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Seisloop based 3D seismic survey: an unconventional approach

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Summary

Seismic methods stay the most advanced and powerful tools to future hydrocarbon discoveries. Its promise is their universality, diversity and robustness. Exploration in fold belts poses a great challenge to any explorationist which has been expanding rapidly due to worldwide intensified demand for hydrocarbon. On account of increasing demand of oil and gas, it has become the necessity to explore hydrocarbons even in toughest logistic conditions. Although logistic constraints have so far hampered sustained exploration efforts, improved communication and latest technology have accelerated the pace of exploration.

Mizoram area is very challenging because of steep hills, deep gorge, very high slope, dense forest and small operating window due to pre onset of monsoon. Because of very tough terrain and non-approachability in deep jungles it is almost impossible to conduct 3D survey in the conventional ways. Hence a new approach has been made to conduct the 3D seismic survey in this block.

In this paper seisloop based 3D acquisition technique for collection of seismic information in Mizoram block has been discussed. The paper also summarizes the concept of seisloop based 3D seismic survey and its applications along with its technical advantages in such type of mountainous terrain. The challenges & solutions while carrying out seismic survey and how the geophysical and logistical challenges were overcome through proper designing, optimization, and its implementation are also exemplified.

Keywords: *Seisloop, crooked line, 3D coverage, Fold.*

Introduction

The rugged hilly terrain with thick forest cover pose major constraints for seismic surveys in Mizoram area by way of limited access through the existing roads and tracks. The extreme logistics in Mizoram block could not allow lying out even straight seismic 2D lines and hence 2D seismic studies could be done only in the form of crooked line as shown in Fig-1. In such topographical condition conventional 3D seismic geometry (i.e. Orthogonal, Slant, and Brick etc.) is not implementable. View above, an alternative approach for 3D seismic survey i.e. seisloop approach is adopted.

The Seisloop method made possible to have 3D coverage in mountains or jungles, utililising the available roads and tracks. The receivers are placed all along the loop and energy source moves in and around the loop keeping all the receivers active for every shot.

Dynamite is the only source of seismic energy that can be deployed in this area, involving drilling of shot holes to a depth of about 25 m for loading of adequate charge. This essentially requires man-portable drilling rigs with suitable compressors to cope up with the difficult logistics and acute shortage of water.

As regards the Mizoram block, what is adopted as a feasible approach to 3D seismic coverage is that the loops formed by crooked lines along which 2D seismic shooting has already been carried out, be chosen for seisloop based 3D seismic. This ensured accessibility for drilling of shot holes and laying of seismic profiles so that the loop shooting is absolutely hassle free. In the present study previously acquired crooked 2D lines are reconnoitered for forming closed loops (Fig-1). All the identified loops are accessible with ease as they are formed by already surveyed lines.

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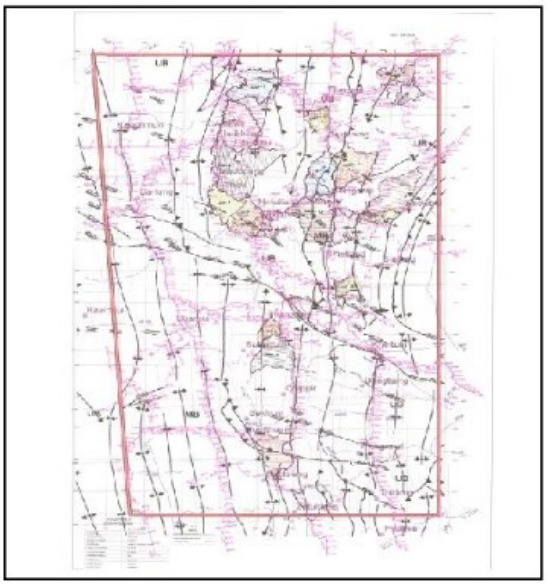

Fig 1: Seisloop identified in study area

Geological setting

The area of operation is a part of Tripura – Cachar – Mizoram fold belt of Assam Arakan Basin. The Mizoram fold belt is composed of tight linear folds with their axes almost in north-south direction. The anticlines are long, narrow and tight, whereas the synclines are broad and gentle. As per the geological section of the area of operation, the area has Tipam formation exposed in the central part and Bokabil formation is exposed in the eastern and western part. The Bhuban formation is divided in three formations as Lower, Middle and Upper Bhuban formations. Lower Bhuban formation is mainly alternations of sandstones and shale. The Middle Bhuban consists of mainly shale with subordinate sandstones. The Upper Bhuban consists of alternations of sandstones and shale. Geomorphology of Manipur-Mizoram-Tripura region is typified by a succession of sub-parallel hill ranges and long valleys. The hill ranges reach a maximum height of around 1800m in Mizoram with most of these between 9001200m.

Study area

The surface topography of the proposed area of seismic operation is that of typical northeastern rugged hilly terrain of India. The topographic features are highly undulating with thick forest cover. The hillocks have very steep slopes ranging between 60-80 degrees with intervening deep gorges.

