Exemplary seismic data acquisition in Tripura fold belt using flip-flop up-dip asymmetrical split spread shooting geometry

Anupam Hazra*
ONGC, India; C.M. Jain, ONGC, India, T.B. Rao, ONGC, India; M.B.S.Boipai, ONGC, India
Hazra_Anupam@ongc.co.in, anupam.hazra.icdi@gmail.com

Abstract

Seismic exploration in fold belt areas is a challenge worldwide. Particularly in the compressed anticlines the structural complexity and rugged topography have a direct effect on the quality of acquired seismic data. Considering these structural complexity, a shooting pattern of 'flip flop up-dip asymmetrical split spread' have been designed and high resolution 2D seismic data have been acquired in three lines crossing Baramura and Atharamura anticlines in the Khowai Kalyanpur area of Tripura fold belt. All possible measures have been taken to improve the data quality and representative seismic sections have been generated for this area.

Introduction

A recent pool discovery in a well together with the literary knowledge of gas discovery in Bangladesh resulted in tremendous enhancement in prospectively perception in Khowai-Kalyanpur area of Tripura fold belt. (Figure 1, 2, 3)

Fig. 1: The area of operation

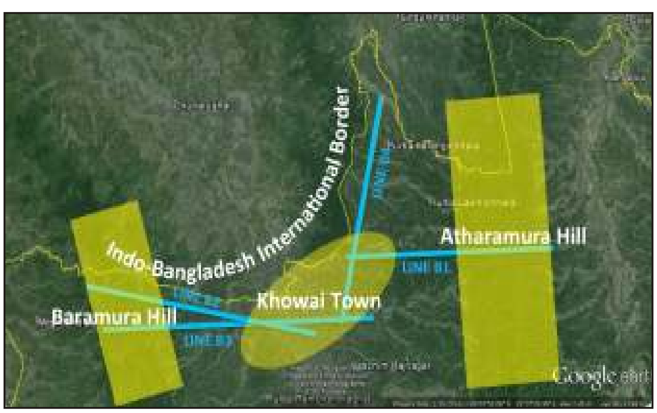


Fig. 2: Google image of the operational area

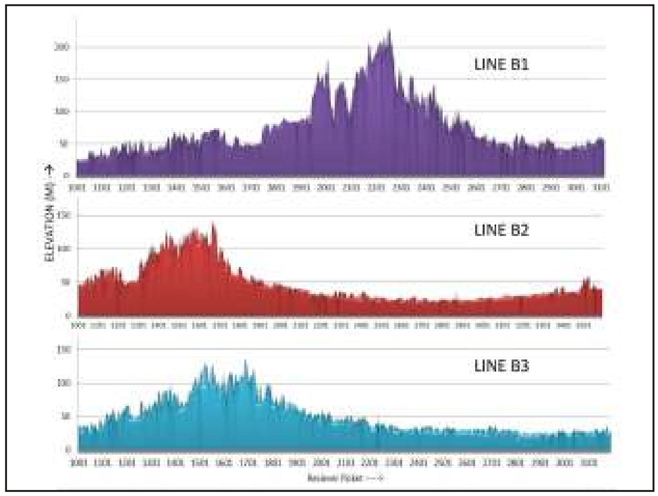


Fig. 3: Elevation profile along the 2D seismic lines

The seismic sections of earlier investigations in Khowai-Kalyanpur area provided very limited information for further hydrocarbon exploration in Tripura Fold Belt. The acquisition in previous investigations had been done using conventional symmetric split spread approach having inadequate fold and offsets. But acquisition in fold belt needs special attention right from the planned geometry until the final shot. After analyzing previous investigations, it have been found that the following points could be emphasized in geometry designing to improve the data quality

i. The signal-to-noise ratio (S/N) of acquired seismic data becomes very low as we approach the anticline due to the subsurface condition and S/N is directly proportional to the square root of fold. Hence, if acquisition geometry can be designed where the fold, instead of being constant throughout, increases towards the crest of the anticline the result may be substantially benefited.

ii. Offset also play a major role in reconstructing reflection points as the reflecting ray paths do not follow conventional paths in fold belt area and longer offsets are always necessary to map the limbs of the anticlines. Hence, in the planned geometry, offset should be kept more than the required as per rule of thumb.

