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Crooked line seismic survey in thrust-belt and mountainous area of Mizoram, North East INDIA: A Case Study

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Abstract

This paper is an attempt to realize the problems related with hydrocarbon exploration in the best possible manner in frontier areas of thrust-belt and tough terrains with specific case study. The need of an hour is enforcing Exploration and Production company to embark over from already matured fields to Frontier basins in the quest of new discoveries. Logistically difficult and hostile terrain of frontier areas poses terrific challenges ahead of explorationist and our most reliable seismic method of hydrocarbon exploration.

Most of the frontier areas in the world consist of steep mountains, thrust-belt folded geology and unconformable surfaces, which have cascading effect on ray path resulting into distorted reflection pattern. Due to inaccessibility and cost limitations of seismic data acquisition, it becomes quiet logical to modify our conventional straight line acquisition geometry to crooked profiles. Crooked line survey is outcome of that modification where seismic profiles meander along the existing roads and possible paths. It has better solution for no. of reasons in spite of further complication of reflection pattern due to irregular acquisition geometry inclusion at the time of acquisition.

In this paper we have discussed about crooked line survey significance and it's inevitability in such type of area with the help of 2D seismic survey carried out in Mizoram which is located in NE India of Chittagong-Mizoram-Tripura fold-thrust belt.

Introduction

Seismic survey in Mizoram (Fig1) presents a great example of Hydrocarbon exploration in frontier areas. 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. Mizoram is unexplored so far due to tough topography and difficult logistics.

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 from 200m along river valleys to over 1600m along some of the higher ridges. The inclination of hills somewhere is 60-80 degrees. The area is dominated by north-south trending structural systems, the prominent features is the northwest-southeast trending Thenzawl Faults, which cut across the entire area and divides into two distinct sectors. Such a topographical statistics coupled with complex geology poses special challenges and force to do crooked line survey.

The CMP gathers are characterized by variable fold and uneven offset distribution during crooked line survey. Straight line binning at the time of crooked line processing is preferred out of many existing binning strategies available. The static correction utilizes the floating datum concept due to highly undulating topography, while cross-dip move out correction (CDMO) comes into picture due to irregular acquisition geometry. Generally in thrust-belt area high impedance bodies are very close to surface and become major obstacle to the propagation of seismic energy. Incoherent scattering further complicate energy penetration problem.

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Wide offset acquisition geometry offers better solution to such type of problem which widens the possibility of undershooting localized complexities as well as gaining the advantage of improved S/N ratio. Wide offset geometry provides enhanced velocity discrimination and larger amplitude at far offsets. Building velocity model in such type of area is an important and critical step during seismic data processing.

Even there was lack of proper tracks inside the block to lay the seismic profiles. Somewhere we were bound to move our seismic profile along the national highways where to avoid cultural noise very early morning shooting was required. Taking the depth of interest 4000-4500 m two types of shooting i.e. split-spread and end on shooting have been done and comparison has been made. Ignoring the cost and time consumptions few straight-line survey has been done to compare the data with crooked line data.

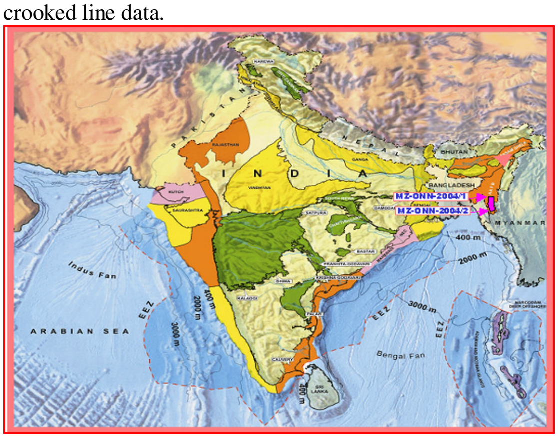

Fig1: Map showing the Mizoram.