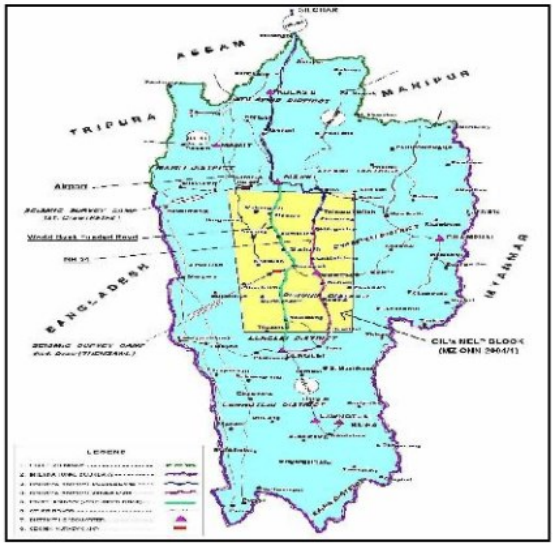

Fig 2: Study area depicted over the Mizoram map.

Objective

The main objective of espousing seisloop based 3D seismic survey is to acquire high quality 3D seismic data for proper delineation and imaging of hydrocarbon prospects in this geologically complex thrust fold area where zone of interest lies between 2000 – 5000 meters.

Design of Seisloop

The problem of surface access led to development of the seisloop technique which provided areal subsurface coverage by placing sources and receivers along the periphery as well as inner tracks of the loop. The loop technique produced highly variable fold, irregularity in offset distribution and highly variable azimuth distribution. The layout of the 2D seismic lines in the block area does not provide much choice for selection of the areas for seisloop to be considered for 3D shooting. The desirable loop is the one that has 3-4 sub-loops which constitute the main loop as depicted in (Fig-3).

Investigations were therefore undertaken for deliberate hunt for the possibilities of a few more tracks falling in between the various loops formed by the 2D seismic lines already covered, so as to form sub-loops. Theoretical response of Seisloop 3D has been ascertained through modeling studies for the designing of the Seisloop.

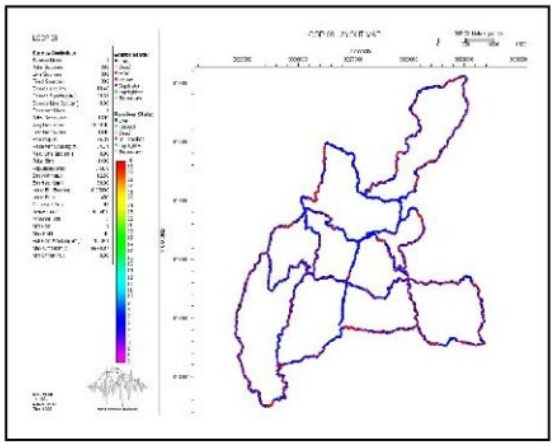

Fig 3: Seisloop or loop technique of seismic acquisition

The receivers are placed all along the loop at a uniform interval of 25m and shots are placed at a uniform interval of 100m along the perimeter of loop and at 200m along the inner track of the loop. All the receivers remain active for every shot and the entire loop is covered by successive shots one after the other.

The response is assessed through the following outputs:

- Midpoint scatter diagram
- Midpoint fold distribution
- Midpoint azimuth diagram
- Midpoint offset diagram

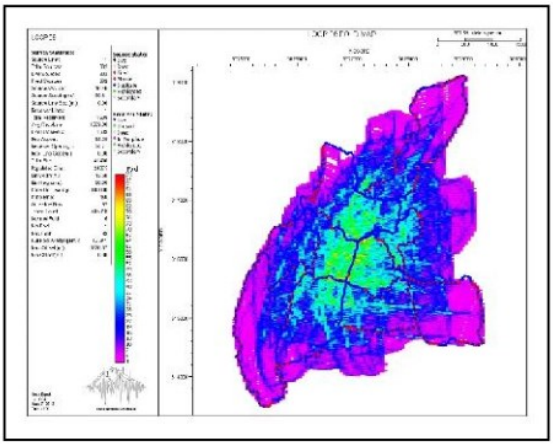

Fig 4: Fold distribution map.

In designing of the seisloop care has been taken to restrict the far offsets to around 6 km, so as to ensure that the receivers placed at far distances get sufficient energy. Certainly a maximum far offset of the order of 6 km. is required to capture the targets occurring at depths in excess of 4 km.

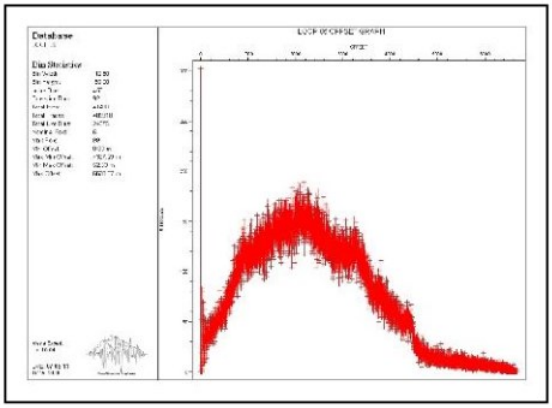

Fig 5: Offset distribution map.