The Geometry

Based on the observations mentioned above, a high resolution up-dip asymmetrical split spread geometry has been designed (Table 1). The concept is to keep the spread asymmetric and shooting up-dip from opposite end of the anticline with some overlapping shots over the crest (Figure 4). The designed geometry encompasses two asymmetric templates, which are mirror images of each other. Each template has 900 receivers planted at 10 m interval. The asymmetric split spread ratio is 2:1 (600 + 300 or 300 + 600 channels). During shooting the greater flank of the template is always in the up-dip direction.

In the final fold map, the fold is inversely proportional to the distance from the crest of the anticline (figure 5) and maximum (180) at the crest of the anticline. This ensures minimum loss of signal at the center.

Table 1: Acquisition parameters for the current geometry

No of channels	900
Geometry type	Updip ASS (300+600 / 600+300)
GI (m)	10
SI (m)	50
Fold	Variable (90 to 180)
Min offset (m)	5
Max offset (m)	5995

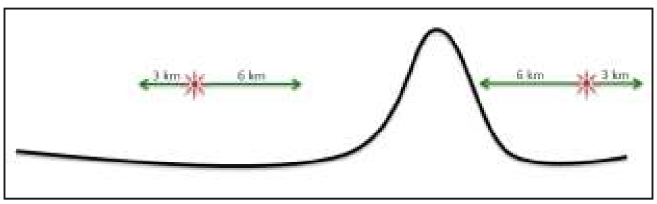


Fig. 4: Flip-flip up-dip ASS Shooting Pattern

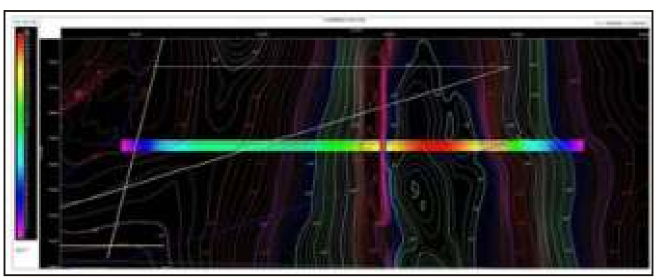


Fig. 5: Variable Fold Map with formation top contours

Modeling

Based on the available geological understanding and seismic data of previous investigations, 2D subsurface model has been prepared using Norsar software for ray tracing (Figure 6). In comparison of the spikeogram, the marked rectangular region depict the importance of higher offset (Figure 7). Since 2D modeling has very limited attributes for understanding the complex geology in fold belts, a 3D model has also been constructed and different attributes were analyzed to understand the advantage of the current geometry over the conventional one (Figure 8 & 9).

