Advanced 3D Seismic Modeling Studies as a Tool for Effectve Seismic Campaign for Exploring Strati-structural Features in Developing Field

G.Sarvesam, S.Choudhury, G.B.Ramamurthy*, Ranbir Singh
Geophysical Services, ONGC, Jorhat, Assam.

Summary

Geleki structure is one of the major fields in Assam shelf in India and was discovered in 1968 with the help of 2D seismic data. Subsequently in 1990's 3D data was acquired in Geleki and surrounding areas with DFS-V which were having limited channel capacity. Due to limitation in offset and signal to noise ratio 3D seismic data could image the sub surface with limited clarity and some data acquisition foot prints were remaining. It was decided to revisit the area to find out the minor structural plays, which are responsible for entrapment of oil. Before acquiring the data with state of art seismic recording equipment with higher channel capacity with smaller bin size and better shot hole drilling capabilities, pre-survey studies like spread geometries followed by 3D seismic modeling studies were carried out. The paper explains the studies and results.

Introduction

Geleki structure is one of the major fields of Assam shelf discovered in 1968 and established presence of hydrocarbons in multiple stratigraphic levels in Tipam sand (Lower to Middle Miocene), BCS (Oligocene), BMS (Oligocene) & Kopili (Eocene). So far, about 86 exploratory 214 development and 22 exploratory cum development wells have been drilled in the field. A total of about 180 MMT (approximately) O + OEG have been estimated in Geleki field with an ultimate reserve of about 30 MMT (approximately) O + OEG. In surrounding fields like Namti, Bihubar, Laxmijan, Mekeypur the presence of hydrocarbons identified. The Location map is shown in Figure 1.

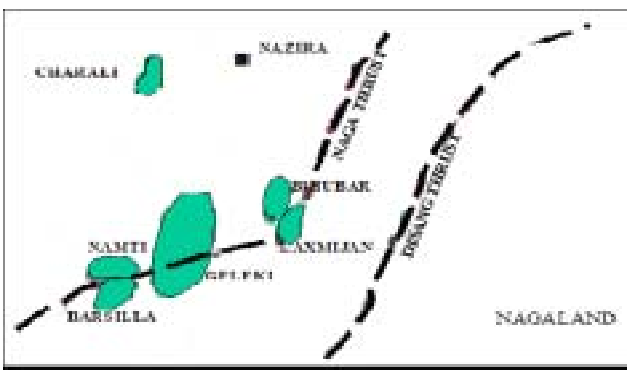

Fig.1 : Map showing Geleki and surrounding fields.

The structural configuration is result of late stage structural inversion of the preexisting Paleogene to early Neogene extensional features due to the compressional stresses evolved from the Burmese and Himalayan orogeny.

The Geleki /Mekeypur structural culmination are the upthrust anticline structures formed against the Geleki main reverse fault system resulted from late stage compression, while satellite fields like Bihubar, Laxmijan in east are also in the similar tectonic setting formed in the upthrust of Naga / Cholimsen thrust system. In a well developed thrust regime, transversely dissected structural culmination folds, ramp structures, duplexes are the dominated structural features in the upthrust part but in the present study area only the gently plunging anticlines like Geleki / Mekeypur is seismically imaged and can be mapped. The more complex part like upthrust Laxmijan and Barsilla could not be imaged seismically. In present seismic data curvilinear arrays are mappable along Geleki main fault corridor. However, seismic data in the inner belts towards Laxmijan –Bihubar doesn't image the subsurface thus mapping ambiguity remains. In the Geleki field also velocity pitfalls are noticed at Tipam level. Due to these factors reflectors corresponding to Tipam seem to be pulled down over the eastern part of Geleki structure and abrupt change in structural pattern is observed. In the thrust part as well as in BCS the imaging is poor. Presence of cross trends in the area could not be seen in the seismic data even though indirect evidences of cross trends are available. LANDSAT data clearly demonstrates the existence of cross trends.

The compartmentalization resulted by these cross trends should provide additional entrapment possibilities in down plunge area of Geleki field and also in Bihubar – Laxmijan area. The NE and SW trending reverse fault system with antithetic plays are the main structure controlling the fault system in the Geleki- Mekeypur area.

