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# Challenges and Strategies of Seismic Survey in Thrust-Belt and Mountainous Area: A case study

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## *Summary*

*Geophysical exploration in general and seismic acquisition in particular is challenged immensely in terms of the difficult logistics and complex subsurface geology of thrust belt and mountainous areas right from data acquisition through processing to integrated interpretation of the dataset. Understanding the orogeny and reconstruction of the structural deformation to understand the subsurface geology has always been challenging for the geoscientific community. Since, seismic involves in war scale movement of man and material, accessibility is the key contributor to successful implementation of the survey apart from mitigating the subsurface challenges during processing that manifest themselves in a variety of way on recorded shot gathers.*

*This paper discusses the challenges and solutions adopted to address the varied challenges while carrying out seismic survey in the state of Mizoram, India. The area of study belongs to one of the frontier projects of OIL. It is pertinent to note that ramming of Indian plate with the Burmese plate created the indo Burmese ranges. These ranges are characterized by very tight folding leading to variation in topography similar to horse saddle type anticline syncline arrangement. These structures are almost north south trending heavily affected by thrust faults. Carrying out seismic survey with conventional approaches/techniques in such areas is largely constrained by the access constraints and other physical and cultural challenges. A well chalked out acquisition strategy/plan comprising of crooked line profiles selected on the basis of rigorous analysis of digital elevation model of the area utilizing GIS were employed in the field. The acquired dataset were further processed employing a minimal process approach with geological insight of the area in the background to aid in reconstructing geologically conformable images of the subsurface.*

***Keywords:*** *Frontier Exploration, Thrust-belt, Crooked Line Processing*

## Introduction

Mizoram is situated in the centre of Chittagong-Mizoram- Tripura fold-thrust belt of NE India between 21°58'N -24°35'N latitude and 91°15'E - 93°29'E longitude (Fig-1). The entire area is mountainous and hilly with precipitous slopes forming deep gorges culminating into several streams and rivers. Elevations of these hill ranges vary 30 to 80 degrees (Fig-2).

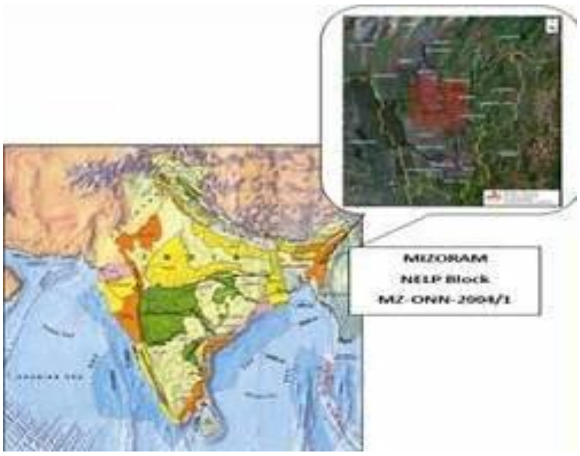

Fig.1: Location of the study area in Mizoram.

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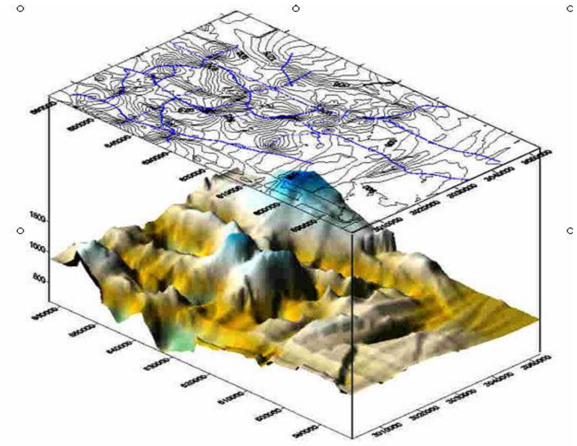

Fig.2 3D Topographic view of Mizoram Block

The area is dominated by north-south trending structural systems, the prominent features is the northwest-southeast trending Thenzawl Fault, which cut across the entire area and divides into two distinct sectors (Fig.3).Seismic Survey campaigns in such areas having varied near surface geomorphology has always been challenging and will continue to be so, however new means of techniques and technology would enable better and better addressal of the challenges. The constraints and challenges of executing seismic survey operations are dynamic in nature with no standard fixed solution; one needs to innovate continuously for addressing the same with efficiency.