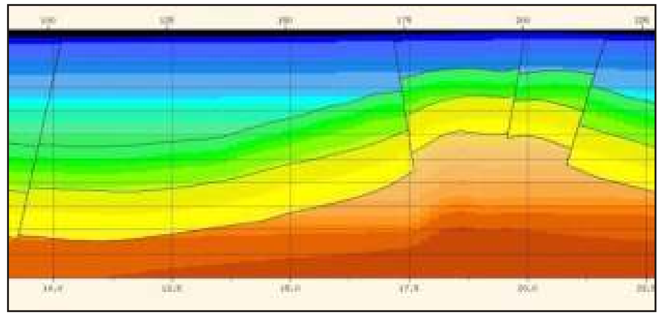


Fig. 6: 2D Model for a seismic line across Atharmura Structure

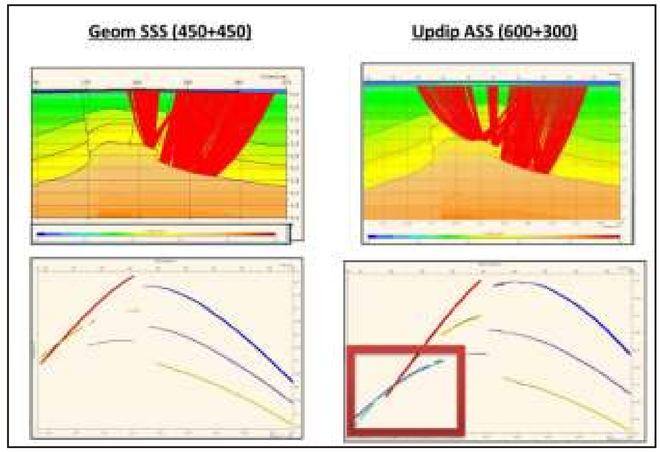


Fig. 7: Comparison of Ray tracing Spikeogram between conventional SSS and Up-dip ASS shooting geometry

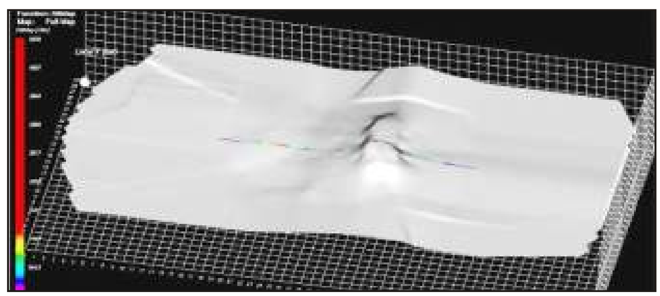


Fig. 8: 3D model for a seismic line across Atharamura Structure

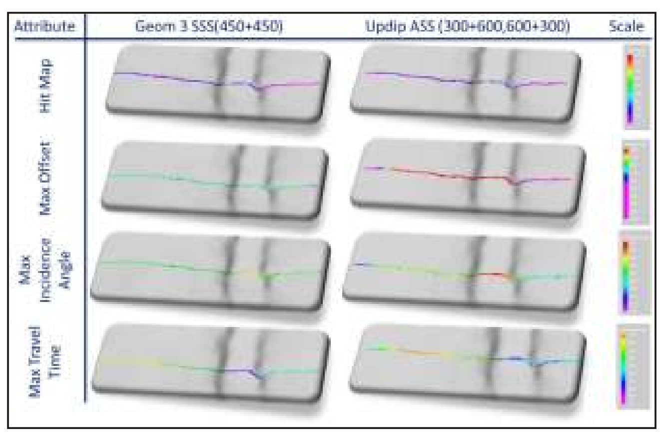


Fig. 9: Comparison of different modeling attributes for conventional SSS and Up-dip flip flop ASS shooting

Elevation guided up-hole Survey

In up-hole planning, the overall elevation profile of the area have also been considered and up-holes have been placed at an interval of 1km in the hilly patch whereas at 2km interval elsewhere. Further repositioning of up-holes has also been done considering the actual stacked elevation variation of the 2D line. (Figure 10)

The acquired up-hole data were examined critically and interpreted meticulously based on attributes viz. velocity, pulse and lithology to prepare the elevation driven Near Surface Models along the lines. (Figure 11 &12).

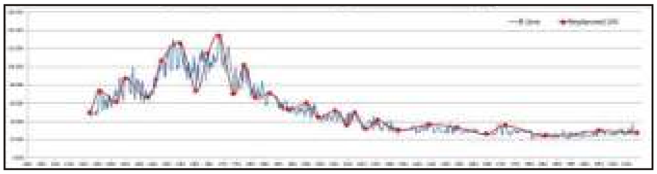


Fig. 10: Elevation driven uphole plan for a seismic line across Baramura Structure

