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# 'Illumination studies'- Tool for Better Sub Surface Imaging – A Case Study

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## Summary

*Three-dimensional (3-D) seismic surveys have been a major tool in the exploration and exploitation of hydrocarbons. Conventional 3D designs were mainly concentrated on analysis of bin attributes in particular: fold, offset distribution, and azimuth distribution. These survey designs assume that Common Mid Point (CMP) coverage and Common Reflection Point (CRP) coverage are equivalent, but this is not the case if the investigated structure is complex. In such cases sub surface mapping may not be accurate, therefore illumination studies should be performed for better understanding of sub surface. Subsurface illumination studies are not most often applied to feasibility studies and survey design, but the concept offers a wider range of applications. Therefore 3D modeling studies are crucial and have become a common way to deal with survey design. There are many ways to perform illumination studies; the most common are binning methods. A 3D modeling study was carried out at Khoraghat –Nambar area of Dhansiri valley Assam and Assam Arakan Basin on MESA software. A 3-D depth model was constructed and subjected to ray tracing and synthetic sections were generated with different survey designs. Various attributes along with synthetic sections were studied and optimized a suitable geometry for data acquisition. The project was successfully executed and the processed sections were compared with the synthetic sections to establish the efficacy of the modeling studies. The present case study deals with the various aspects of illumination studies and its impact on survey design and its parameters.*

## Introduction

3D survey design is still an empirical process based on quantities like fold (CMP coverage), offset distribution on a flat layered model. In order to ensure proper imaging of the sub surface structures, good CMP gathers and offset distribution within a gather were the main criteria. Conventional survey design assumes that CMP and CRP coverage are equivalent and this works well for simple geological structures, but this is not true for complex structures. In such cases conventional survey design will give an inaccurate picture, therefore illumination studies would be better alternative tool. Sub surface illumination studies are important and mainly used to analyze the effects of different survey designs. It gives valuable information in the challenging areas, besides a rough estimate of target surface illumination that can be related to the image quality. Once the influence of the acquisition geometry on the image quality is understood, it is possible to optimize the survey layout and imaging strategy for the best possible results and reduce the risk of seismic exploration. Depending on the illumination of the target surface, the survey layout used for the modeling can be validated, optimized or simply rejected. Performing such studies, will lead to cost effective 3D seismic data acquisition with better sub surface imaging. The Khoraghat-Nambar area

Figure 1: Prospect Map with project area

(Fig-1) is located in the central part of the Dhansiri Valley bounded by the Naga Hills on the east and the Mikir Hills on the west. Khoraghat –Nambar is a major hydrocarbon producing area.

Hydrocarbons are being produced mainly from strati – structural plays of Bokabil formation. Additionally, a few wells produced from Barail and Sylhet formations. Hydrocarbon shows were recorded in Kopili, Tura and Basement rocks in and around the area. 3-D seismic acquisition in the area was first carried out in different phases spreading from 1989 to 1993 and after a gap of ten years the area was surveyed with an objective to map Strati-structural / Stratigraphic features in Bokabil and Paleogene sequences Illumination studies were carried out to understand the sub surface at the pre survey stage and optimized the survey design to have a better imaging of the sub surface with high resolution.

## Methodology

Keeping the geological aspects into consideration a detailed study was made on various survey designs and its attributes. Out of which four geometries (Table-1) were short-listed, the orientation of three geometries was in NW- SE direction and one W-E direction. The basic aim of the seismic survey is to acquire good quality data at a low cost. Achieving the optimum fold does guarantee a good signal to noise ratio and overall illumination, but not necessarily proper resolution. There are several methods available in order to investigate both the illumination regularity and resolution quality. 3-D ray tracing followed by target – oriented binning method is the most common of the illumination methods in the industry because it is relatively simple to handle, robust and cost effective.

Table 1: Parameters of Different Geometries

| Sl.No | Parameters | Geom-1 | Geom-2 | Geom-3 | Geom-4 |
|---|---|---|---|---|---|
| 1 | Type | End On Slant | End On Slant | End On Slant | End On Slant |
| 2 | No of # per line | 70 | 70 | 64 | 60 |
| 3 | No of Receiver lines | 12 | 12 | 10 | 12 |
| 4 | Total Number of Active # s | 840 | 840 | 640 | 720 |
| 5 | Shot Interval (x-line) | 100 | 100 | 100 | 100 |
| 6 | Shot Line Interval | 250 | 250 | 200 | 250 |
| 7 | Receiver Line interval | 200 | 200 | 200 | 200 |
| 8 | Fold | 42 | 42 | 40 | 36 |
| 9 | Shooting Direction | 125º13’ | 90º00’ | 125º13’ | 125º13’ |