The entrapment is structural either fault controlled or independent structure closure. As far as BCS reservoir is concerned sands are more discrete in nature as they represent distributary channel sands because of discrete nature. BCS reservoir has stratigraphic implications in the form of lateral facies variation. 3D seismic survey carried out for the past two decades in this area mostly with DFS V system (bin size 25 meter x 50 meter), which was having limitation in number of channels and faithful recording of amplitudes in bandwidth. Due to limitations in number of channels limited number of receiver lines could be laid with larger near offset ranging upto 1000 meters. This resulted in absence of near traces, which are, in general rich in high frequency content and also it led to errors in velocity analysis and also these investigations were carried out with different spread geometries and left foot prints in the data. There were also limitations in shot hole drilling capabilities in the hard formation, which are prevalent in south east portion of the Geleki field.

All these factors led to limitation in imaging the subsurface and couldn't address the exploratory objectives like imaging the cross trends, faults with smaller throw, channel sands and stratigraphic features.

To meet these objectives 3D seismic survey has been planned once again in the area with smaller bin size (25 m x 25 m). The State of art of seismic data acquisition system 408 UL, with larger number of channels (1000) is planned to deploy in the area. Drilling inputs have been augmented with mechanized portable drilling rigs for better penetration of seismic energy.

3D seismic coverage, if not acquired properly, may not be able to resolve structural details in this area and in many instances may not even be superior to 2D seismic data in preferred orientations (Ray et al 2004). Ray trace modeling before data acquisition often plays a critical role in understanding imaging issues in structurally complicated areas. For survey design, 3D ray trace modeling is having certain advantages over wave equation modeling, such as cost and ease of determining optimized attributes, which are directly applicable to acquisition parameter decisions (Suarez et al 2004). Optimized survey geometries achieve balance between cost and illumination capability based upon known prospect data (Cain et al 1998). Due to these reasons various spread geometry studies followed by modeling was carried out before 3D data acquisition. The article explains the methodologies adopted in studying different spread geometries along with seismic modeling studies to arrive at best field parameters.

Methodology

The target depth for ensuing campaign is 5000 meters, bin size is 25 m x 25 m and about 720 active channels can be utilized out of 1000 number of available channels. For these parameters numerous number of spread geometries may be studied. However to short list the best spread geometries four spread geometries (Endon – Orthogonal) were studied. For these studies initially flat layer is assumed. MESA Expert software was used and different attributes like fold, minimum/maximum offset, Azimuth and aspect ratio etc analyzed. The parameters and attributes for four geometries are tabulated in table 1.

Table. 1 : Four geometries

Parameters/units Type	G 1 End-on . Ortho.	G 2 End-on Ortho	G 3 End-on Ortho.	G 4 End-on Ortho.
Bin Size (m)	25 X 25	25 X 25	25 X 25	25 X 25
Fold	7X6=42	7X6=42	10X4=40	9X4=36
GI (m)	50	50	50	50
SI (m)	50	50	50	50
No. R/L	112	112	100	90
NRL	6	6	8	8
T Ac/Rollover	672 /48	672 /48	800 /40	720/40
SLI (m)	400	400	250	250
RLI (m)	300	200	300	250
Shots/Salvo	36	24	24	20
Min. Offset (m)	50	50	50	50
Max. Offset (m)	5838	5707	5265	4698
Swath Rollover	Half(3RL)	Half(3RL)	Half(4RL)	Half(4RL)
Shot overlap	18	12	NIL	NIL
Shots/Sq.Km	100	100	80	80
Unique fold	14 - 38	11 - 36	19 - 40	17 - 33
Aspect Ratio	0.321	0.214	0.480	0.44

Various bin attributes like offset distribution, azimuth, percentage of bins and traces in different offsets and fold, offset distribution in different ranges were generated with MESA software for geometries G-1, G-2, G-3 & G-4. Figure 2a to 2d represents Unique offset distribution. Geometry G-3 in Figure 2c shows better offset distribution when compared to other geometries.