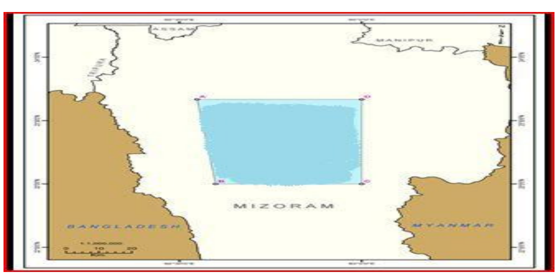

Fig2: Map showing the block where 2D survey has been carried out.

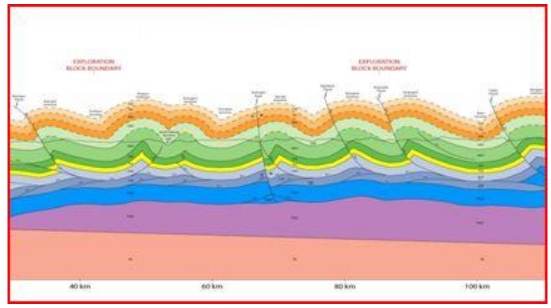

Fig3: Internal formation (cross section) of the block area.

Methodology

The entire block was theoretically divided into several strike and dip lines, dip line being E-W and strike line being N-S, but due to hostile terrain practically it was not possible and seismic profiles show high irregularity and no more actual dip or cross-line. Initially symmetric split-spread shooting was followed with 160 channels each side. Later on, keeping the source interval (50m) constant for investigation of better reflection continuity the group interval changed to 12.5m from 25m and split-spread shooting was replaced by End on shooting. In both the cases total no. of channels are 320, but somewhere the maximum no. of channels in the case of end on shooting is 500 to study effect of the extended offset geometry. The record length is 6 ms and sampling interval is 2ms. Shot hole depth is 25m.

Due to crooked behaviour of seismic profiles the midpoints between shot point and receiver locations are scattered in both the in-line and cross-line directions (Fig4). Not only does this scattering invalidate 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 slalom line. The effective profile is first subdivided into equal chord lengths and then each trace is assigned to the gather point whose chord centre is closest to the shot point-receiver midpoint corresponding to that trace. Depending on the scattered midpoints bin length has been defined separately for each line.

The travel time equation for straight line survey is given by $t^2(x, h) = t^2_0(x) + p^2h^2$

where x is the position of the CMP on the survey profile, h is the source-receiver offset, t(x,h) is the source-receiver travel time via the reflection point, $t_0(x)$ is the zero-offset reflection travel time, and p is the slowness depends on host medium velocity and the reflector geometry.

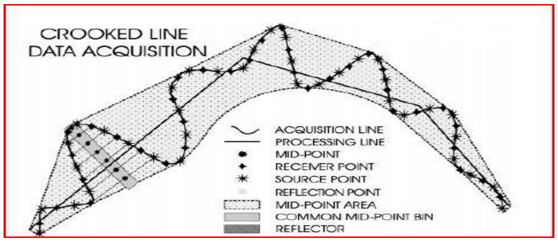

Fig4: Binning during crooked line processing

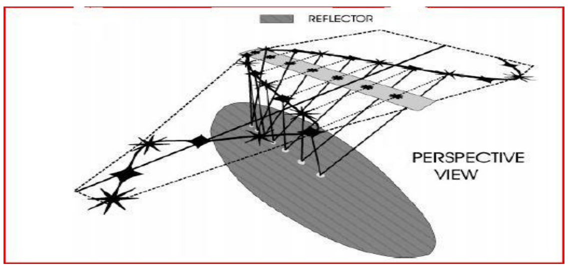

Fig5: Cross-line dipping reflector shown in a perspective view.

During the processing of crooked line survey data the correction in time along cross dip is required and the travel-time equation for crooked line survey is given by the equation

$$t^2(x, y, h) = (t_0(x) + P_y y)^2 + p^2h^2$$

where x is the position of the CMP bin centre on slalom line and y is the cross-line offset, the shortest distance from the midpoint to the processing line; and p and p_y are slowness associated with the given host medium velocity and the reflector geometry. Conventional processing scheme has been adopted except special treatment of binning at the time of geometry preparation. Initially the floating datum was used for the better velocity analysis and finally the statics has been applied at the datum value of 500m. Due to highly complex geological area PSTM and PSDM for each profile has been made.