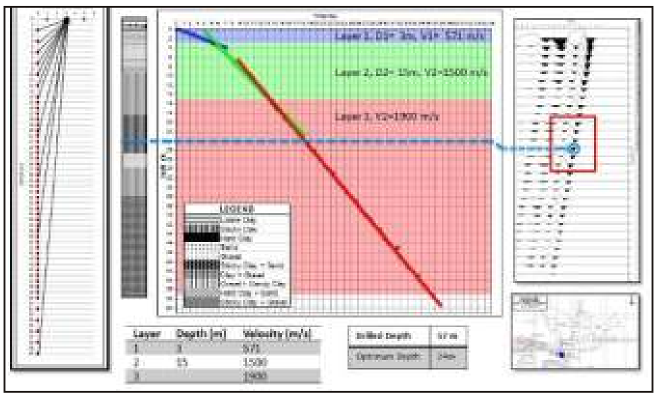


Fig. 11: An interpreted uphole plot

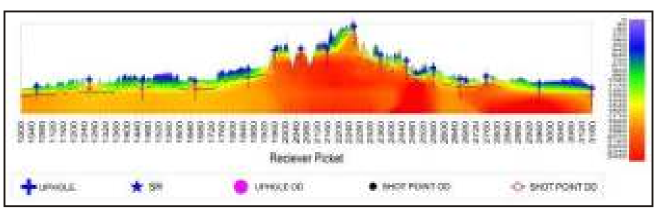


Fig. 12: Near Surface Model of a seismic line across Atharamura Structure

Quality Control

Quality has been given the top priority at each and every stage of this project. The points that have been focused, not only to control but also improve the quality of data are discussed below

1. The acquired data have been monitored continuously by signal-to-noise ratio analysis and frequency spectrum analysis (Figure 13). The frequency analysis plot of one of the 2D line crossing Baramura Hill in Figure 14 shows a good range of frequency content throughout the line with a little narrow band over the hilly region.
2. Mirror image scans for static correction with respect to elevation provided a good amount of confidence to have error free static correction. (Figure 15).
3. Incorporation of closely spaced (25m S.I) shots in seismic patches of poor signal strength has enhanced the signal there (Figure 16).
4. A Quality Matrix has been prepared and followed for quantification of quality measures as a self-assessment tool. This matrix covers all the aspect of acquisition right from the survey to the QHSE (Figure 17).

GPS Integration with Shot-pro has given real time coordinates of Shot Locations. (Figure 18)