The spread geometry G-3 shows uniform distribution of offsets in a bin (histogram in Figure 3 c) while G-2 gives better offset variation in lower side as well as higher side in Figure 4b.

Figure 5 shows the Rose diagram which gives the information about azimuth verses offset. G-1 and G-2 geometries are having narrow azimuth at longer offsets than G-3 and G-4.

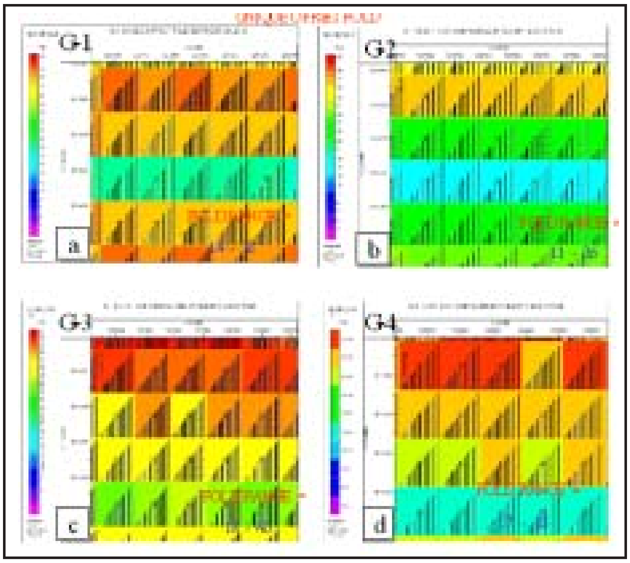

Fig. 2 : Unique offset fold

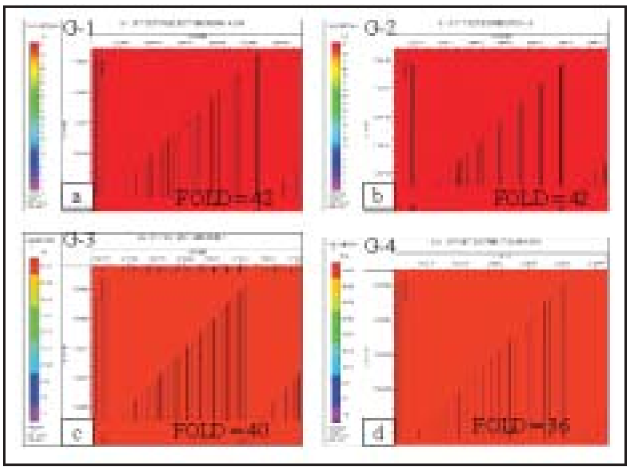

Fig. 3 : Offset histogram

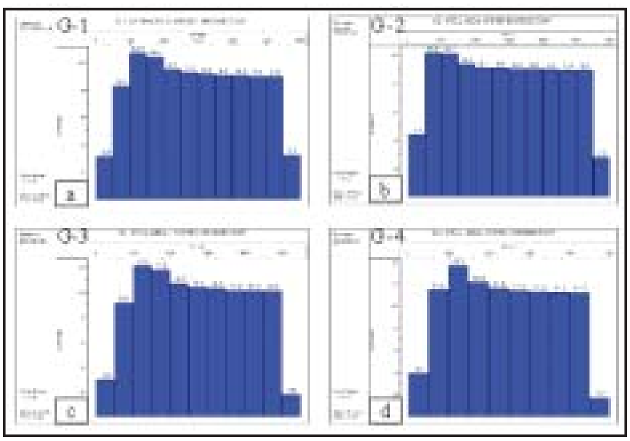

Fig. 4 : Percentage of traces with offset

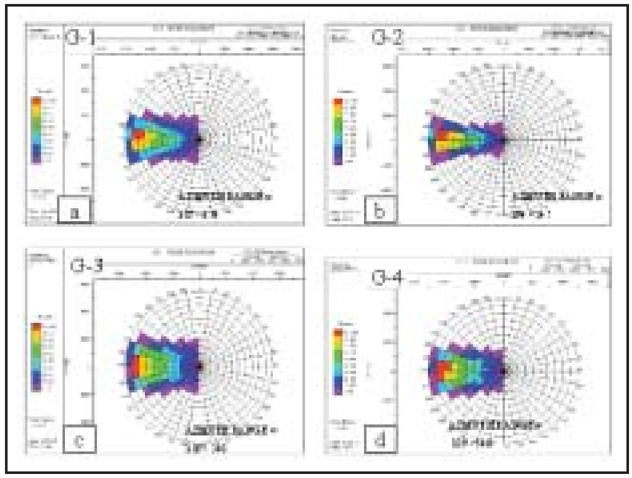

Fig. 5. Rose diagram showing azimuth

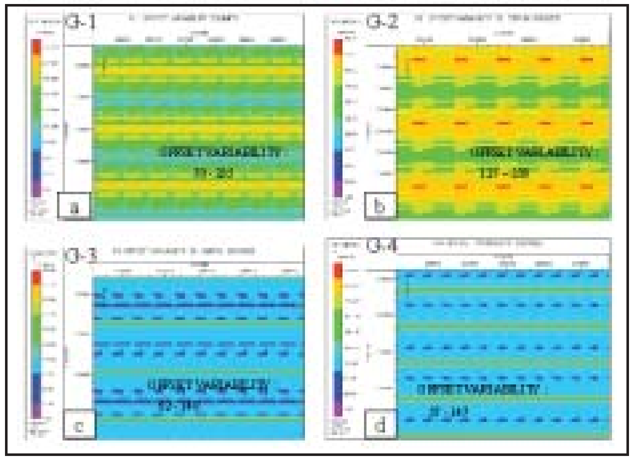

Fig. 6. Offset variability

Figure 6 shows Offset Variability which is relative dispersion measurement in each bin. Initially it calculates the standard deviation of the gaps in the offset range and divides by the mean gaps. The lower the values in the colour scale, the better the offset variability. Comparing the offset variability of the geometries it is observed that G-3 has the minimum offset variability (Figure 6c.) After studying the above attributes it has been inferred that G-3 and G-4 spread geometry are having edge over other geometries. Number of shots per square kilometer is less for G-3 and G-4 there by the seismic data acquisition is more economical.