Inaccessibility, severe topography coupled with subsurface geological complexity poses extreme challenges for conventional straight line seismic shooting.

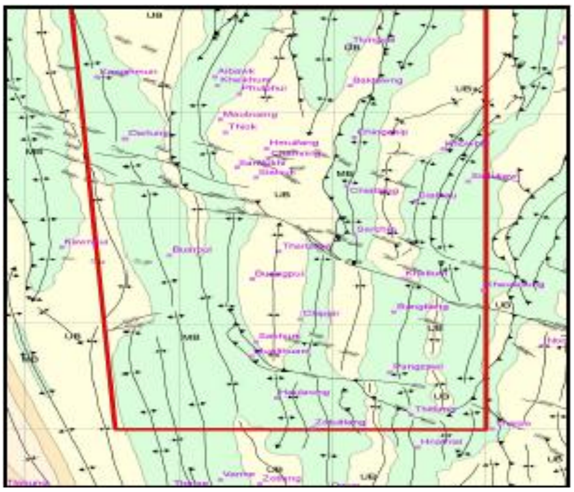

Fig: 3 Geological Map of Mizoram Block

## Geology of the Area

The folded structure of the Arakan Yoma, (i.e. Mizoram) and the Tripura ranges are found at the junction of two moving continental plates (i.e. Indian and Burmese Plates). It is an actively deforming transpressional plate margin and associated with fold-thrust belt and is generally referred to as the Indo-Burmese fold-thrust belt or the Arakan-Yoma Orogen (Fig-4).This structure comprises of early Miocene and late Palaeogene clastic sediment of Surma Group.

The folded belt of Mizoram is a part of Assam Arakan Geosyncline which can be divided into a frontal sub-belt consisting of narrow box like anticline separated by wide flat syncline of Tripura and South Assam and inner mobile belt consisting of tight linear folds of Mizoram and West Manipur(Fig-4). It comprises a series of sub parallel arcuate elongated doubly plunging folds arranged enechelon with asymmetric and tight anticline and broad syncline and trending in an average North–South direction with a slight convexity towards the west. The Ranges is (are) characterized as a fold and thrust belt developed in a fore-arc environment underlain by oceanic crust. An accretionary prism best characterizes the tectonic setting of the region and it is possible to categorize the fold and thrus belt as a “retreating accretionary prism”. Two main detachments linked by ramp faults are present. The lower one is located at the interface between the base of the Disang Group and the oceanic crust and the upper one at the base of the Barail Group. Fig 5 shows the structura cross-section across the exploration block. Bhuban from the Miocene age and Renji from the Oligocene age are the target horizons for this Area.

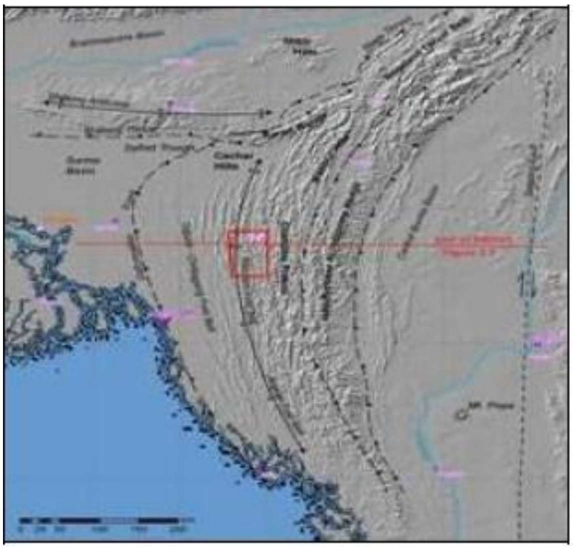

Fig: 4 Westward - convex deformation belt of Arakan - Yoma orogen.

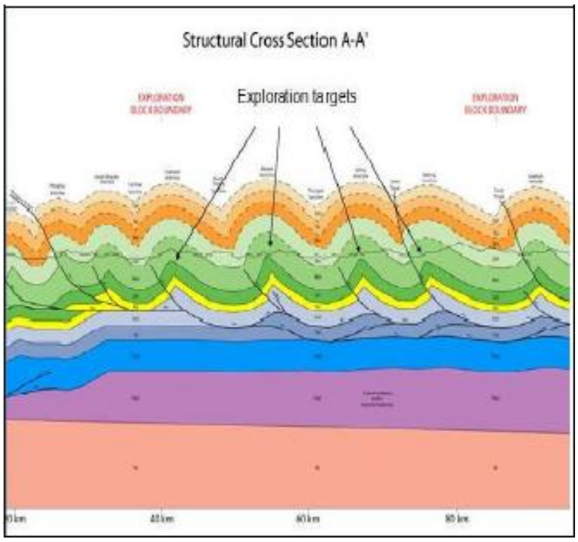

Fig 5: Structural cross-section across the exploration block.