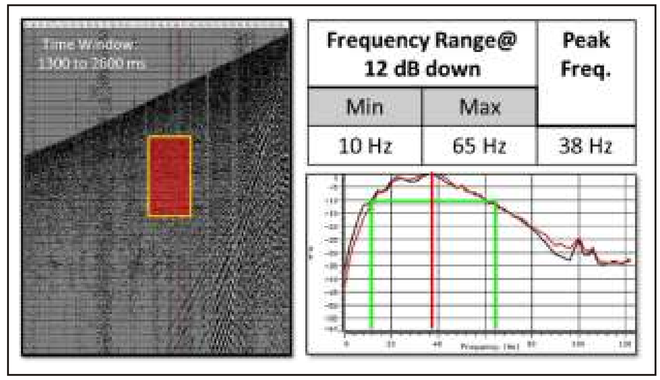


Fig. 13: Frequency Spectrum Analysis

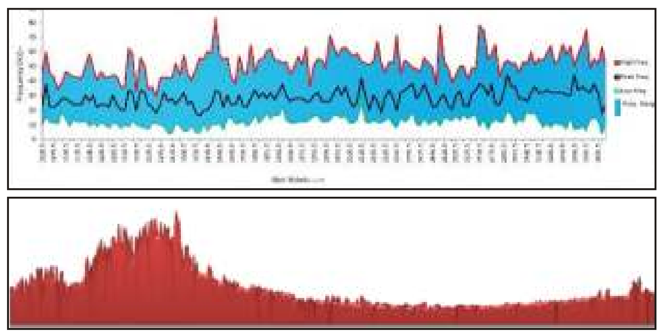


Fig. 14: Frequency Plot and elevation profile

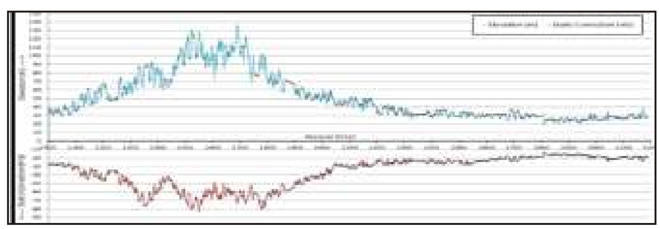


Fig. 15: Static Correction Mirror image Plot

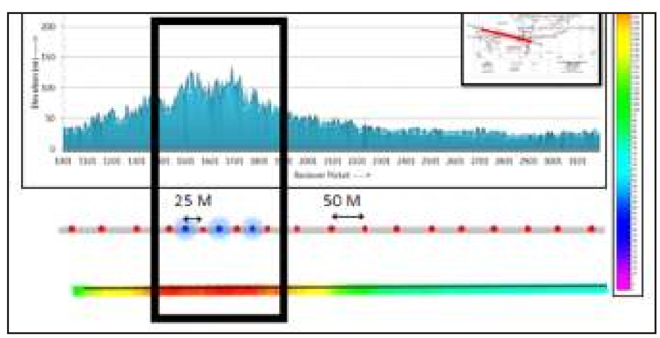


Fig. 16: Closely spaced shots for the area of poor signal strength

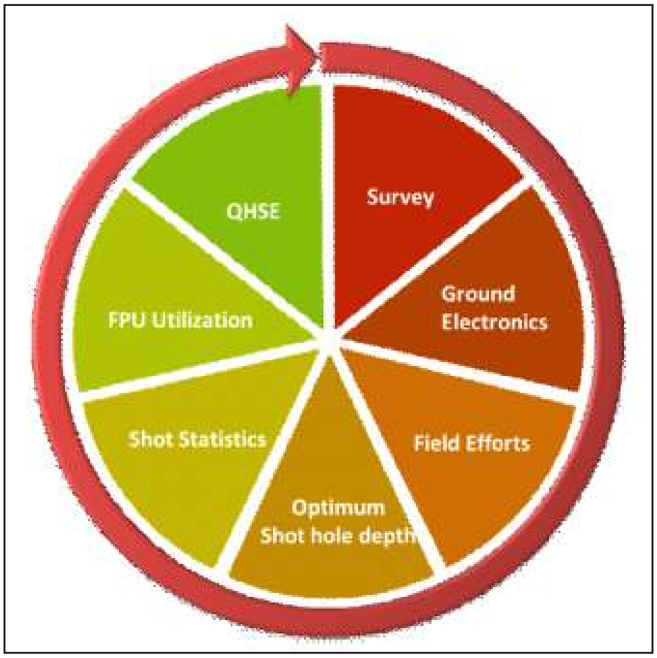


Fig. 17: Quality Matrix

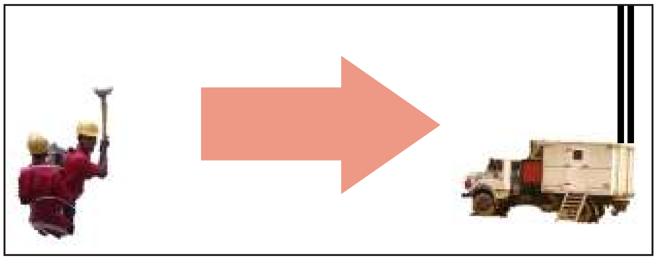
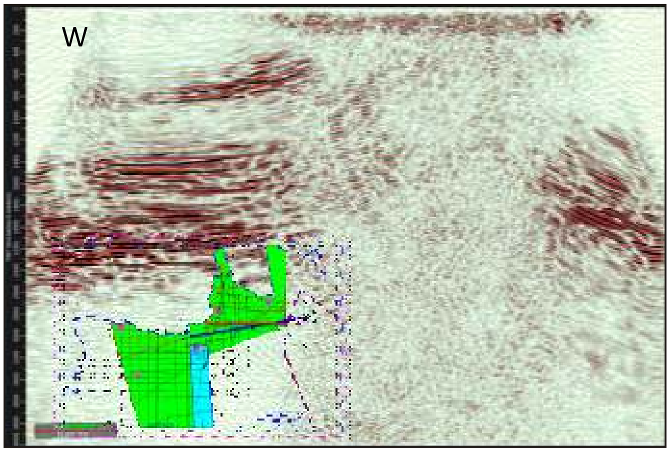