The distribution of CMP fold and near offset of geometry G-3 and G-4 are represented from Figure 7a to Figure 7d.

The above studies are purely theoretical and assumes flat geological layer for calculations. This study gives the general idea how to converge to suitable geometries out of various geometries available for given seismo geological objectives. However the converged geometries are to be tested on geological model to select best out of them. These converged spread geometries are to be used while carrying out 3D seismic modeling studies to simulate illumination attributes like fold, amplitude, azimuth, offset etc for studying the effect of spread geometries on the attributes for selecting best geometry.

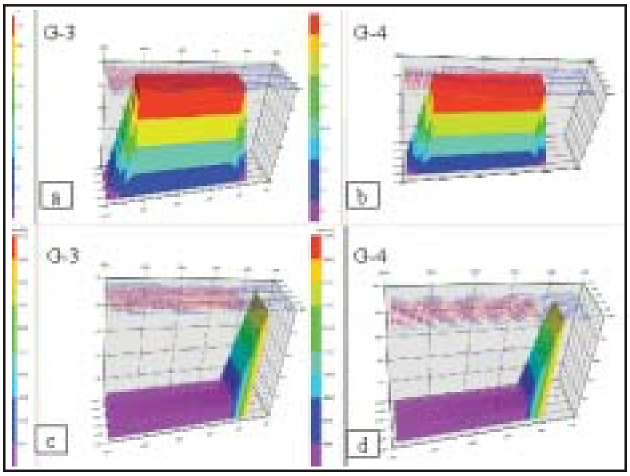

Fig. 7. a) G-3: CMP Fold b) G-4: CMP Fold c) G-3: Near offset d) G-4: Near offset.

Before actually acquiring a 3D survey for a complex target, it is desirable to model the response of the chosen geometry with reasonable representation of the expected geology. This exercise can validate or dismiss acquisition geometry depending on how well the modeled target is illuminated.