## Challenges and Solutions Adopted.

Though the use of fit for purpose tools and techniques are central to any seismic exploration campaign, other physical aspects are as critical and become more significant in Thrust belt & Mountainous areas. Manpower the workhorse of the acquisition crew be it qualified geophysicists, skilled technical personnel's, or unskilled laborers all are critical to the successful realization of the survey objectives. In this context it is understood that well trained and experienced manpower minimizes the operational downtime and HSE concern. However, the study area being located at the remotest corner of NE India had scarcity of manpower having awareness of seismic operation. Although regular training and HSE awareness programs elevated their skill but it consumed considerable amount of operation time.

The next challenge was accessibility to the operational area due to topography and dense vegetation. NS trending saddle type anticline syncline geometry of the surface with 30 to 80 degree dipping sides of the landforms made seismic acquisition next to impossible. However, from the Initial reconnaissance of the area it was clear with the team that straight line geometry will never be successful and will involve astronomical expenditure. Crooked line appeared to be the best solution as crews can mobilize through the river banks and channels following the valleys. To overcome accessibility challenges and complete the expedition within the operation window mobile camps were deployed which can change its position without involving much of civil work. Similar philosophy was adopted for while acquisition also. Two or more crews were deployed at different part of the area to cover it in record time.

## Technical Challenges and Strategy Adopted For Acquisition & Imaging.

Geophysically unexplored this area is not benefited from any additional geophysical information and hence reduces reliability of depth estimation. During the crooked line survey seismic profiles move along existing roads and available foot-tracks. Before full-fledge 2D crooked line seismic survey a comparative study was carried out between straight line survey and crooked line survey. Different shooting pattern like-end on and split-spread was also tested. In case of 2D Seismic survey in Mizoram Block, End-on shooting is preferred over Split-spread shooting due to the following reasons:

(a) The possibility of rapid change in the direction of shooting (up dip/down dip) is more in Split-spread Crooked Line survey compared to End-on which makes the ray path geometry more complicated and also resulting into the loss of signal.

(b)Velocity analysis becomes a tedious job and accuracy is suffered during Split-spread Crooked Line survey while End-on shooting gives improved Velocity analysis and hence better multiple suppression.

| Geometry | End-on |
|---|---|
| No of channels | 320 |
| Sampling Interval | 2ms |
| Group Interval | 12.5 m |
| Shot Interval | 50.0 m |
| Fold | 40 |
| Record Length | 6.0 ms |
| Shot hole depth | 25m |
| Charge Size | 7.5kg |

## Processing Strategies

Compared to conventional 2D seismic data processing, crooked line seismic data processing needs some special strategies for Imaging. Complex subsurface geometries and crooked seismic profile make the ray-path of reflected events very intricate for extracting precise information on the subsurface features. A representative snapshot of the Raw Data recorded in the field exhibiting very low S/N ratio is shown in Fig (6).

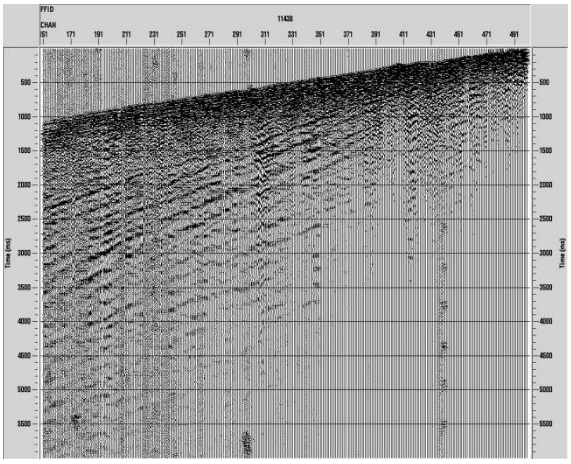

Fig (6) Field Record

## Geometry

Due to crooked behavior of seismic profiles, the midpoints between shot point and receiver locations are scattered in both the in-line and cross-line directions. The scattering of the midpoints not only invalidates the concept of a common midpoint gather of traces, it also introduces ambiguity as to the location of the seismic profile itself. As the first step in processing the data, a new effective line of profile is defined, known as track. The track (Fig 7 & Fig 8) is drawn over midpoints scatter-gram which gives effective profile over which further processing is done. In this particular line, inline and cross-line width of the bin is taken as 6.25m and 500m respectively.

