of the vintage datasets through re-processing. This is not only time effective, but also efficient and has lower cost strategy. It is only through such studies and the active collaboration between the geologists and geophysicists which ultimately discovers newer prospects and helps increase the exploration portfolio of any E&P company.

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REFERENCES

Al-Gain, M. et.al, 2020, Impact of 5D regularisation and interpolation on 5D imaging: A case study of Stratton field,South Texas, United Stattes of America, Journal of King Saud University, Science 32, 2733-2740.

Malajczuk, S. et. al., 2016, Improved Subsurface Imaging and Interpretability through Broadband Reprocessing of Legacy Seismic Data. Examples from NorthWest Shelf Australia, ASEG, 2016:1, 1-8

Koson, S. et. al., 2021, Seismic Attributes and Their Applications in Seismic Geomorphology. Bulletin of Earth Sciences of Thailand, 6(1), 1–9.

Wandrey, C, J., 2004, Sylhet-Kopili/Barail-Tipam Composite Total Petroleum System, Assam Geologic Province, India, US Geological Survey Bulletin, 2208-D

www.wiki.SEG.org