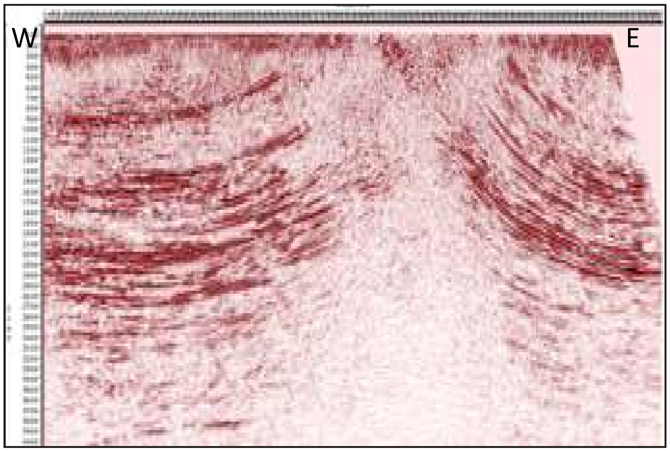
Fig. 18: Shot Pro Integration

Conclusion

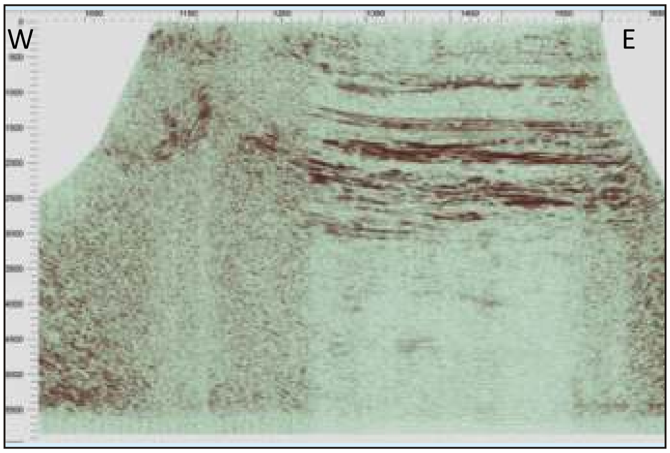
The raw data have been processed very carefully and excellent PSTM sections have been generated. The data comparisons have been shown in figure 19. The hitherto invisible subsurface anticlines are now mapable to a large extent in the new seismic sections. Further, reflector at two-way-travel time close to 4500 milliseconds has been brought out for the first time in this area. These all together define a remarkable achievement and open new doors for further exploration in the less-explored fold belt areas.



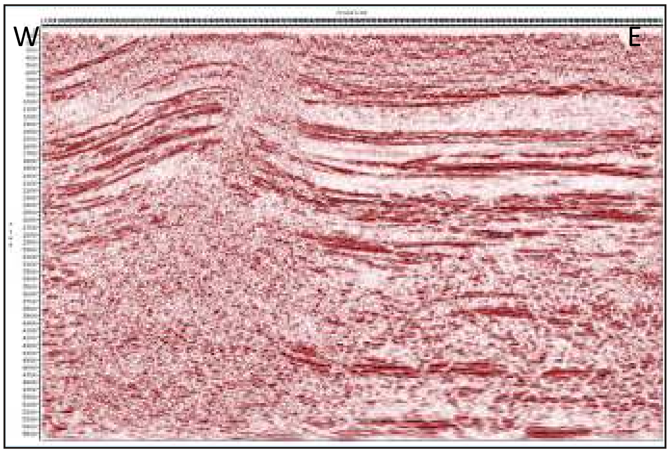
LINE A1 (Old Section)



