Optimizing Spread Geometry for Effective 3D Survey in South Nambar, A&AA Basin, Assam

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Summary

South of Nambar area, has become very promising exploration target in the South Assam Shelf of A&AA Basin due to recent hydrocarbon finds in the Bokabil formations of Neogene in the Nambar area. 3D seismic surveys have been carried out to map the reservoir sands in south Namabar area. 3D data were acquired using End-on Slant and Orthogonal shooting geometries during 2003-04 and 2004-05 respectively. The present paper deals with a comparison between various attributes of the shooting geometries and their effects on the data quality. The processed data quality is also compared and it is observed that orthogonal shooting geometry has provided better data quality.

Introduction

South Nambar area lies in the southern fringe of Upper Assam in Dhansiri valley close to Naga thrust-Shuppen belt .The area is very close to the prolific oil producing fields like Khoraghat, Uriamghat and Nambar lying towards north east and north. Figure-1 shows the prospects map of the area. The area has been covered by gravity, magnetic, aeromagnetic and 2D seismic surveys of various vintages with 12 & 24 folds. Gravity and Magnetic data have brought out undulating basement with a broad high at the central part. Residual gravity map shows a high south of the Bokajan. In the Nambar field, five exploratory wells have been drilled based on the interpretation of 2D seismic data . Testing results shows the average daily production from the field is approximately 60 tonnes of oil and 28000 SCM of gas per day from Barail & Bokabil formations. The study area lies south of the Nambar Field. The preliminary interpretation of existing 2D seismic data reveals that the pay horizons of Namabar field are most likely extended towards south. Hence, in South Nambar area, the prime exploration targets are the Neogene Bokabils and Paleogene Barails. These formations are lying within from 1500m to 3500m and corresponding two way travel times are from 1000msec to 2500msec.

2D seismic data in the area show frequency bandwidth of 10-25Hz which is not adequate for resolving 5-20m thick reservoir sands in Bokabil formation (Neogene). Therefore, for better mapping of thin & isolated reservoirs and mapping of different fault patterns in the area, 3D seismic survey was conducted during 2003-04 using SN388 instrument with 360 active channels in a bin of 12.5mX25m having 30 fold using Slant shooting geometry. The data quality was improved as compared to the existing 2D data in the area.

Again, during 2004-05, the Crew was given a task to acquire 3D seismic data with state-of-art instrument 408UL using maximum number of active channels (up to 1000). Different acquisition geometries with more number of active channels were studied to optimize the data quality and production with the help of various attributes such as Fold, Offset & Azimuth distribution, Minimum & Maximum offset distributions in the bins. These studies were carried out using state-of-art GEOLAND and MESA software.

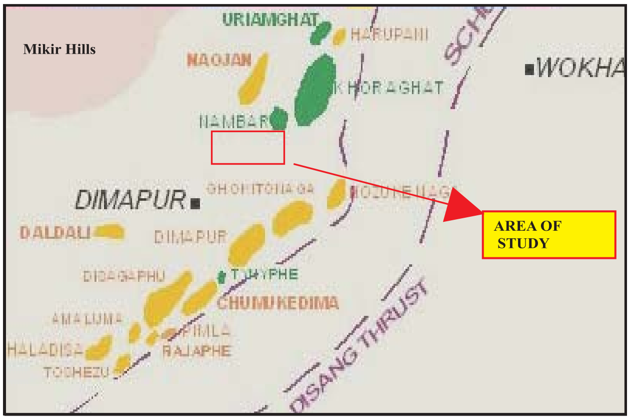


Fig.-1 Prospect Map of the North Assam Shelf

The paper explains the studies involved in fixing the acquisition geometry and the value addition in the seismic data thus acquired with the help of new spread geometry.

Geology

The area lies in the southern fringe of Upper Assam in Dhansiri Valley close to the Naga–Shuppen belt. The drilled wells in the area have penetrated from Alluvium to Basement through Neogene (Moran, Tipam and Bokabil) and Paleogene (Barails, Kopili, Sylhet & Tura) sequences. In the area, all pay sands are mainly confined between Barail top unconformity and an Erosional surface above Lower Bokabil. Bokabil formation was deposited in the deltaic environment and consists of sand shale alterations with sand units varying from 5 to 20m with limited horizontal extent (Reddy et.al.,2004). Hydrocarbon bearing Bokabil sands of Miocene age encountered in the N#A well are likely to be extended in southward direction.

Anticipated plays in the area are Sylhet, Kopili and Bokabil.

Hydrocarbons do occur in the clastic reservoirs of Eocene i.e. Sylhet consisting of sand, shale, and limestone alternations with sand unit thickness varying from 5m to 10m. Kopili formation of middle Eocene age is mainly shale section with sand units having thickness of 5-10m.