The total no of receivers are also variable for different loops subject to the size of the loop. The lines constituting most of the loops are such that no valley falls in between them. The seismic energy would thus be travelling although in the lifted anticlinal areas only. To take care of the attenuation of energy at far offsets the charge size were increased from 7.5 kg used for 2D seismic to 15 kg (distributed in two shot holes each having a depth of 25m).

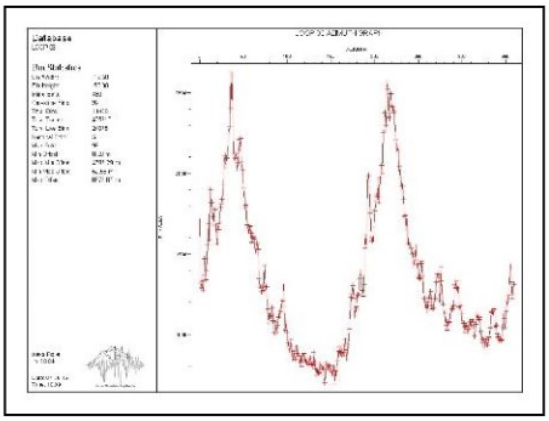

Fig 6: Azimuth distribution map.

The optimized acquisition parameters for seisloop shooting are as follows:

Recording Instrument	24 bit Delta-Sigma technology equipped with suitable noise shaping filter and having a minimum dynamic range of 120 dB
Number of Channels	Variable in the range of depending on the size loop
Nominal Fold	Variable
Receiver Interval	25 m
Shot Interval	100 m
Minimum near offset	25 m
Maximum far offset	About 6 km. in most of the loops and about 7 km in a few loops
Energy source	Dynamite
No of geophones per receiver point	12 (bunched)
Recording length	10 sec

It is observed from the response of the loops that middle part of the loop area does get sufficiently illuminated with foldage of more than 12 and up to 80 in most of the cases. Such well illuminated parts occupy areal extents in the range of 20% to 40% of the total loop area.

Seismic data recording:

The data were recorded using seisloop method, in which the cables were laid out in a loop comprised of roads through the study area. The source is then moved along the periphery as well as along the inner track of the loop. Due to large size of loops and irregular in shape, shots were also placed along inner track of the loop in order to get rid of energy issues at larger offsets (Fig-3). Figure-7 shows a raw shot gather recorded using seisloop technique.

In any event, there is a problem in this type of coverage, associated with the azimuthal variations that can exist between rays which constitute a common depth point (CDP) gather at a particular reflection point, or which arrive at adjacent reflection points and may appear side-byside on a seismic section. Thus it is important to recognize the variable ray path azimuth in the seisloop method, because this greatly affects the interpretation of the data which follows.

Conclusion

- Conventional 3D seismic is not at all implementable in Mizoram area. Seisloop method is the only operable way of 3D coverage.
- Adoption of seisloop based 3D seismic survey in Mizoram has opened up a new vista & invigorated fold belt exploration.
- This technique provides reasonable azimuthal information; however, offset information is generally limited in most areas of the survey.
- Relatively high fold in well illuminated central part of the loop improves S/N ratio and thereby yield better quality of data.
- The method didn't suffer from any serious limitation in obtaining useful 3D seismic data except the access problem, and the limitations imposed by topography as well as by other environmental factors like weather & wildlife.

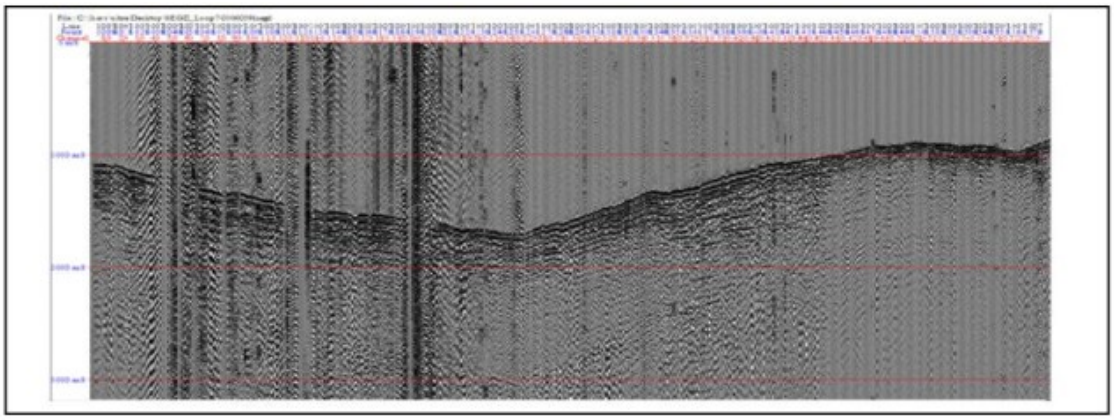

Fig 7: Raw seismic record acquired in one of the seisloop.

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