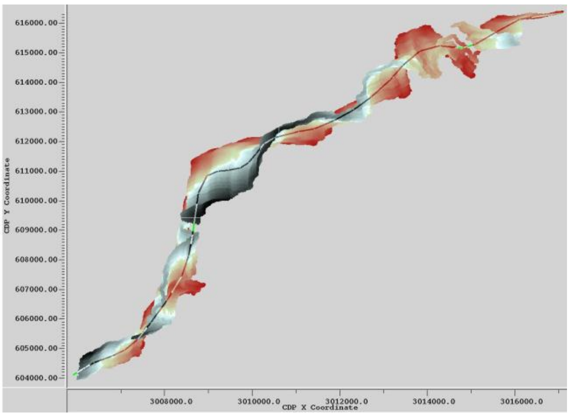

Fig (7) Track for Bining

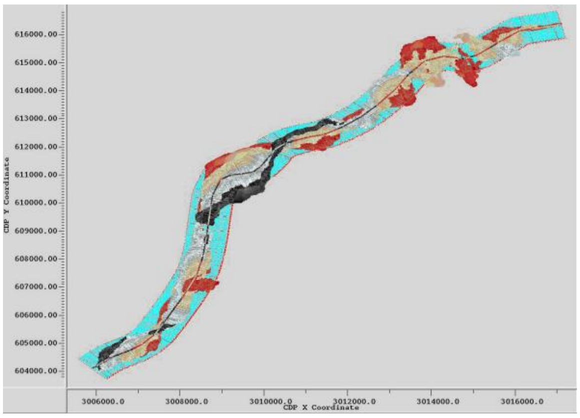

Fig (8) Binning

## Statics

After trace-editing, testing of different statics solution fit for the data carried out. Elevation static has been preferred over refraction static because refraction static calculation requires regularized offset which were not available during crooked line survey. Due to very rugged topography floating datum has been taken into account for the minimum static correction before NMO correction. The replacement velocity has been taken 3100 m/s and final datum is 1200m.

## Preprocessing

Low energy penetration coupled with poor plantation of geophone results into very low S/N ratio seismic data. Ground roll dominantly overshadowed the primary events. Different methods have been tried to reduce the coherent noise in the data. Predictive Deconvolution taking operator length of 240 ms has been used with gap of 36 msec. Fig (9) shows the Preprocess data and Fig (10) and Fig (11) are amplitude spectrums before and after preprocessing respectively.

## Velocity Analysis

Thrust-belt area typically includes steep dips and a complex pattern of folded, faulted, and unconformable surfaces which complicate velocity estimation. For velocity analysis, velocity spectrum method has been adopted. Due to large velocity variation, velocity analysis has been done at 125m intervals (Fig-12). Fig (13) shows the Stack – section with F-x Decon.

## Migration

Migration errors and imaging problems are common due to uncertainty in migration velocities. Migration velocity analysis was carried out with great caution and was guided and driven by the geological insight of the area. Explicit Finite difference Migration technique was finally applied on the dataset as it was giving better results.