Structural framework

Existing 2D seismic data in the area has brought out a series of alternating ENE-WSW trending fault blocks bounded by faults showing normal separation. A seismo-geological section prepared across the block in WNW-ESE direction depicts the overall structural setup of the area (Figure-2). Time structure map of reflectors close to top of Sylhet, Barail and Bokabil formations(Tertiary) bring out a similar structural features. Two fault trends have been identified in the area; in the northern part the dominant trend is N-S to NNE-SSW that is consistent with the Khoraghat & Nambar trends whereas in the southern part, ENE-WSW is the dominant trend that is similar to that of the Dimapur & Karbi -Anglong area. These faults exhibit strong strike slip component also. There are small faults at the reservoir levels (Bokabil & Barail) playing very important role in hydrocarbon entrapment. Identification and mapping of these faults is the prime objective to carry out 3D survey in the area.

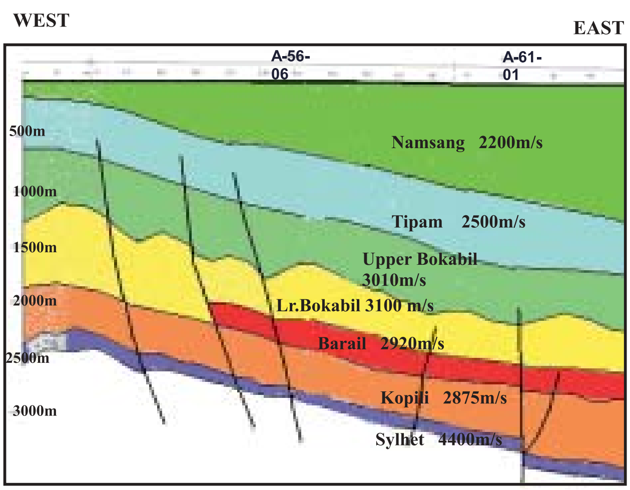


Fig. 2: Seismo-Geological Cross Section

3D Data acquisition

During 2003-04, 3D seismic data was acquired by SN388 instrument using Slant shooting geometry in a bin of 12.5mX25m. The acquisition parameters are given in Table-1. Slant shooting geometry having 3 Receiver lines and 6 Shot lines is used and the unit template is shown in figure-3. Various attributes- Fold, Minimum offset, Maximum offset, and Azimuth distributions are shown in the figure-4.The offset distribution in a bin is uniform but restricted to a limited azimuth. Fold, Minimum and Maximum offset distribution are quite good.

The area was revisited during 2004-05 with a new instrument; 408UL deploying more number of active channels than in the previous campaign. Before starting the data acquisition, various acquisition geometries were studied using GEOLAND and MESA software in order to select the best possible geometry which would provide the quality

Table-1 Acquisition Parameters

Source Line Interval	:	50 M
Group Interval	:	25 M
Shot Interval	:	150 M
Receiver Line Interval	:	50 M
Bin Size	:	12.5 M X 25 M
Fold	:	30 (10x3) fold
No Of Receiver Line Per Swath	:	3
Total Number of Active Channels	:	360
No. of shots/Salvo	:	6
Near Offset	:	400M to 580M
Far Offset	:	3375M to 3510M

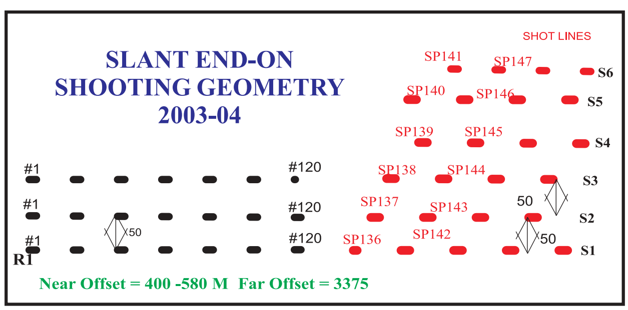
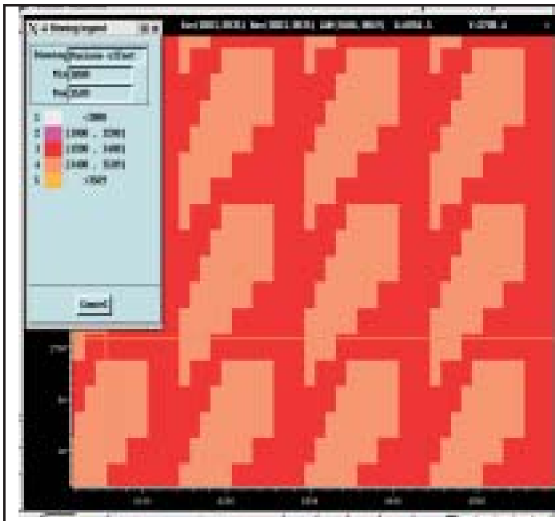
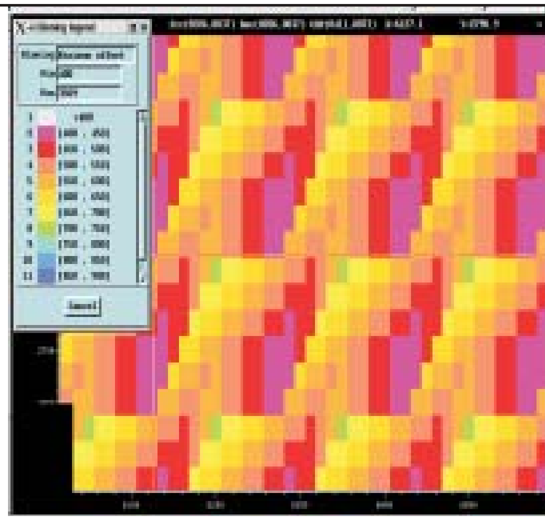