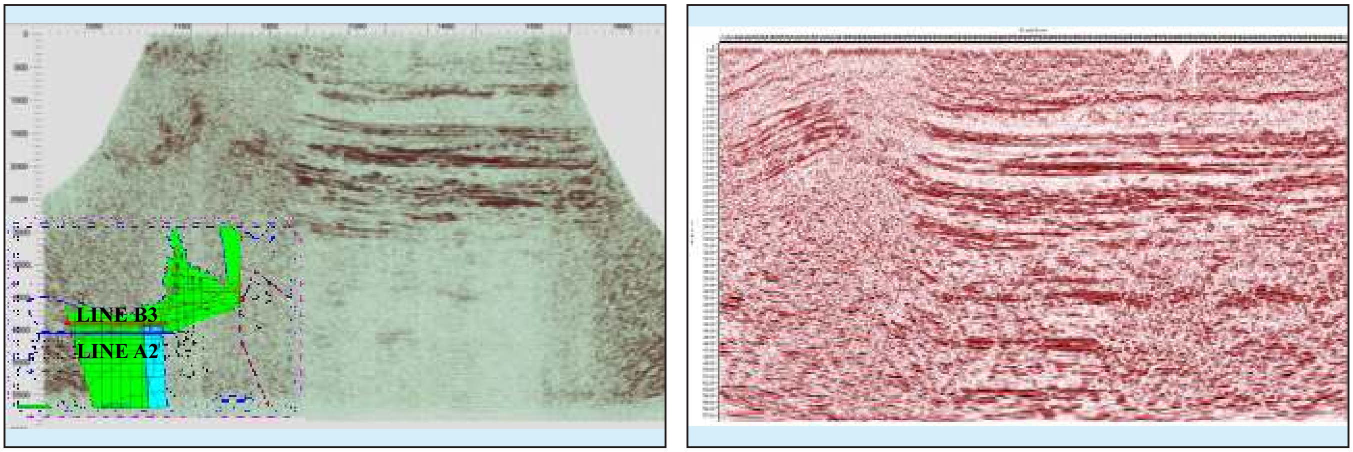
LINE B1 (New Section)



LINE A2 (Old Section)



LINE B2 (New Section)



LINE A2 (Old Section) **LINE B3** (New Section)

Fig. 19: Comparison between seismic sections of earlier seismic investigation and the current one

Acknowledgment

Authors are grateful to Oil and Natural Gas Corporation Limited, India for providing the necessary facilities to carry out this work and giving permission to publish this paper.

The authors sincerely acknowledge constant encouragement and support by Shri C. Mahapatra, ED-Basin Manager, Shri F. Dotiwala, GM (Geol) Block Manager (AAFB) and Shri K V Krishnan, GM (GP)-I/C RCC.

The authors are grateful to Shri S.K. Sharma, GM (GP), Shri B.K. Gogoi, DGM (GP), Shri S.K. Mukherjee, DGM (GP), Shri A.K. Rai, DGM (GP) Shri T. Upadhya, DGM (GP), Shri A.K. Sharma, CG (S) and Shri B.K. Sharmah, CG (S) for value addition in execution of the project.

Authors are especially thankful to the geophysicist (M. Mann, G. Singh, M. Mitra, A. Choudhury, A Bhardwaj, M. Pal, A. Mehta, J. Rehman & R. Adhikary), E&T engineers (V.V. Pendharkar, S.B. Kambli & A.H. Hazarika), Surveyors (P. Kachari, A. Sarkar, B.S. Rai & U.K. Hazarika), Admin, Auto & Field workers (L. Saikia, P. Phukan, A.C. Patra, B.C. Tai, M. Sonowal, P. Ojha, P.C. Borah, J.R. Panging, C.K. Bharali & N.C. Goyan) for outstanding effort and successful execution of the work.

Authors are thankful to RCC, ONGC, Jorhat for processing the data with additional effort during and after the project.

Authors are also thankful to QCG, ONGC, Jorhat team for continuous monitoring and feedback in improving quality of the data during the project.

Views expressed in this paper are that of the author(s) only and may not necessarily be that of ONGC.

References

Balak P.R. et. al., 2008, Enhancing Seismic Imaging through Close Spatial Sampling in Fold Belt Terrain; A Case Study, SPG.

Nandy D.R., Dasgupta S., Sarkar K, Gamguly A, Tectonic Evolution of Tripura-Mizoram Fold Belt, Surma Basin, Northeast India; Quart. Jour. Geol. Min. Met. Soc. India, Vol. 55, No. 4, p. 186-194, 1983.