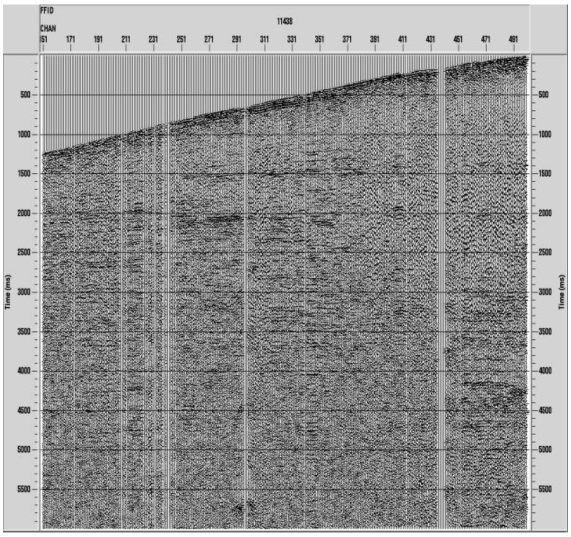

Fig (9) Preprocess Data

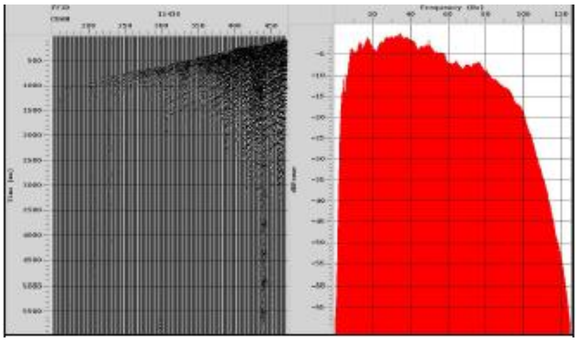

Fig (10) Amplitude Spectrum of field record.

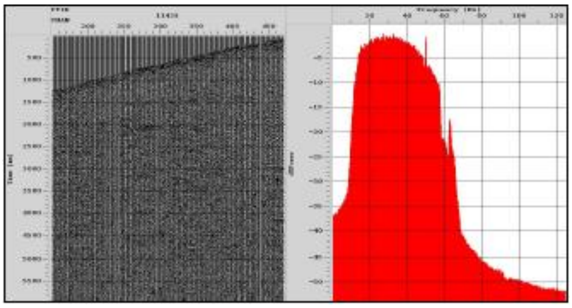

Fig (11) Amplitude Spectrum of Preprocessed Data.

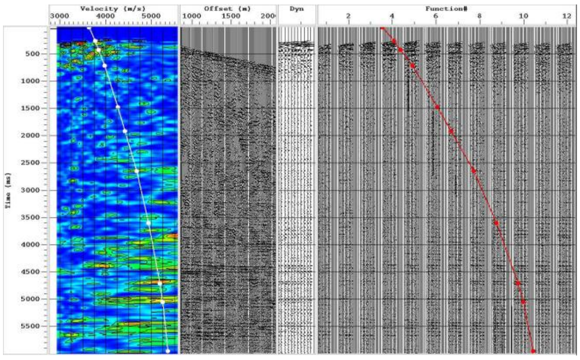

Fig (12) Velocity Analysis

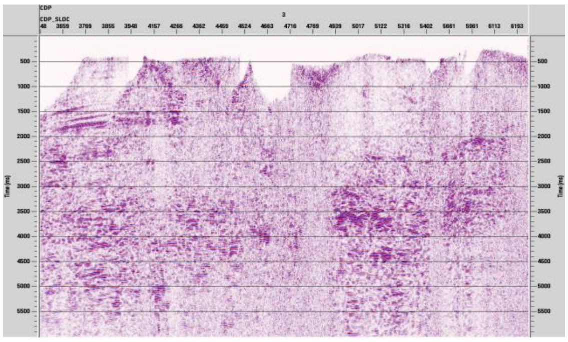

Fig (13) Stack-section

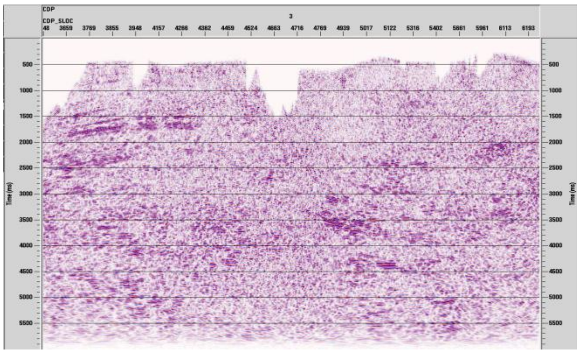

Fig (14) Migrated-section

## Conclusion

Though the Thrust belt areas are generally characterized by difficult near surface logistics and complex subsurface geology, innovative approach and fit for purpose acquisition and processing strategies can help in overcoming the varied challenges. Crooked line seismic survey is a good option for thrust-belt area which contains rugged terrain like Mizoram. The 2-D seismic survey campaign carried out in Mizoram could realize the objective of the survey within the realms of the challenges posed by the area & subsurface geological complexity.

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