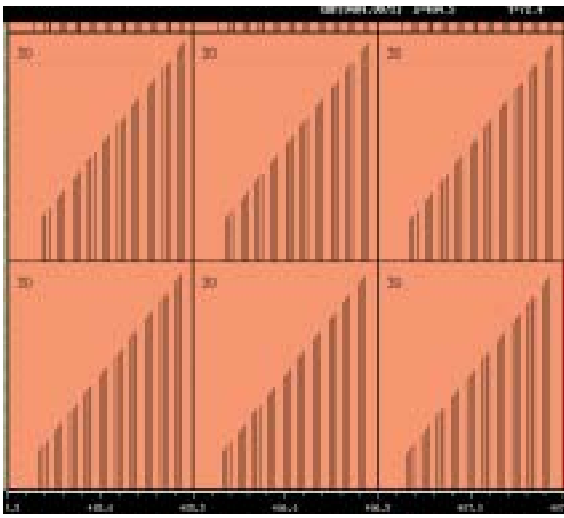
Fig. 3: Acquisition Geometry for the Slant End-on shooting



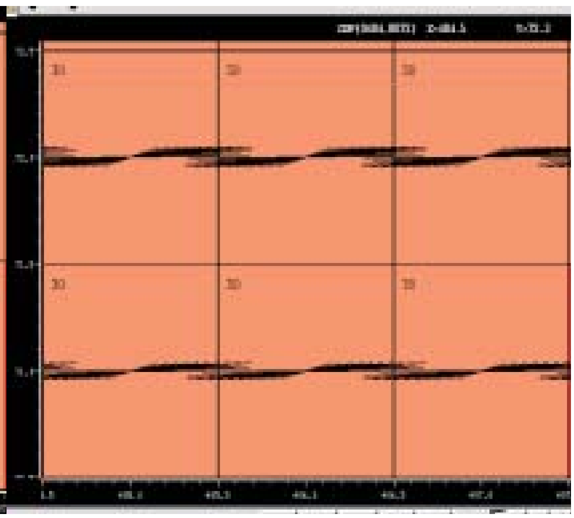
(a) Maximum Offset Distribution



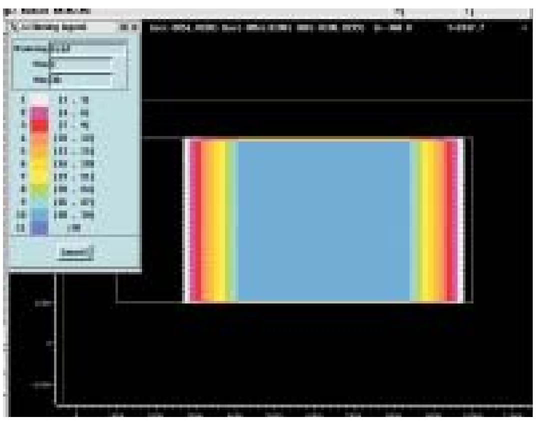
(b) Minimum Offset Distribution



(c) Offset Distribution in a bin



(d) Azimuth Distribution in a bin



(e) Fold Distribution

Fig. 4: Attributes of Slant End-on Shooting Geometry

data cost effectively. Various attributes of these geometries are shown in the Table-2. The study shows that wide orthogonal geometry using 720 channels and 60 shots per salvo is the most suitable geometry. The geometry provides the aspect ratio 0.8 which is very close to the ideal situation (Aspect Ratio=1.0) because physically there is no difference between properties in the in-line direction and in the cross-line direction (Vermeer, G.J.O., 2002). The bin size and fold are kept same so that there will not be any problem while merging the two 3D data sets. The acquisition parameters are given in the table-3. Seven hundred and twenty active channels are spread in 5 receiver lines as shown in the figure-5. Fold, Minimum and Maximum offset distribution