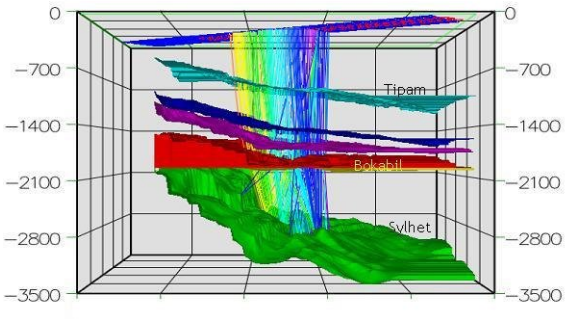


Figure 2: 3-D Depth Model

3-D depth model (Fig-2) of Khoraghat – Nambar area was built with the help of six horizons viz Tipam, Bokabil Top, Mid Bokabil, Lower Bokabil, Barail, and Sylhet The basic assumption in the depth model, the layers were considered as homogeneous with no lateral velocity variations. Velocities were taken from the available sonic logs and density was derived using Gardener’s formula. On the 3-D depth model, reflections from the target surfaces were ray traced for all the four geometries.

Ray tracing allows not only computation of two way travel times, but also many other attributes like CRP fold, AVO Average and Maximum incidence angle, CMP to CRP displacement and attributes were mapped on the target surfaces for all the geometries. With the available software on MESA, synthetic gathers and sections were generated for these geometries.

## Discussion

The diagnostic attributes displayed for the deepest horizon Sylhet for discussion. Synthetic seismic sections were also analyzed for all the geometries.

- *CRP fold*
  CRP fold (hit count) is the number of hits on each bin cell of the target surface. It gives illumination aspect of the focusing areas as well as identifying potentially low

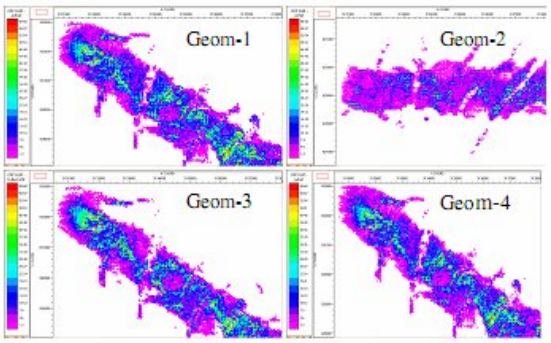

Figure 3: CRP Fold at Sylhet Level

S/N ratio areas (low fold Zones). The CRP fold (Fig-3) is displayed for the deepest horizon Sylhet. The average CRP fold in Geom-1, 3, 4 is 16- 22, whereas in Geom-2 is in the range of approx 8-10. After a detailed study it was observed that the Geom-1 and 3 had better CRP coverage then the Geom-4.

- *Average Amplitude*
  The average amplitude at the deepest horizon was shown in fig-4. The amplitude strengths were comparable in the down thrown side of the fault in all the options. Geom-1 and 3 were showing better amplitudes at the up thrown side of the fault.

- *CMP-CRP displacement*
  It computes the average horizontal displacement between CRP and CMP for all the rays and the values

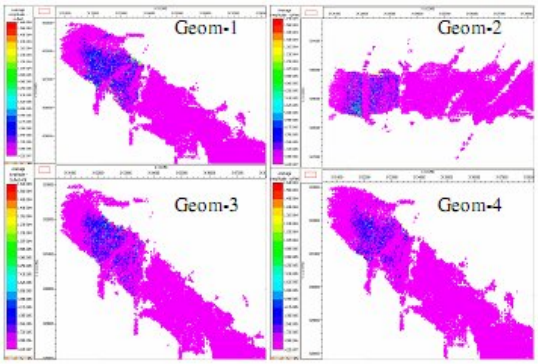

Figure 4: Average Amplitude at Sylhet Level

then plotted at the CMP location. It gives a direct estimate of migration aperture; smaller CMP-CRP distances are preferable. After a detailed analysis this attribute (Fig-5) it was found that the displacement values were higher and varied from 0 to 900 mts in Geom-1 and 2, whereas Geom-3 is having low displacement values (0-700). At the boundaries the displacement values were of minimum in the range of 0-180 mts in Geom.-3.

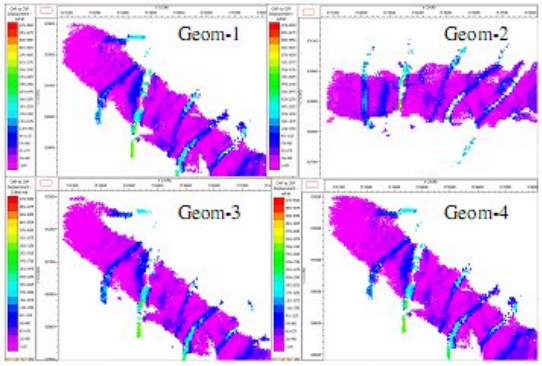

Figure 5: CMP-CRP displacement at Sylhet Level

- *Angle of Incidence*
  It helps in understanding AVO. A point on the target surface with a narrow interval of incidence angles has a poor lateral resolution. Minimum, Average , Maximum (Fig 6), incidence angle in each bin mapped on to the target surfaces. The contribution maximum incidence angles were observed Geom-1 and 3