Not running such a test would involve taking considerable risk given the high cost of 3D seismic acquisition. Further more, ray tracing can potentially reduce acquisition cost by indicating the optimum number of source points needed to illuminate the identified targets. This is critical for thrust belt areas (Cain et al 1998).

The geological model has been prepared from depth contour maps at TS2, TS3, TS5 and BCS horizons. These horizons were based on depth data taken from interpretation of previously acquired 2D or 3D seismic data sets. After the horizons were selected, a grid was created for these surfaces. There are about 10 wells in which VSP surveys were carried out. The interval velocity between the layers is estimated by using the available VSP data. The interval velocity taken are as follows Surface to TS2 is 3000m/s, TS2 to TS3 is 3150 m/s, TS3 to TS5 is 3300 m/s, TS5 to BCS is 3700 m/s and BCS to bottom (5000m) is 4000 m/s. these interval velocities are uniform within the layer.

The 3D geological model was subjected to 3D modeling studies by ray tracing method using MESA EXPERT software. The spread geometries G-3 and G-4, which were short, listed by the above studies, were applied while carrying out seismic modeling studies and attributes were obtained for two swaths for each geometry.

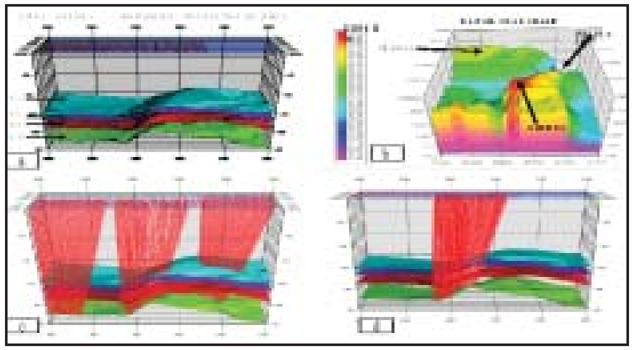

Fig. 8. a) Four Horizons – TS2, TS3, TS5 and BCS b) BCS Horizon - zoomed c) Ray diagram for 3 shots d) Ray diagram for 5 shots in a single salvo

Figure 8 shows the geological model and ray diagram related to modeling studies. In Figure 8b Nazira low and fault plane is seen and structural features are expected to have bearing on various attributes like fold, amplitudes and offsets. Even though the attributes were calculated for each horizon the attribute presented in the figure corresponds to BCS only for clarity purpose.

Elastic reflection effects (AVO) can also be calculated by measuring Average angle of incidence and Maximum angle of incidence. An integrated study of angle of incidence offsets and amplitudes will give information about amenability of data for AVO analysis. The amplitude attributes for the BCS horizon for two spread geometries are shown in Figure 9a and Figure 9b and average amplitude in each bin varies from 1.87E-007 to 2.79E-007. In the eastern portion in G-4 the amplitudes are higher.

The average angle of incidence in both the geometries is more or less same (Figure 10a and Figure 10b) and maximum angle of incidence (Figure 10 c and Figure 10 d) is also same.

Figure 11a & Figure 11b show CRP fold coverage on BCS. In general the coverage is same in G-3 and G-4. However at fault zone the coverage is not there in some bin. The empty bins are more in G-4 when compared to G-3. In