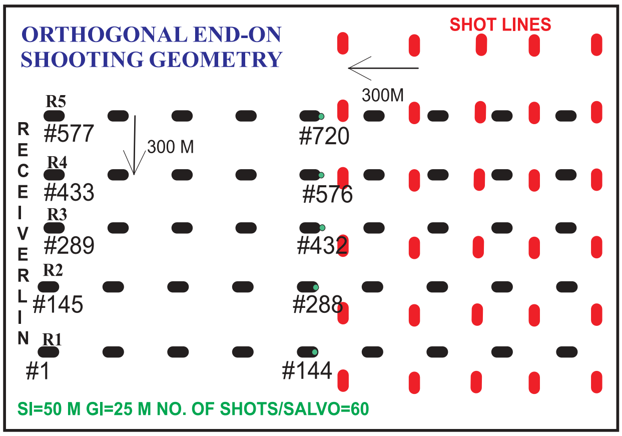


Fig. 5: Orthogonal End-on Shooting Geometry

Tabl-2 **Attributes of Different Acquisition Geometries**

TypeOf Geometry	**End-on Ortho-gonal**	**End-on Ortho-gonal**	**Sym. Split Spread Orthogonal**	**Slant End-on**
Attribute				
Bin Size	12.5mx 25m	12.5mx 25m	25mx 25m	12.5mx 25m
Active Channels	140x5= 700	144x5= 720	140x5= 700	144x 720
Fold	7x5=35	6x5=30	7X5=35	6X5=30
Unique fold @25m	**28-35**	**23-30**	25-35	25-30
Fold (0-1000m)	3-6	2-6	4-6	5-10
Fold (1000-2000m)	10-14	6-11	11-14	5-10
Fold (2000-3000m)	10-13	7-13	10-12	5-10
Fold (>3000m)	5-11	5-11	5-9	5-9
Fold (2200-3700m)	12-17	11-16	14-16	10-15
RLI	300m	300m	300	100m
SLI	250m	300m	500	300m
Shot/salvo	60	60	60	5X4
LMO	640m	640m	600	640m
Max. far Offset	3374-4069m	3404-4115m	3313-4047	3266-3761

are good and comparable with the Slant method, however the offset distribution in a bin is random covering all the azimuths as shown in figure-6.

Table-3 Acquisition Parameters

Group Interval	:	25M
Shot Interval	:	50M
Receiver Line Interval	:	300M
Shot Line Interval	:	300M
Near Offset	:	25M
Far Offset	:	4168M
No of Receiver Lines	:	5
Total Number of Active Channels	:	720
No. of Shots / Salvo	:	60
Fold	:	30 (6X5)
Bin size	:	12.5Mx25M

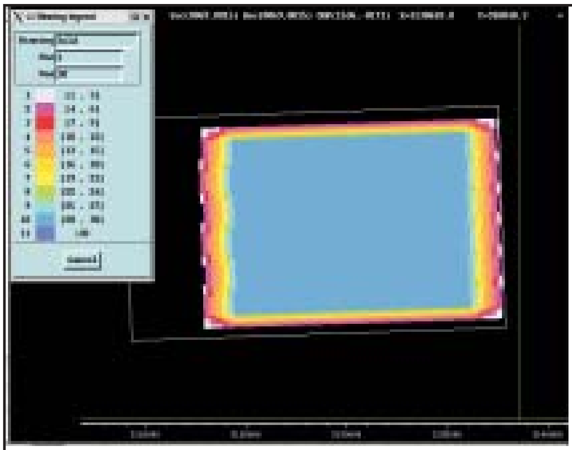
Strict quality control was also maintained for geophone plantation, depth of the shots, loading of charge and tamping the shot holes which have also contributed towards better data quality.

While comparing the two shooting geometries which were used in 2003-04 and 2004-05, it is observed that for Orthogonal method, traces from almost all the azimuths are contributing in a bin where as for Slant method the traces from narrow azimuth are contributing to a bin as shown in figure-7 .Therefore, a CDP gather from orthogonal method represents complete seismic wave field which would definitely give better stack response and it, in turn would provide better estimates of the rock properties.

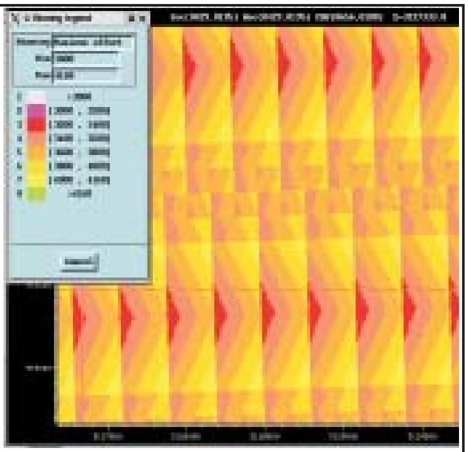
In the Orthogonal method, the absolute–offset distribution in a bin(figure-8) is more or less random resulting in better stack response, while in Slant geometry, paring of offsets are seen which would deteriorate the velocity estimation and stack response. Vermeer, G.J.O.,2004 studied the distribution of offsets in a bin for various acquisition geometries and its effect on stack response. Minimum and Maximum offset distribution in a bin are comparable in both the geometries, although largest minimum offset is more in Slant method.