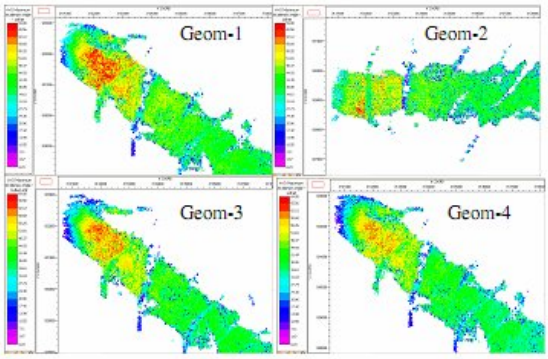

Figure 6: Maximum Incidence Angle

- *Synthetic sections*
  Synthetic sections were generated with limited processing procedures. Synthetic sections (Fig-7), all the horizons were well developed for all the geometries. Detailed study of these sections suggests that the good resolution and better delineation of fault was observed in Geom-1 and Geom-3. The synthetic sections well supported the line orientation i.e. NW-SE

The above study suggested that Geom- 1 and 3 were most suitable geometries for the data acquisition. Seismic data acquisition was carried out with Geom-3 in Khoraghat- Nambar area successfully. High frequency content was observed on the raw data. The data was processed and the section (Fig -9) in the model area was compared with the

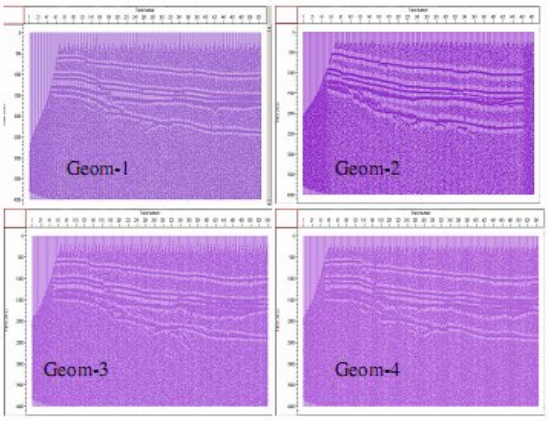


Figure 7: Synthetic Seismic sections with different Geometries.

synthetic section ( Fig-8) genereated with Geom-3. Comparitive study suggestes that the resolution of different layers and fault patterns were successfully delineated besides good frequency.

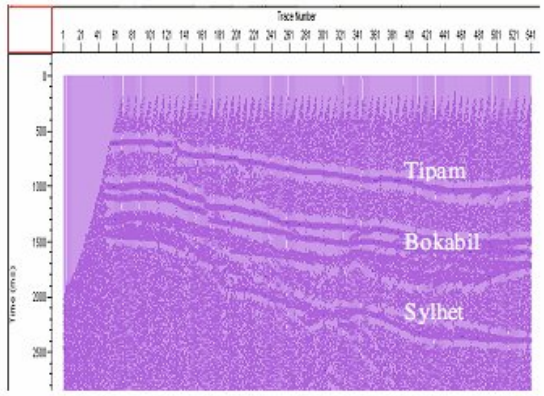


Figure 8: Synthetic Seismic section with Geometry-3

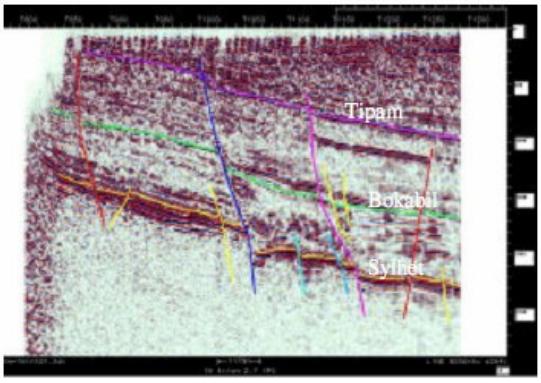


Figure 9: Seismic section in the Model area

## Conclusions

3D modeling studies were successfully carried out for Khoraghat-Nambar area which helped in selecting suitable geometry.

Modeling studies successfully established the efficacy of the proposed shooting geometries, direction of shooting, and quality of imaging.

Illumination gave valuable information about what can be expected from the data before the acquisition at a reasonable cost, time and reduces the risk of seismic exploration.

3D modeling studies were crucial and vital to deal with survey design, achieving the optimum CMP fold does guarantee a good signal to noise ratio and overall illumination, but not necessarily proper resolution.

## References

i **)** Vermeer Gijs J.O - 3-D Seismic Survey Design SEG Geophysical References vol 12 ,2002

ii) Renaud Laurain et.al - A Review of 3-D illumination Studies ., Journal Of Seismic Exploration I3 17-37(2004)

iii) Havar Gjoystdal et.al - Review of ray theory applications in Modeling cum imaging of seismic data Stud.geophs.geod ; 46 (2006)

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