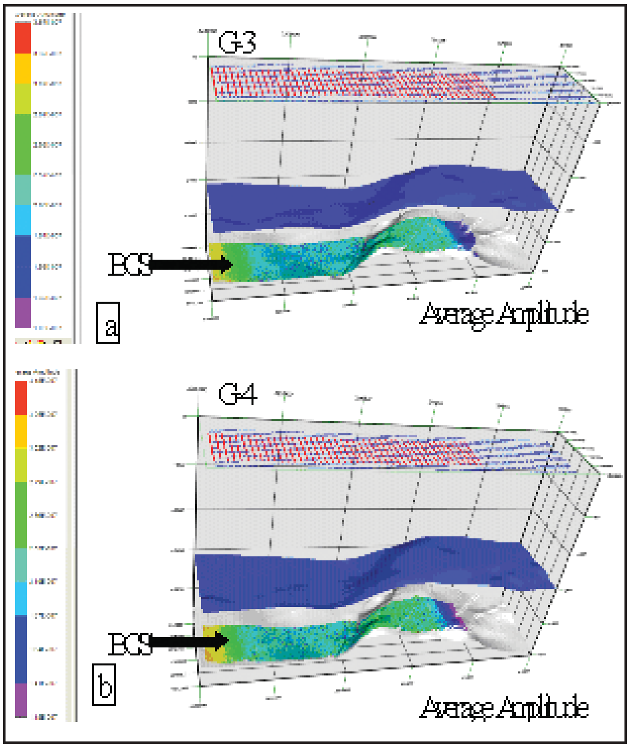

Fig. 9: a) G-3: Average amplitude of BCS horizon b) G-4: Average amplitude of BCS horizon

some places (blue portion) illumination is more. Where ever the coverage is not there some recovery plans may be made.

Another attribute, which is important to study, is

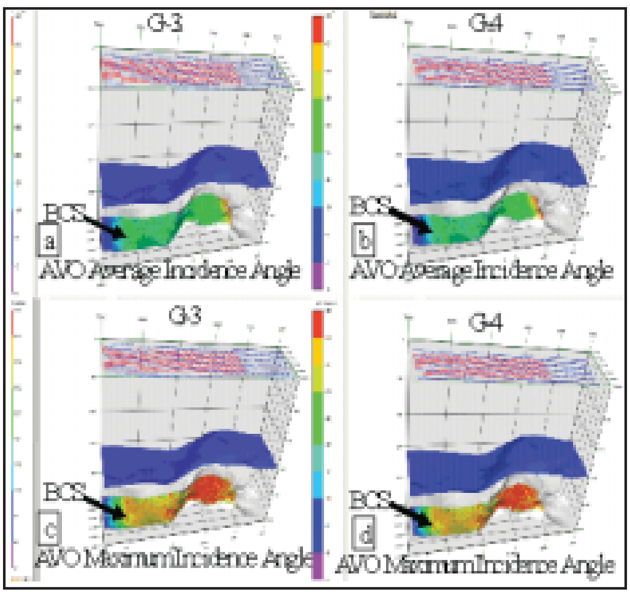

Fig. 10: Attributes for the BCS Horizon a) G-3: Average Incidence angle b) G-4: Average Incidence angle c) G-3: Maximum Incidence angle d) G-4: Maximum Incidence angle

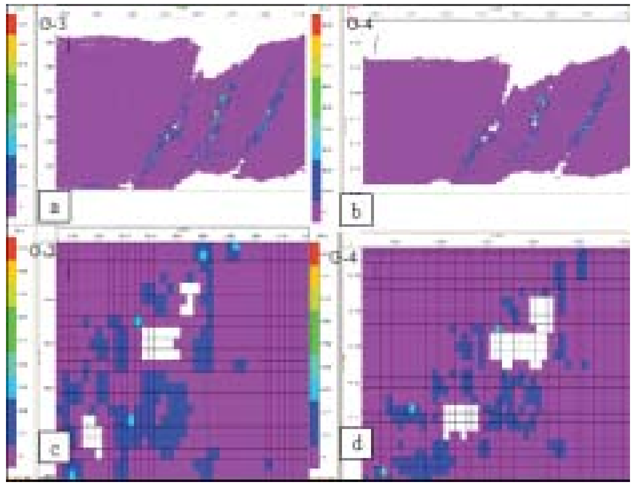

Fig. 11: Comparative study of CRP Fold of BCS in the fault zone a) G3: CRP fold at BCS b) G-4: CRP fold at BCS c) G-3: CRP fold at BCS Zoomed d) G-4: CRP fold at BCS – Zoomed