In case of Slant shooting method, missing near offsets would result in loss of high frequencies as well as poor velocity estimation.

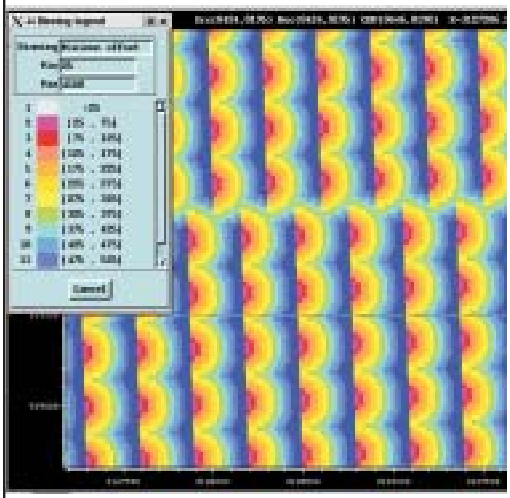
It is therefore, by using Orthogonal geometry, seismic wave-fields (from all the azimuths) are better captured during the data acquisition which would result in better final output .The stack response would also be better because of the random distribution of offsets leading to suppression of noise of different wavelengths (Vermeer,



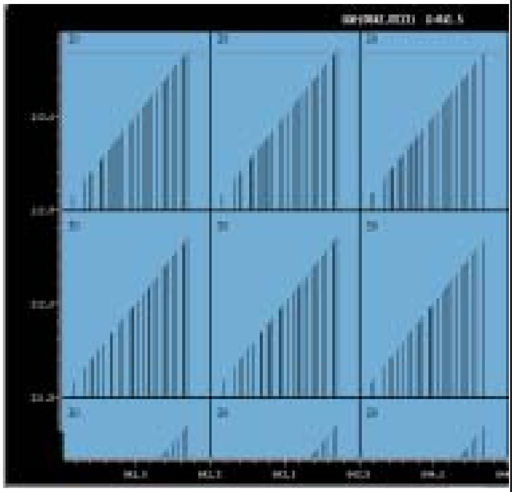
(a) Fold Distribution



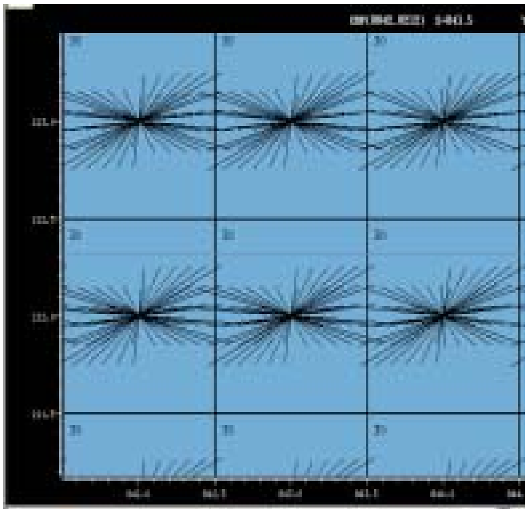
(b) Maximum Offset Distribution



(c) Minimum Offset Distribution



(d) Offset Distribution in a bin



(e) Azimuth Distribution in a bin

Fig. 6: Attributes of Orthogonal End-on Shooting Geometry

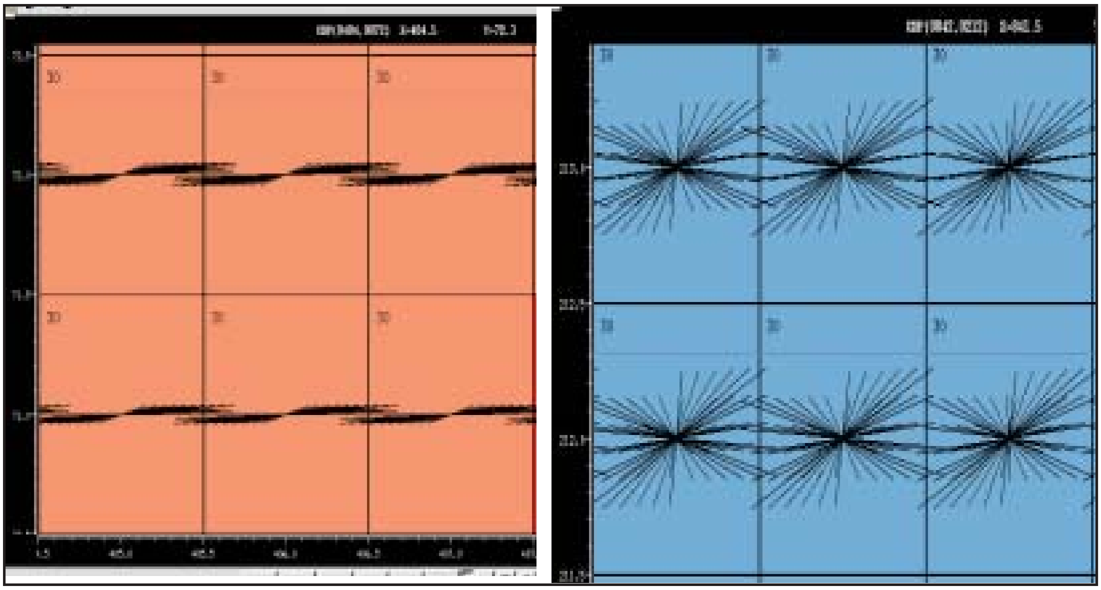


Fig. 7: Azimuth Distribution in a bin

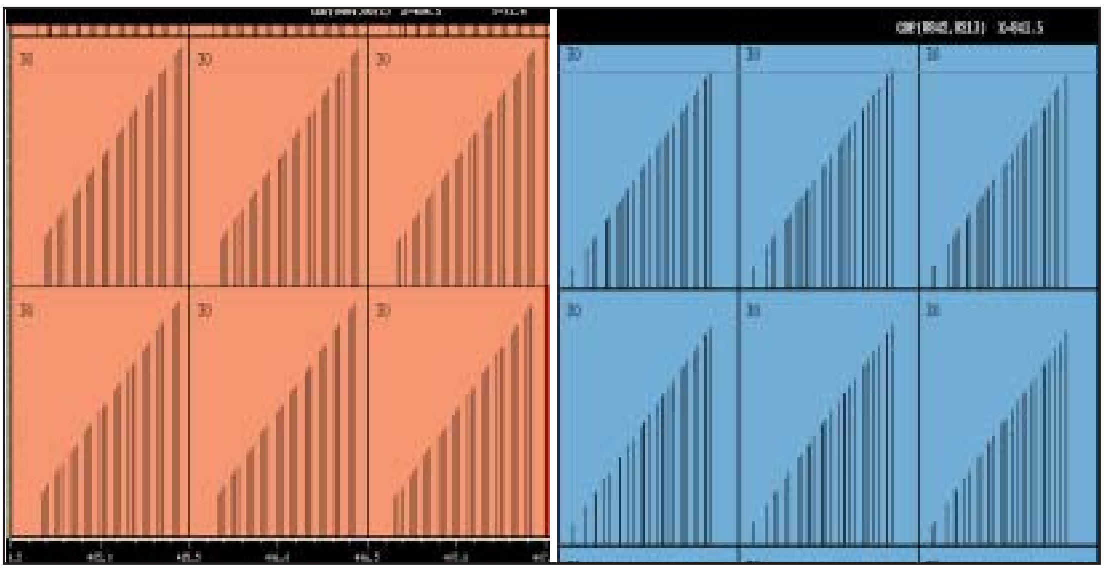


Fig. 8: Offset Distribution in a bin

G.J.O. 2004). Additional benefits accrued are : (1) it is easy to lay out in the field (2) number of shots per salvo is more in comparison to other acquisition geometries (3) it can be laid out ahead of the shooting (3) roll along operations are very easy and (4) it is easy to monitor by the instrument.

Analysis of seismic data