Results and Discussion

If a straight-line 2D survey is conducted in such type of geological terrain and for which no assumptions can be made about cross-line structure, the position of any observed reflectors will be completely ambiguous in a cylinder surrounding the acquisition/processing line. Also, no assurance can be given that all reflectors that cut the vertical section containing the survey profile will be imaged by the survey, because only those that directly face some part of the survey line will generate appreciable signal. So cross-line concept becomes necessary in such type of terrain and correction become necessary in time for cross dips. The other advantage of 2D crooked line survey is the partial information of 3D structure of the reflector and it is also known as pseudo 3D seismic survey. The foldage variation due to crooked profile is high and after stacking it badly affects the reflection pattern. The most important and critical step during the processing of crooked line processing is the velocity estimation. End on shooting has given better result and continuity in the reflector due to reduced group interval. In some seismic profiles the No. of channels is 500 and it gives better results which support the extended offset concept in this type of terrain. Comparison has been made with the migrated section of straight line and crooked line with the help of Fig (6) & Fig (7) and it is quite obvious from the seismic sections that crooked profile is giving the better result.

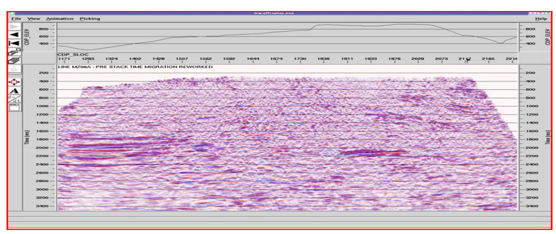

Fig 6: PSTM of a crooked line profile.

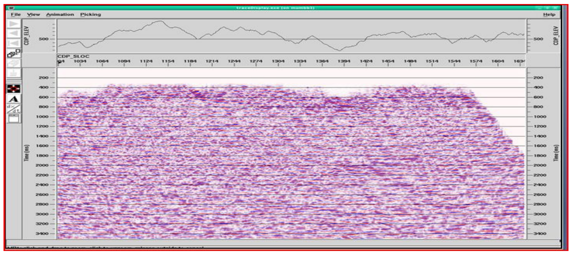

Fig 7: PSTM of a straight line profile.

Fig8: The map showing the terrain of Mizoram.

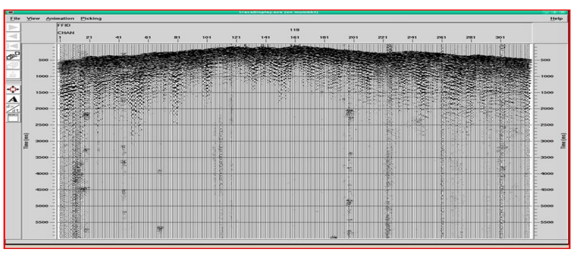

Fig9: the example of a raw shot of split-spread shooting.

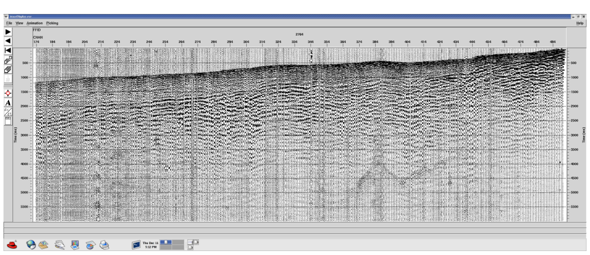

Fig10: the example of a raw shot of end-on shooting

Conclusion

In hilly and thrust belt area it is need of hour to follow crooked line seismic survey because as the time passes we have to face much tougher area of operation. Further straight line survey data is not much different and even seems poor quality in comparison of crooked line data which is evident from the results. Due to high cost of survey and hostile terrain it also negates the straight line survey. Special attention is required at the time of processing of crooked line seismic survey. With the help of extended offset geometry we can have a much better quality of data.

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