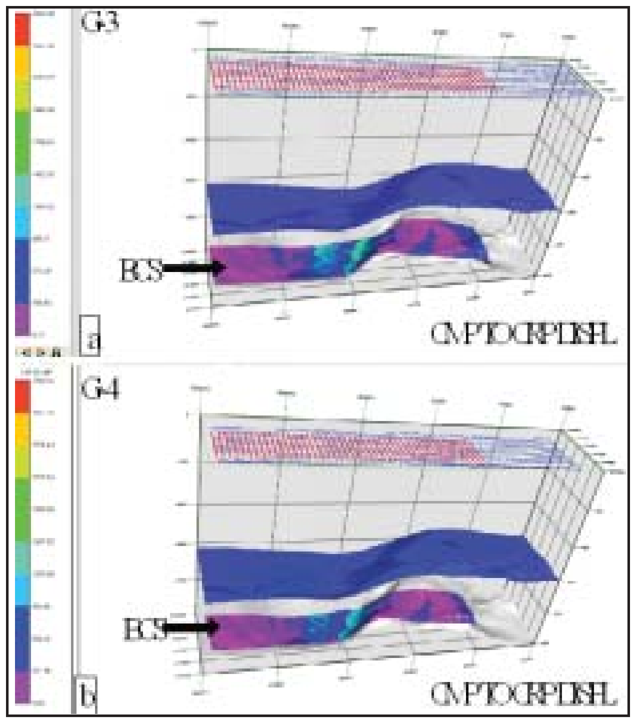

Fig.12: Attributes for BCS Horizon a) G-3: CMP to CRP Displacement b) G-4: CMP to CRP Displacement

CMP to CRP displacement in particular. The largest displacement shown is 1423 to 1990 meters. This indicates that any event with a CMP to CRP displacement below this value will be properly migrated. The major displacements are 6 to 289, 289 to 856 and 856 to 1423 meters and they are concentrated in zones (Figure 12 & Figure 13). In the edges the displacement is maximum up to 856 meters and the migration aperture of about 900 meters will take care of this displacement.

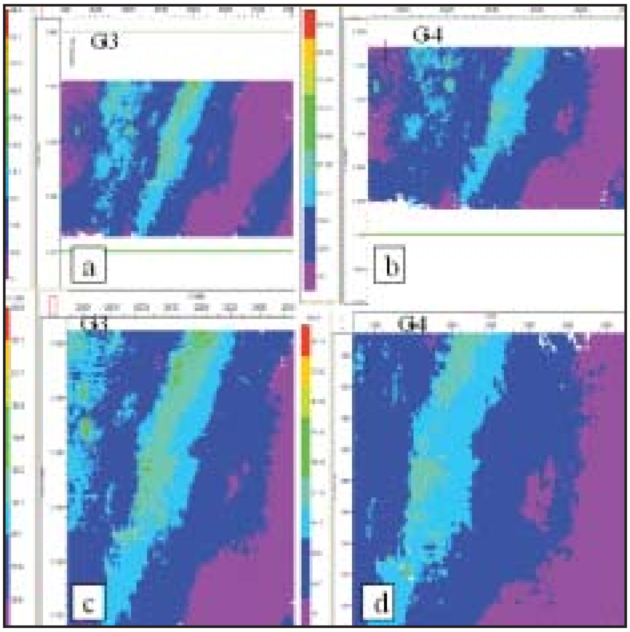

Fig 13: a) G-3: CMP-CRP Displacement b) G-4: CMP-CRP Displacement c) G-3: CMP-CRP Displacement - Zoomed d) G-4: CMP-CRP Displacement - Zoomed

Conclusion

3D seismic modeling studies by ray tracing reduce the risk of poor imaging. Preliminary spread geometry studies followed by 3D seismic modeling studies led to optimize the spread geometries and facilitated in deciding best geometry. The various attribute studies helped in analyzing the illumination in terms of offsets, azimuth, CMP - CRP displacement and angle of incidence.

In Geleki, the seismic modeling by ray tracing helped in concluding that G-3 and G-4 spread geometries more or less give same illumination except for fold, CMP to CRP displacement and amplitudes. For G-3 the CMP to CRP displacement is more and the amplitudes are higher in G-4. Finally G-4 geometry is more appropriate due to its technical edge over G-3.

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Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

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