2D surveys having 12 and 24 folds acquired so far in the area facilitated identification and mapping of structural features quite nicely but did not provide the stratigraphic features clearly because of the lower frequency bandwidth of the data. However, 3D data acquired during 2003-04 using Slant method is better than existing 2D data. The reflectors are seen from 500msec. to 2400msec in the raw records shown in figure-9. The reflection from Sylhet formation, the deepest target horizon, is also seen. The frequency spectrum of the raw data shows frequency band width of 8-40 Hz at 12dB level of attenuation as shown in figure-10

However, raw records from 3D data acquired during

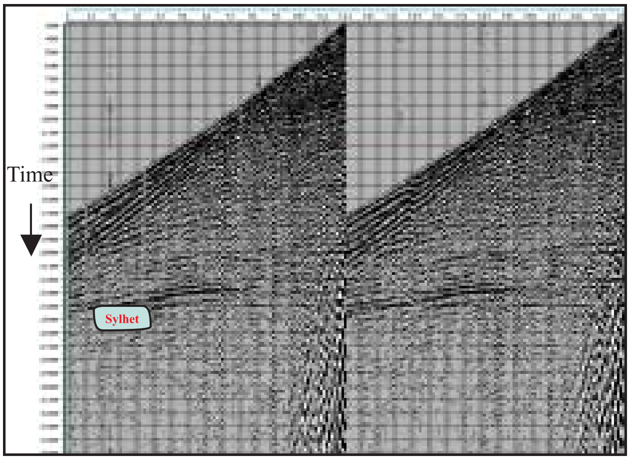


Fig. 9: A raw records from 3D data volume acquired using Slant geometry

2004-05 using Orthogonal method show very high S/N and broader frequency spectrum as compared to the data shown in figure-9. Very good reflectors are seen from 400msec. to 2500msec. The deepest reflector corresponding to Sylhet formation is also seen quite nicely (figure-11). Raw data shows very good frequency bandwidth of 8Hz-80Hz at 12 dB of attenuation (figure-12). Comparing the raw records and frequency spectra(Figure-9 &10 Vs Figure-11 &12) it is very clear that the data acquired by using Orthogonal method is better than that acquired by using Slant method.

As far as final processed data quality is concerned, a representative 2D processed section is shown in Figure-13. Top of the Lr. Bokabil, Barail, Sylhet and Basement are interpreted and marked on the section. The dominant frequency is approximately 25Hz which is not adequate for resolving sand layers of 5-20m thick.

Seismic section from finally processed data volume acquired by using Slant method corresponding to the 2D

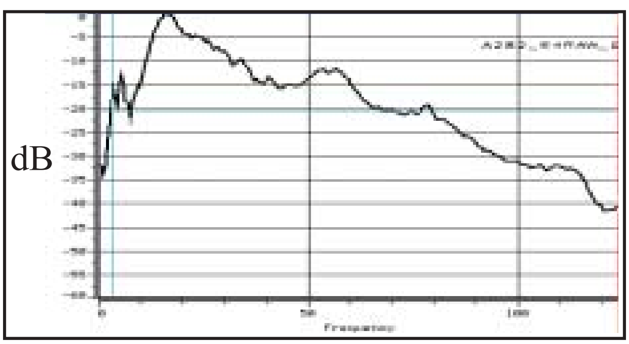


Fig. 10: Frequency Spectrum of the raw record in the figure 9

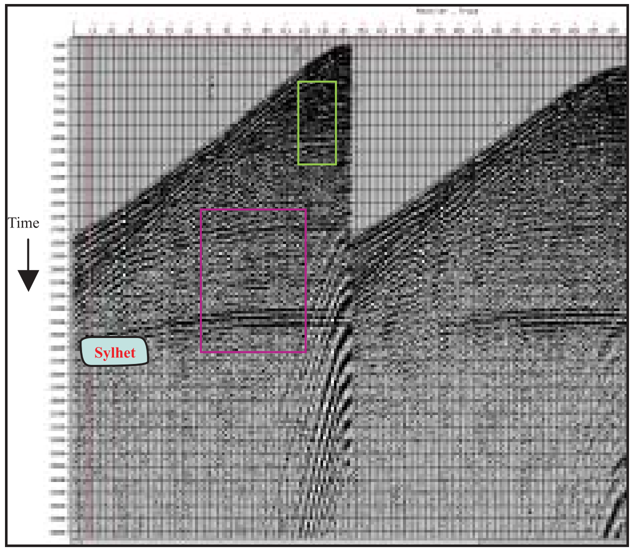


Fig. 11 : A Raw Records from 3D data volume acquired using Orthogonal geometry

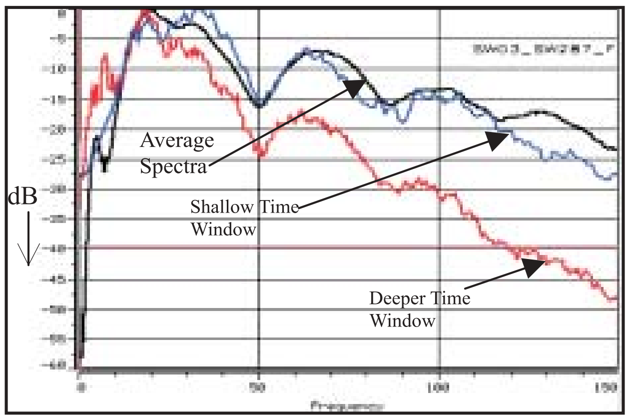


Fig.12 : Frequency Spectra of the raw records shown in fig.11

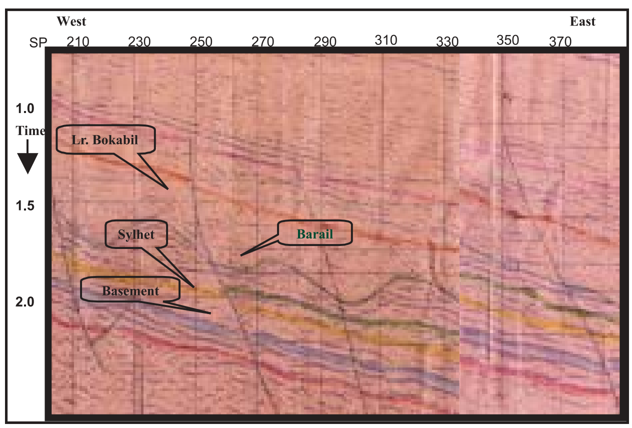


Fig. 13 : Interpreted 2D seismic section

line(Figure-13) shows far better S/N ratio and frequency content. The section reveals the Erosional unconformity marking the top of the Lr. Bokabil formation(Middle Miocene) quite nicely.

Top of the Barail and Basement are also brought out very clearly. Frequency bandwidth is in the range of 10- 48 Hz (figure-16) which is more than that of 2D data. 3D seismic section shows far better temporal and spatial resolution.

Further, 3D data acquired during 2004-05 with Orthogonal End-on shooting geometry is currently under processing and the intermediate seismic sections show higher temporal and spatial resolution as compared to the sections shown in figure 13&14. However, a 2D line (1.5km north of the 3D inline shown in figure-14) is taken out from the 3D data volume and processed using normal processing sequence. The seismic section in figure-15 shows better amplitude anomaly at the Lower Bokabil level. The reflectors corresponding to Middle & Upper Bokabil and Tipam are better brought out. Faults and other stratigrphic features are better deciphered in the section. The frequency bandwidth is observed as 10-58 Hz at 12dB level of attenuation. The frequencies more than 20 Hz are better preserved in orthogonal method than in Slant method as shown in Figure 16. The final processing of the data in 3D mode would certainly provide better frequency content and higher S/N ratio which would meet the geological objectives of the 3D survey.

Thus, 3D data acquired during 2004-05 with Orthogonal End-on geometry shows better S/N ratio, better temporal and spatial resolution as compared with the 3D data acquired during 2003-04 with Slant End-on shooting geometry.

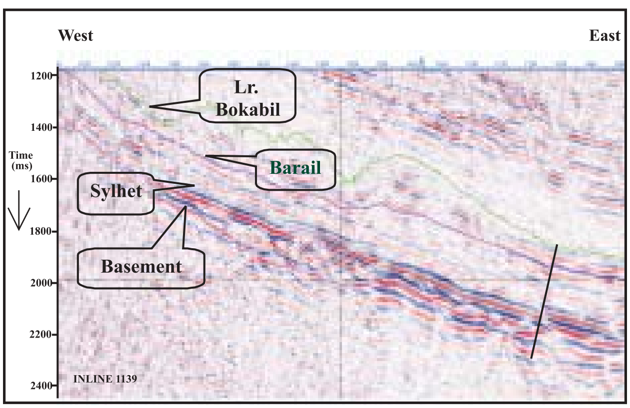


Fig. 14 : Interpreted Seismic Section From 3D data volume acquired using Slant End-on shooting geometry

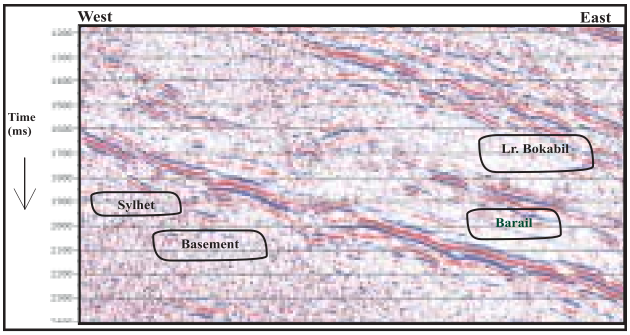


Fig. 15 : Seismic Section processed in 2D mode (Orthogonal method)

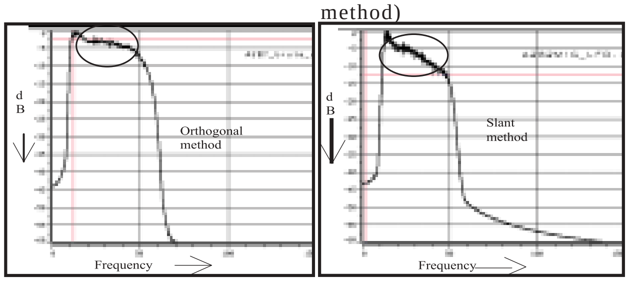


Fig. 16 : Frequency Spectra of the two stack sections (data acquired using Orthogonal and Slant geometry)

Conclusions

Choosing most suitable 3D data acquisition geometry and monitoring geophone plantation, proper shot-hole depth and its tamping are the crucial factors for obtaining high quality final output data fulfilling the geological objectives. The paper has clearly brought out that Orthogonal End-on shooting geometry coupled with the strict monitoring of the shot hole depth and geophone plantation has given us better data as compared to the data obtained using Slant End-on shooting geometry. One of the major reasons for the better data quality is that seismic wave fields from the entire azimuth are captured while using Orthogonal End-on shooting geometry rather than using Slant End-on shooting geometry. Other attributes of the two acquisition geometries are comparable.

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References

Vermeer,G.J.O.,2002, 3D seismic survey design: Soc. Expl. Geophys.

Vermeer, G.J.O.,2004, CSEG Recorder

Reddy,G.V. et.al.,2004, interpretation report of South Nambar area (unpublished)